WORKING GROUP ON FISHING TECHNOLOGY AND FISH BEHAVIOUR (WGFTFB)

VOLUME 1 | ISSUE 61

ICES SCIENTIFIC REPORTS

RAPPORTS SCIENTIFIQUES DU CIEM

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
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International Council for the Exploration of the Sea
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H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

ISSN number: 2618-1371 I

ICES Scientific Reports

Volume 1 | Issue 61

WORKING GROUP ON FISHING TECHNOLOGY AND FISH BEHAVIOUR (WGFTFB)

Recommended format for purpose of citation:

ICES. 2019. Working Group on Fishing Technology and Fish Behaviour (WGFTFB). ICES Scientific Reports. 1:61. 363pp. http://doi.org/10.17895/ices.pub.5592

Editors

Haraldur Arnar Einarsson • Pingguo He

Authors

Serena Binti Adam • Taweekiet Amornpiyakrit • Shannon Bayse • MohdFadzliee bin Asmat • Åsmund Bjordal • Mollie Brooks • Daomei Cao • Thomas Catchpole • Isara Chanrachkij • MingruiChen • Xinjun-Chen • Zhihai Chen • Zhaohai Cheng • Wenhua Chu • Mingyun Dai • Ying Dai • Qingyan Deng • Ruizhi Ding • Dérien Lucie Vernetti Duarte • Stephen Eayrs • Wei Fan • Ema Fatima • Lauren Fields • Kratzer Isabella Maria Friederike • Yanjie Gao • Eric Gilman • Georg Haney • Rong Hua • Hongliang Huang Liuyi Huang • Ólafur Ingolfsson • Keji Jiang • Weiping Jiang • Terje Jørgensen • Junita Karlsen Breddermann Karsten • Hyun Young Kim • Lotte Kindt-Larsen • Ludvig Ahm Krag • Yiting Li • Yuwei Li Zengguang Li • Uwe Lichtenstein • Lili Liu • Wang Liu • Ying Liu • Peter Ljungberg • Huajie Lu • Kexiang Lu • Yoshiki Matsushita • Matthew McHugh • Valentina Melli • Pieke Molenaar • Ebango Ngando Narcisse • Mattiasvan Opstal • Subong Park • Michael Pol • Yukun Qi • Weiguo Qian • Yongsong Qiu • Daniel Aguilar Ramirez • Shiyu Ren • Yiping Ren • Kelsey Richardson • Pedro Sá • Antonello Sala • Juan Santos • Stephan Schacht • Carol Scott • Huihui Shen • Daisuke Shiode • Maarten Soetaert • Weihua Song • Daniel Stepputtis • Go Takayama • Hao Tang • Jianhua Tang • Weiyao Tang • Yanli Tang • Maria Tenningen • Jianfeng Tong • Raymon van Anrooij • Aud Vold • Di Wang • Jing Wang • Jintao Wang • Teng Wang • Xuefeng Wang • Yongjin Wang • Daniel Watson • Timothy Werner • Binbin Xing • Shuangquan Xu • Lei Yan • Fei Yang • Xuchang Ye • Leiming Yin • Noëlle Yochum • Congda Yu • Yinliang Zang Heng Zhang • Jian Zhang • Jingjing Zhang • Min Zhang • Peng Zhang • Shengmao Zhang • Xueqing Zhang • Xun Zhang • Yu Zhang • Ji Zhen • Chunyi Zhong • Xiaming Zhong • Cheng Zhou • Wang Zhou Yingqi Zhou • Yongdong Zhou • Guoping Zhu • Wenbin Zhu • Xiaoli Zhu • Xiaorong Zou

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i Executive summary

The Working Group on Fishing Technology and Fish Behaviour (WGFTFB) is jointly supported by ICES and FAO, which have fostered a fruitful working relationship in an international forum. The ICES-FAO WGFTFB discusses and reviews research and practices of fishing technology and fish behaviour in relation to commercial and survey gears, and provides guidance for management including, inter alia, the impacts of fishing on the environment.

This year's WGFTFB meeting was sponsored by FAO and organized in collaboration with Shanghai Ocean University (China) and was held from 8 to 12 April 2019. More than 120 fishing technology experts from 23 countries attended the meeting, making this meeting one of the larg-est that WGFTFB has ever held.

This annual meeting included a special ICES-FAO WGFTFB symposium and Topic Group meetings. The Symposium on Responsible Fishing Technology for Healthy Ecosystems and Clean Environment included sixty oral and poster presentations on the interaction of fishing gears with the environment and new technological developments in fisheries. A special session was dedicated to Chinese fisheries, its status, challenges and opportunities. Many issues presented were connected to the management of bycatch and ways to reduce discard through improvement of the selectivity of fishing gear; this continues to be the main research activity of the group. Of particular interest were presentations on measures to reduce abandoned, lost or otherwise discarded fishing gear (ALDFG), which has become a major issue worldwide in recent years. For many at the meeting, an insight into the Chinese fisheries was noteworthy, considering how large the Chinese fisheries are on a global scale.

The three Topic Groups examined issues relating to passive gear, especially as it pertains to bycatch of protected species, the use of artificial lights for bycatch mitigation, and groundgear for bottom trawls, with a particular focus on seabed impact and fuel use. It is clear from those topics that bycatch and impact of fishing gear on the environment has a high level of interest.

There are still many issues facing fishing technologists in areas of fishing impact on the environment and on biodiversity. Modifying fishing gear and/or operational methods that have the least impact on non-target species, especially protected species and their essential habitat requires innovative thinking and research methods in fishing technology. The group members are developing new instruments and analytical methods to enhance our ability to acquire and analyze data to provide better guidance to the industry and management.

The key message of the meeting was an urgent need for solutions to mitigate the impact on the environment and reduce the interaction of the fishery with protected species with better fishing technologies using an increasing understanding of the physics of fishing gears and other potential solutions. Challenges also remain on how the management and fishing industry can take advantage of the findings from this group.

ii Expert group information

Expert group name	ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB)
Expert group cycle	Year 3
Year cycle started	2017
Reporting year in cycle	3/3
Chair(s)	Haraldur Arnar Einarsson, Iceland, (ICES chair)
	Pingguo He, Italy (FAO chair)
Meeting venue(s) and dates	4-7 April 2017, Nelson, New Zealand, (60 participants)
	4-8 June 2018, Hirtshals, Denmark, (101 participants)
	8-12 April 2019, Shanghai, China, (120, participants)

1 Explanatory Notes on Meeting and Report Structure

ICES and FAO have had a fruitful working relationship on fishing capture technology and related fields for many years. The ICES Working Group on Fishing Technology and Fish Behaviour (WGFTFB) was given a global mandate in 2002 when FAO accepted the invitation of the ICES to form a joint Working Group with the new title ICES-FAO Working Group on Fishing Technology and Fish Behaviour (ICES-FAO WGFTFB). The primary objective of the ICES-FAO WGFTFB is the incorporation of fishing technology issues and expertise into management advice including, *inter alia,* the impacts of fishing on the environment (e.g. bycatch, unaccounted fishing mortality, habitat impacts, energy use, greenhouse gas emission). Accordingly, in the 2011 ICES-FAO exchange of letters, FAO agreed to co-chair the WGFTFB and host the annual meeting of WGFTFB every third year in the location chosen by FAO, beginning in 2013. Based on this background, the annual meeting of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) was held from 8 to 12 April 2019 in Shanghai, China. The meeting was organized in collaboration with Shanghai Ocean University (China).

Consequently, this year's WGFTFB meeting was divided into two sections where a special ICES-FAO WGFTFB symposium with eight sessions was held during the three first days and followed by traditional WGFTFB Topic Group meetings and working group business during the last two days.

The ICES-FAO WGFTFB symposium "Symposium on Responsible Fishing Technology for Healthy Ecosystems and Clean Environment" had the following eight sessions:

- Session 1: Abandoned, lost or otherwise discarded fishing gear (ALDFG): Assessment of quantity and measures to prevent ALDFG and its impact
- Session 2: Interactions of protected species in capture fisheries
- Session 3: Light, fish behaviour and fishing
- Session 4: Technology and management to reduce bycatch and discards
- Session 5: Selectivity of fishing gear: Means and methods
- Session 6: New technologies for fisheries research and education
- Session 7: Energy, technology, analysis and simulation
- Session 8: Chinese fisheries – Status, challenges and future
- Posters

The abstracts from the oral and poster presentations including two keynote lectures are included in Chapter 3 of this report. This is followed by report of Topic Groups (TpRs) and outcomes of the WGFTFB business meeting. The reports of Topic groups were developed during the meeting and edited and finalized by Topic Group Conveners. The summaries and recommendations for the working documents for each ToR were reviewed by WGFTFB and were accepted at the meeting; accordingly reflecting the views of the WGFTFB. However, the contents of these working documents do not necessarily reflect the opinion of the WGFTFB. Some Topic Groups included small numbers of individual presentations based on specific research programmes related to that topic. These abstracts are included in this report, together with the authors' names and affiliations. Although discussion relating to the individual presentations was encouraged, comments are not included in the text of this report. The contents of the individual abstracts were not discussed fully by the group, and as such, they do not necessarily reflect the views of the WGFTFB. National reports are included in this report as has been done in previous WGFTFB annual reports.

2 Opening of the meeting

The meeting began with the ICES-FAO Symposium, and a formal opening ceremony was held with opening and welcome addresses given by the host and co-organizers of the meeting. The vice present of Shanghai Ocean University, Professor Jialu Li officially opened the meeting. The President of the University Professor Yudong Cheng gave a welcome address which emphasized the importance of developing fishing technologies that contribute to more responsible and sustainable fisheries. Recognizing the many students that attended the meeting, he added that the current fisheries students, the young generation, will in the near future support fisheries science and management and will have key roles to play in making fisheries more sustainable. Dr. Raymon van Anrooy, Senior Fishery Officer of FAO, stressed the importance of implementing the "Voluntary Guidelines on the Marking of Fishing Gear", which were adopted by the FAO Committee on Fisheries at its 33rd session in 2018. Dr. van Anrooy later presented details of FAO's effort in combating ALDFG and its harmful effect, including strategies to implement the Voluntary Guidelines. Dr. Haraldur Arnar Einarsson, Working Group co-chair, noted the importance of sharing experiences with experts in China, given that China's capture fisheries sector contributes nearly 20 percent to the worlds' capture fisheries production. Improvements that can be made to increase selectivity and reduce bycatch in China's fisheries will benefit everyone. Dr Pingguo He, the chair of the organizing committee and co-chair of the working group, thanked FAO and Shanghai Ocean University for their support to the meeting, and stressed that sustainable fisheries require sustainable ecosystems, and that all stakeholders need to work together to reduce the impact of fishing operation on the environment for a cleaner ocean and healthy ecosystem. A full text of the opening speech is given in Annex 3.

3 Symposium on Responsible Fishing Technology for Healthy Ecosystems and Clean Environment

Abstracts

3.1 Keynote presentation, Pingguo He

Responsible fishing operations for clean oceans, healthy ecosystems and sustainable fisheries

Pingguo He[1,2]

[1]School for Marine Science and Technology, University of Massachusetts Dartmouth, New Bedford, MA 02744 USA, [2]FAO Fisheries and Aquaculture, Fishing Operations and Technology Branch, 00153 Rome, Italy

This presentation will outline status and trends in on how global marine capture fisheries may have affected our oceans and their ecosystems, which may jeopardize sustainable fisheries and global food security. Marine capture fisheries are recognized as primary causes of overfishing with number of overfished stocks still in the upward trend. Bycatch and discard in capture fisheries threaten biodiversity and protected species, cause extirpation of species, and represent a waste of food. Fisheries-related marine litter in the form of abandoned, lost or otherwise discarded fish gear (ALDFG) pollute marine environment, and threatens marine lives and reduces commercial fisheries resources. Fishing operations on or near seabed causes modification to physical, chemical and biological structure of the seabed, which may influence productivity, subsequently harvestable resources. Food and Agriculture Organization of the United Nations (FAO) has spearheaded these issues as they affect ecosystem sustainability and long-term production of fisheries. From the cornerstone of the Code of Conduct for responsible Fisheries, many guidelines, agreements, and action plans have been reached or formulated. Together with other UN agencies and other international organizations and member states, FAO has pushed for the passage of instruments on bycatch management and reduction of discard, plans for the protection of seabird, turtles, marine mammals, sharks and other sensitive and protected species, agreements on measures to combat illegal, unreported and unregulated (IUU) fishing, and measures to combat ALDFG, including the guidelines on the marking of fishing gear. FAO's work on these areas contribute to UN's Sustainable Development Goals, especially on SDG target 14 – Life below water.

*phe@umassd.edu

3.2 Session 1: Abandoned, lost or otherwise discarded fishing gear (ALDFG): Assessment of quantity and measures to prevent ALDFG and its impact

Assessing and Estimating Global Fishing Gear Losses

Kelsey Richardson*, Britta Denise Hardesty and Chris Wilcox

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Abandoned, lost or otherwise discarded fishing gear (ALDFG) represents a significant, yet ultimately unknown, amount of global marine debris, with a diversity of socioeconomic and environmental impacts. Fisheries impacts include damage to and loss of fishing gear, loss of catch, the potential to diminish fish stocks and hazards to navigation and safety at sea. This ALDFG can also injure and/or kill marine wild life and damage marine ecosystems and benthic habitats. Recovery and clean-up of gear is expensive, complicated, time intensive and can be dangerous. While studies have been conducted since the 1970s on the amounts of fishing gear lost for various gear types, fisheries and geographic areas around the world, no statistically rigorous estimates exist to date that quantify global fishing gear losses. This lack of global estimates for fishing gear losses acts as a barrier to implementing solutions designed to prevent and/or decrease amounts of ALDFG as a key and distinct source of marine debris, as well as an obstacle in monitoring the effectiveness of these interventions on a global scale. This presentation reports the research project "Assessing and Estimating Global Fishing Gear Losses". The project aims to provide statistically rigorous global baseline estimates of the total amounts of commercial fishing gear losses annually across key gear types, geographic areas and fisheries, focusing on losses from a variety of net, trap and line fisheries. The project is achieving these goals through: 1) a global literature review and meta-analysis of fishing gear losses; and 2) surveys with fishers from different countries around the world about why, when and how they lose gear. The presentation will summarise key findings and progress from this project including sharing our estimates of global gear loss by fisheries around the world from the global literature review and meta-analysis. We will also present initial finding from the surveys with fishers around the world.

*Kelsey.Richardson@csiro.au

International actions on reducing sea-based marine litter, especially abandoned, lost or otherwise discarded fishing gear and its impact on fisheries resource and marine environment

Joanna Toole[1], Raymon Van Anrooy[1]* and Pingguo He[1,2]

[1]Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department, Fishing Operations and Technology Branch, Rome, Italy, [2]University of Massachusetts Dartmouth, School for Marine Science and Technology, New Bedford, MA, USA

Abandoned, lost or otherwise discarded fishing gear (ALDFG) constitutes a significant part of marine plastic pollution, threatens marine life, wastes fisheries resources, and fouls sensitive marine habitats. ALDFG also poses problems to navigation and safety at sea. There is also a link between ALDFG and illegal, unreported and unregulated (IUU) fishing, because fishers may dump their gear to try an evade detection by authorities, or there may be conflict between gears due to poor regulation of fishing effort in a particular area.

Marking of fishing gear is widely regarded as one of the most effective tools that can prevent and reduce ALDFG, by facilitating identification (of the owners of the gears) and the recovery of gears. This presentation will provide background on the global processes that led to the recent-adoption of the Food and Agriculture Organization of the United Nations (FAO) "Voluntary Guidelines on the Marking of Fishing Gear" by the Committee on Fisheries at its 33rd session, held in July 2018. The presentation highlights key items in the guidelines, and stresses how its implementation may benefit the marine environment and sustainable fisheries. A review will be provided of technologies for the marking of fishing gear and technology limitations will be identified. Barriers to implementation of the Guidelines by in developing States and small-scale fisheries will be discussed and some solutions will be proposed. Finally, some information will be provided on the FAO umbrella programme on "Responsible practices for sustainable fisheries and reduction of impacts of fishing operations", which aims to support the implementation of the Guidelines.

*Raymon.vananrooy@fao.org

Reducing marine litter – a practical example of the Icelandic fisheries

Georg Haney* and Haraldur A. Einarsson

Marine and Freshwater Research Institute (MFRI), Iceland, Skúlagata 4, 101 Reykjavik

As the general public is waking up to the issue of our polluted oceans, legislators and government agencies in many countries are scrambling to find mitigation measures. While many sources contribute to the waste in our oceans, lost and discarded gear is in focus especially in countries with large and active fishing fleets. As the recent study on the voluntary uptake of proven fishing gear by fellow FTFB members Eayrs and Pol (2018) pointed out, engaging with fishermen for a behavior change is difficult and unpredictable which extends to environmental awareness and practices. However, the Icelandic fishing industry seems open to engaging on environmental issues associated with lost or discarded fishing gear.

Recent data shows that up to 90% of all Icelandic fishing gear that has reached its end of life has been sent to be recycled. Several factors contribute to achieving this remarkable number. Laws prohibit the discard of gear at sea. They further implement that vessel operators are liable and responsible for gear recovery and have a duty to report it. In 2005 the organization of companies of the marine sector of Iceland (SFS) signed a contract with the government run recycling fund to provide gear collection facilities in all major harbors. These facilities take old fishing gear from the Icelandic fleet without additional fees. Large companies and net makers take responsibility to sort disused gear by material and send it to facilities in Denmark and Lithuania. Foreign vessels can use these facilities as well but must pay for recycling. This voluntary commitment by the Icelandic fishing industry paired with the existence of a fund mandated by law led to nearly 1200 tons of fishing gear being sent to recycling facilities in 2016 alone (SFS, 2017).

While it is promising to see a scheme like this working effectively there are many questions regarding the role of the fishing industry as a polluter still to be answered. Of the debris washed up on beaches around Iceland a large proportion can be linked to the fishing industry. During cleanup of remote areas several tons of gear waste are removed form short sections of beaches. Is this only indicative of a past mindset of discarding gear or are we still not fully able to tackle the issue?

For that reason, the Marine and Freshwater Research Institute of Iceland (MFRI) has begun to collect distinct data on marine debris. Annually over a thousand survey stations are sampled with various gears in the Icelandic EEZ and, beginning with March 2019, all marine debris found during these stations will be registered by source in a universal database. The hope is, that over time the data collected will give a better view of the spatial distribution of certain types of gear waste in relation to their use.

*georg.haney@hafogvatn.is

Using Side Scan Sonar to Detect Lobster Pots in Simple and Complex Habitats

Michael Pol*, David Chosid, Kathryn Ford and Steve Voss

Massachusetts Division of Marine Fisheries 836 S, Rodney French Blvd New Bedford, MA 02744

The collateral impact of abandoned, derelict, lost or otherwise discarded fishing gear (ADLFG) includes entanglement of protected species, fishing gear conflicts, habitat damage, unaccounted mortality, and other problems. In the waters of Massachusetts, ALDFG has been examined with advanced technologies beginning in the 1980s. Recently, high resolution side-scan sonar has been promoted as an appropriate means of achieving wide area coverage and overall estimates of the scope and extent of ALDFG, particularly for lobster pots. As well, high resolution side scan sonar offers anon-impacting, alternative method to identify and quantify gear on-bottom. However, the effectiveness of the method is not generally known, creating major uncertainty in estimates of derelict gear abundance and locations, despite growing interest in the methodology. In a recent study, we determined the detection efficiencies (rates) for side scan sonar lobster pot identification over two bottom habitats - featureless (sandy) and complex (rocky) habitats. An area of Buzzards Bay, Massachusetts was surveyed to characterize the bottom and then side scan sonar was used to identify set pots (with pot locations unknown to the sonar analyst) to derive the detection rates. We found a significantly improved detection rate over simple bottom. However, resulting detection rates for both habitats were low and not sufficient for pot abundance estimation in a larger survey area. These findings demonstrate that using side scan sonar surveys to quantify ALDFG lobster pots may be highly prone to error and that detection rates should be determined prior to estimating quantities of derelict gear.

*mike.pol@state.ma.us

Stripping the beam trawl – get rid of abrasion protection

Uwe Lichtenstein*, Bernd Mieske, Thomas Noack and Daniel Stepputtis

Thünen Institute of Baltic Sea Fisheries, Alter Hafen Süd 2, 18069 Rostock, Germany

In the European beam trawl fishery, strands of polyethene woven in to the lower panel of the trawl are widely used as abrasion protection. These - so called - ’dolly ropes’ fray away very easily and consequently need to be replaced frequently. The torn off parts end up in the sea and contribute to the vast amount of marine litter. In addition to the general litter problem, dolly ropes pose a direct danger to marine wild life, because sea birds use these strands as nesting material and therefore risk to get entangled in them. Last but not least, the fishery itself suffers, as the twines wrap around the ships propellers and the trawl gear, resulting in danger, damage and difficult removal procedures.

Other projects aimed at finding alternative materials to replace the dolly ropes. However, it is the authors' opinion that the best solution would be to find a way that makes any kind of abrasion protection superfluous - especially under the assumption that the abrasion protection is affecting the fishing gear's selectivity.

To identify reasons for ground contact of beam trawl nets and to develop and test potential solutions for avoiding such bottom contact, our project "Dolly Rope Suspension, DRopS" focuses on the North Sea beam-trawl fishery, targeting brown shrimp (*Crangon crangon*).

As the intended catch is more or less neutrally buoyant, the two main reasons for the trawl being dragged over the seafloor is heavy sediment and benthos getting into the trawl and the shape of the net and codend during towing. Within the project, four approaches are considered minimize the ground contact of the trawl.

a) use of passive (e.g. floats) and active (e.g. kites) buoyancy at the rear part of the net,

b) reshaping the actual trawl design by using a special net cutting that results in an ascending trawl or using round straps to avoid ballooning of the codend,

c) reduction of the amount of sediment that is swirled up by the ground gear using alternative groundgear designs,

d) reduction of the amount of sediment in the trawl by releasing sediment, e.g. using benthos release panels or larger mesh sizes in the front sections of the lower panel.

Several of these possibilities have been tested in various set-ups so far. The results presented helped to identify the most promising solutions that we are going to endeavour further within the project.

*uwe.lichtenstein@uni-rostock.de

3.3 Session 2: Interactions of protected species in capture fisheries

An Overview of Mitigation Strategies for Non-Target Species Bycatch in Gillnets

Timothy B. Werner*

ACCOL, New England Aquarium, Central Wharf, Boston, MA 02110 USA

At the same time that gillnets are considered one of the most selective forms of fishing gear, principally by adjusting the dimension of mesh sizes, they also contribute to some of the highest rates of incidental mortality in protected, endangered, and threatened (PET) species. Bycatch can occur within the nets themselves and also the buoy lines used with bottom-set gear. For example, approximately two-thirds of all marine mammals are known to occur as bycatch in gillnets, and this gear is primarily responsible for the looming extinction of the vaquita porpoise in Mexico’s upper Gulf of California, the unsustainable rates of bycatch for the Francis can a dolphin in the southwest Atlantic, threatening the endangered population of Arabian Sea humpback whales, and population reduction in the endangered Baltic Sea harbour porpoise. Another consequence of this bycatch is to fishermen who experience lost or damaged gear, temporary loss of active fishing gear, depredation of their catch, and the potential for increased regulatory restrictions, all of which can affect their operating expenses and revenue.

Avoiding and mitigating bycatch of non-target species in gillnets—and other types of gear—can involve several fisheries management and operational strategies. These include the establishment of permanent or temporary area closures, modifying fishing practices, changing the type of gear used, introducing acoustic or visual deterrents, reducing fishing effort, facilitating release post-capture, or implementing economic-based approaches such as product boycotts, financing fishermen to cease fishing, or pursuing industry practices that maximize profits. It is rare that any of these, used alone or in combination with others, have been shown to reverse bycatch to sustainable levels, especially across the entire geographic range of a species or subpopulation. Furthermore, bycatch mitigation generally focuses on reversing population decline in single species or populations, even though it is essential to ensure that strategies will not adversely affect others nor the environments in which they occur.

Research undertaken at the New England Aquarium as well as by other groups world wide will be used to illustrate some of these measures and the lessons learned, especially drawing from experience with marine mammals. I will also introduce some recent policy initiatives to address bycatch at the international scale, including the recent endorsement by FAO of a marine mammal-gillnet bycatch workshop, and the launch of the Global Bycatch Exchange to help serve as a clearinghouse of information on bycatch mitigation techniques, facilitate cooperation among stakeholders from government, industry, academic, and NGO sectors, and providing assistance to fisheries in identifying how to address bycatch obstacles in becoming certified or recertified under Marine Stewardship Council Standards.

*twerner@neaq.org

Porpoise bycatch mitigation and manage menttools used in Denmark

Lotte Kindt-Larsen* and Finn Larsen

Danish technical university of Denmark (DTU Aqua) Kemitorvet, 2800 KGS. Lyngby, Denmark

The bycatch of harbour porpoise *Phocoena phocoenais* an issue of major concern for fisheries management and for porpoise conservation. Several solutions are available to prevent bycatch incidents here among acoustic deterrent devices (pingers), modification of fishing practices, gear change, reduction in fishing effort and area closures. In Denmark, the main tool to reduce bycatches used is pingers and currently new trials are conducted to collect knowledge on pinger effects with respect to increased pinger spacing. However, even though pingers have shown to have a positive effect on bycatch rates they can potentially keep porpoises away from e.g. important feeding grounds and maybe cause an even higher negative impact on the population than the incidental bycatch. Thus, if pingers are to be implemented it is important that it is only in areas where the risk of bycatch is substantial. To identify are as with potentially higher and lower risk of porpoise bycatch high-resolution spatial and temporal data on porpoise abundance and fishing effort has been used. Commercial gillnet vessels have been equipped with remote electronic monitoring (REM) systems. The REM system recorded time, GPS position and closed-circuit television (CCTV) footage of all gillnet hauls. REM data were used to identify fishing grounds, quantify fishing effort and document harbour porpoise bycatch. Movement data from porpoises equipped with satellite transmitters were used to model population density. A simple model was constructed to investigate the relationship between the response (number of individuals caught) and porpoise density and fishing effort described by net soak time, net string length and target species. The result showed that a simple model including both porpoise density and fishing effort data could predict harbour porpoise bycatch. Thus, this type of model can thus be used as a tool to identify areas of bycatch risk and help managers to select the most appropriate solution for protection of the harbour porpoise.

*lol@aqua.dtu.dk

Update on the U.S. Marine Mammal Protection Act import provisions: Implementation process and analysis of marine mammal bycatch in commercial fisheries

Lauren G. Fields* and Nina M. Young

United States National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of International Affairs and Seafood Inspection Program

The United States' Marine Mammal Protection Act (MMPA) states that the United States shall ban the importation of foreign commercial fish or fish products which have been caught with commercial fishing technology which results in the incidental kill or incidental serious injury of marine mammals in excess of United States standards or of any fish or fish product that was produced in a fishery that intentionally kills marine mammals in the course of those fishery operations. Previously, NOAA Fisheries, in consultation with foreign trading partners assembled a List of Foreign Fisheries (LOFF). This LOFF contains global fisheries information for fisheries that export seafood products to the United States, including the target catch, gear type used, number of vessels or participants, area of operation of the fishery, and data regarding incidents of marine mammal interaction in the course of fishing operations. Fishery and marine mammal interaction information was provided by nations and cross-checked with published information from regional fishery management organizations and Food and Agricultural Organization's national reports, scientific publications, and grey literature.

NOAA Fisheries is in year three of the five-year implementation period and here we provide updates on the implementation of this regulation, including the introduction of a new web-based portal for accessing fishery information and completing the 2019 Progress Report. The Progress Report asks fisheries managers to provide information regarding their nation's regulations relating to marine mammal bycatch and fisheries management with the goal of tracking the reduction of marine mammal interaction in commercial fisheries. We previously analysed fishing areas and gear types with the highest marine mammal incidental mortality. Passive gears, particularly gillnets, disproportionally entangle and kill more marine mammals than active gear types. A tried and true mitigation method to reduce harbour porpoise mortality is the use of net pingers, which act as a warning for porpoises in areas of submerged nets. However, for fisheries impacting multiple marine mammal species, no one method has been proven effective in reducing all interactions with nets. We pose the following questions and look forward to discussing these further in the Passive Topic Group: How can bycatch levels be mitigated in disparate fisheries (large-scale/industrial with few species impacted vs. small-scale/artisanal with many species impacted)? How can we explore mitigating strategies and increase scientific capacity in fisheries where multiple species of marine mammals are impacted?

*lauren.fields@noaa.gov

A newly developed soft-type turtle releasing device (Soft-TRD) for set net fisheries

Daisuke Shiode[1]*, Maika Shiozawa1, Fuxiang Hu1, Tadashi Tokai1 and Yoshio Hirai[2]

[1] Tokyo University of Marine Science and Technology, [2]Nitto Seimo Co., Ltd

This study presents a newly developed soft-type turtle releasing device (Soft-TRD) for set nets. Setnets are one of the coastal passive fishing gears and consist of a lead net, pound nets, funnel nets, and fish chambers (bag nets). Migrating fish schools are intercepted by the lead net and led into the bag net through the pound net and the funnel net. Some bag nets are closed with ceiling nets and submerged below the sea surface.

Sea turtles straying into the fully-submerged bag net of the set net are often drowned because the ceiling net of the bag net prevents the turtles from swimming up to the surface to take breaths. A turtle releasing system developed for the set net comprises a turtle releasing device (TRD) and about 20 degrees sloping (quadratic-prism shaped) ceiling net of the bag net. A solid flap door made of a stainless-steel frame covering the vent for turtles in the original TRD has a possibility to cause troubles during fishing operation especially when hauling up the net.

In this study, a new type of TRD (Soft-TRD) without any solid frame was developed. The Soft-TRD has a slit as an escape component in the centre of a 2 m square net. By overlaying the net of both edges of this slit each other and attaching a float at each end, the escape part is closed to prevent fishes from getting out. When sea turtle pushes the escape component upwards, the escape slit opens and allows the turtle to escape out from the bag net. A turtle releasing trial was conducted in an outdoor water tank, using an experimental bag net of which the Soft-TRD was mounted at the centre part of the ceiling. Four loggerhead turtles (SCL:67.1-72.8cm) and five green turtles (SCL:42.4-63.4cm) were deployed for the experiment. A single turtle was separately put into the experimental bag net, and its escaping behaviour was observed. In the model that has an escape slit of 1.5 m long, the width of overlaying 10 cm, and with a float of 4 kgf in buoyancy at each end, all turtles successfully escaped out. The escape component was immediately closed after the turtles escaped. Sea trials were also performed in a submerged bag net (30m x 10m x 10m) with application of this system.

About 90% of loggerhead turtles entrapped successfully escaped out through the Soft-TRD in 2-months of fishing operations. The operational activities of the respective fishermen were not interrupted by the introduction of the device. Our result revealed that the use of the Soft-TRD would be helpful in releasing sea turtles from the passive fishing gears such as the set nets, and contribute to the efforts of conserving sea turtles.

* shiode@kaiyodai.ac.jp

Length based selectivity of different mesh sizes in gillnets for cetaceans from two different fisheries

Haraldur Arnar Einarsson[1]*, Guðjón Már Sigurðsson[1], Georg Haney[1] and Justina Adaugo Obienu[2]

[1]Marine and Freshwater Research Institute, Iceland, [2]The Nigerian Institute for Oceanography and Marine Research

Gillnets are well known for strong size selectivity of target species relative to mesh size. At the same time gillnets are responsible fora large part of the worldwide unwanted bycatch of marine mammals, turtles and birds. How gillnets select against bycatch like marine mammals is rarely discussed as data collections on unwanted bycatch are usually too poor. In this presentation, we attempt to compare data from Iceland and Nigeria. The gillnet fisheries of the two countries have distinct differences but both have bycatch of small whale and dolphin species. Harbour porpoise (*Phocoena phocoena*) and some dolphins species are common in the Icelandic bottom gillnets fishery targeting cod (*Gadus morhua*) while Nigeria is dealing with bycatch of various dolphin species in driftnet fishery targeting mainly various shark species. In Iceland, during the annual gillnet surveys the length of Harbour porpoise bycatch has been registered for each of 4 mesh sizes used (152,178, 203 and 229 mm) which represent commonly used mesh sizes in the fishery. The length distribution of the Harbour porpoise is very narrow. While no clear selectivity by length can be seen there is a significant difference in the number of bycatches per mesh size. The data from the Nigerian fishery was collected by observers of 8 fishing boats of over a two-year period (2017 and 2018). 5 mesh sizes (102, 127, 152, 178 and 191 mm) are in use to catch diverse species. The different mesh sizes show clear size selectivity for dolphins.

The two datasets will be compared and discussed. They both show possible approaches how management of gillnet fisheries around the world can avoid or reduce the bycatch of small cetaceans.

*haraldur.arnar.einarsson@hafogvatn.is

3.4 Session 3: Light, fish behaviour and fishing

Mesopelagic fish: responses to artificial light

Åsmund Bjordal*, Melanie Underwood, Anne Christine Utne Palm and Jan Tore Øvredal

Institute of Marine Research, Bergen, Norway.

The behaviour of mesopelagic fishes to natural light, in particular their diurnal vertical migration has been described in numerous studies over the last decades. However, little is known about the response of mesopelagic fish to artificial light.

This study was done in the Masfjord (a fiord close to Bergen, Norway) known to have a standing stock of mesopelagic fish (*Maurolicus muelleri* and *Benthosema glaciale*). At a fiord depth of about 480m, there were three distinct layers of mesopelagic fish (and other organisms) at about 100m, 200m and 300m depth (layer L1, L2 and L3).

The observations were done from the research vessel "Hans Brattstrøm" (25m) using a rig equipped with wide band acoustic transceivers (WBAT), GoPro camera and different light sources. Lights used were diving torches with infrared, red, blue, green and white light – and stronger, white lights. Acoustic data were also recorded by the vessel's echosounder (Simrad EK60) and environmental data were collected by CTD and ADCP.A few biological samples were taken from the two upper mesopelagic layers, using a MIC-sampler.

As the rig was lowered, the following responses were observed (Simrad EK60):

- No/little response to the rig without lights and with infrared and red lights.

- No attraction to light was observed.

- Horizontal avoidance was observed to green, blue and white light.

When lowering the rig with strong white light slowly (2-3 cm/sec), the following response was observed: L1 showed horizontal avoidance. When the rig approached L2, the layer concentrated and descended at the lowering speed of the rig, keeping a constant distance from the rig of about 10m. The L2 was "pressed" down from about 200m to about 300m where L2 joined L3. From 300m and downwards, part of the fish in L3 joined the descending L2 layer and was pressed down to the bottom (480m), while other organisms in L3 remained at L3-depth, possibly because of no response to light or no capability of avoidance. When the rig was lifted from the bottom, "pressing up" of the layers was not observed.

These studies should be regarded as introductory regarding behavioural responses of mesopelagic fishes to artificial light. The observed avoidance response should be investigated further with different light qualities and intensities and how the responses to light may be used to improve catch rates of mesopelagic fish with traditional or alternative capture methods.

*aasmund@hi.no

3.5 Session 4: Technology and management to reduce by-catch and discards (1)

Vertical distribution of North Sea brown shrimp inside the trawl

Daniel Stepputtis[1]*, Juan Santos[1], Bernd Mieske[1]. Jimmy van Rijn[2] and Karsten Breddermann[3]

[1]Thünen Institute of Baltic Sea Fisheries, Alter Hafen Süd 2, 18069 Rostock, Germany, [2]Wageningen Marine Research, IJmuiden, The Netherlands, [3] Chair of Ocean Engineering, University of Rostock, Albert-Einstein-Strasse 2, 18059 Rostock,Germany

The brown shrimp (*Crangon crangon*) beam-trawl fishery is one of the most important North-Sea fisheries, supporting an international fleet of more than 500 vessels with yearly revenues of up to 100 million Euro. Surprisingly, the fishery remains largely unregulated, in part due to the short life cycle of the targeted shrimp, which hamper the establishment of usable biological reference points to support management actions on the exploited stock. However, the question regarding the sustainability of the exploitation pattern of the fishery emerged during the last years. To ask such a question, the size selectivity of thirty-five different codends was assessed and used for a theoretical analysis based on bio-economical assessment of the fishery under different environmental and fishing scenarios. This study suggested that size selection patterns sharper than available codend selectivity might be of great benefit in terms of economical revenues for the fishermen and the sustainability of the fishery (stock size, population structure, recruitment). Consequently, grid technologies are being investigated as potential technical solutions to achieve sharper selectivity patterns and therefore meet the theoretical advice.

The vertical distribution of shrimp influences where the shrimp hit the grid and hence how the contact probability and contact duration of shrimp and grid. To further understand and improve the efficiency of grids, it is important to take into account the vertical distribution of shrimp inside the trawl and its dependency on selection devices (i.e. sieve nets) and/or guiding panels. In this study, we experimentally investigated the vertical distribution of brown shrimp, using a device which split the aft of the trawl into four vertical compartments. In particular, the standard codend was replaced by an extension piece mounting a quad-split frame, used to establish four vertically-arranged compartments. Small-mesh covers were connected to each frame compartments to collect the shrimps at different heights of the water column. Further, three different gear designs (D) were tested to assess the effect of sieve nets (D2, the most used Bycatch Reduction Device in the fishery) and guiding panels (D3) on the brown shrimp vertical distribution, relative to the baseline trawl design (D1).

*daniel.stepputtis@thuenen.de

Investigating grid technologies for improved exploitation patterns in the North Sea Brown shrimp fishery

Juan Santos[1], Daniel Stepputtis[1] *, Bernd Mieske[1], Jimmy van Rijn[2] and Karsten Breddermann[3]

[1]Thünen Institute of Baltic Sea Fisheries, Alter Hafen Süd 2, 18069 Rostock, Germany, [2]Wageningen Marine Research, IJmuiden, The Netherlands, [3] Chair of Ocean Engineering, University of Rostock, Albert-Einstein-Strasse 2, 18059 Rostock,Germany

The brown shrimp (*Crangon crangon*) beam-trawl fishery is one of the most important North-Sea fisheries, supporting an international fleet of more than 500 vessels with yearly revenues of up to 100 million Euro.

Surprisingly, the fishery remains largely unregulated in part due to the short life cycle of the targeted shrimp, which hamper the establishment of usable biological reference points to support management actions on the exploited stock. However, the question regarding the sustainability of the exploitation pattern of the fishery emerged during the last years. In recent years, the size selectivity of thirty-five different codends was assessed and used for a theoretical analysis based on bio-economical assessment of the fishery under different environmental and fishing scenarios. This study suggested that size selection patterns sharper than available codend selectivity might be of great benefit in terms of economical revenues for the fishermen and the sustainability of the fishery (stock size, population structure, recruitment). Consequently, we investigated grid technologies as potential technical solution to achieve sharper selectivity patterns and therefore meet the theoretical advice. Three grid-designs, varying in construction material (plastic, fiberglass and steel), bar design (polygonal, drop-shape-like, round) and bar thickness were tested in experimental fishing onboard a research vessel. The selectivity parameters and contact probabilities for the different grids were obtained using the covers method. As intended, the L50 estimated for the three grids were close to the minimum marketable shrimp length (50 mm), while the Selection Ranges (SR) ranged from 5.0 mm to 7.9 mm, far below the expected SR obtained by codends providing similar L50. Contact probabilities ranged from 55% to 69% indicating further investigations are required in order to make the observed grid selectivities available for larger percentages of shrimps entering the gear.

*daniel.stepputtis@thuenen.de

Gear innovations to reduce the catch of undersized whiting in flyshooting fisheries

Van Opstal Mattias and Soetaert Maarten*

1Institute for Agricultural and Fisheries Research (ILVO), Animal Sciences - Fisheries, Ankerstraat 1, 8400 Oostende, Belgium

Flyshooting is a quite recent fishing technique with a continuously increasing fleet. Most target species like squid (*Teuthida*), striped red mullet (*Mullussur muletus*)and gurnard (*Triglidae*) are not limited by TAC. However, whiting (*Merlangius merlangus*) may become a choke species under the landing obligation, which went into effect in all European fisheries on 1 January 2019.

The goal of this research was to reduce the bycatch of undersized whiting with an acceptable loss of other marketable fish. Scientific literature on flyshoot fishing is very limited, therefore the first phase of the project focused on acquiring video recordings of the behaviour of the caught fish. The fishing gear of a commercial flyshooting vessel (SCH-135) was equipped with go pro cameras to observe the behaviour of fish during the different catch phases, in relation to a square-meshed panel in the back of the net (mesh opening of 87.8 ± 2.3 mm) and to additional stimuli such as LED-lights and coloured ropes close to the panel. The recordings showed that a significant amount of whiting escaped through the panel. The LED-lights showed to have an effect on the behaviour of whiting, while the effect of other visual stimuli was negligible. A second phase of the project aimed at quantifying the escape rates through the panel without the use of additional stimuli. This was done by using a 2ndcod-end (mesh opening of 55.2 ± 1.0 mm) to collect all fish going through the panel. The results confirmed that 90% of the fish going through the panel was whiting, 48% of the total amount of undersized whiting (<27 cm) escaped. The only marketable species that was lost in a significant amount was red mullet smaller than 18 cm (20%), no squid or flatfish escaped.

Our experiments show that the implementation of the panel can help to reduce the bycatch of undersized whiting under the landing obligation, with only a very limited effect on the loss of marketable species.

*maarten.soetaert@ilvo.vlaanderen.be

3.6 Keynote presentation, Åsmund Bjorndal

The becoming, being and return of a fish behaviour and fishing technology scientist

Åsmund Bjordal*

*Institute of Marine Research, Bergen, Norway.

This presentation will recall why and how I become a marine scientist, focusing on fish behaviour and fishing gear research in the late 1970s. I will first review what we did and how we did it, and what was our thoughts in these early days. Then about the paradigm shift in the mid-1980s, from effective and efficient fish capture only, towards stronger focus on responsible fishing, sustainability, ecosystem effects and fish welfare. This clearly changed the gear and behaviour research over the next decades. Finally, I will reflect upon the challenges that face us today and further possibilities in marine fisheries in general and fish capture technology in particular.

*aasmund@hi.no

3.7 Session 4: Technology and management to reduce bycatch and discards (2)

Applying new technologies and approaches at different phases of commercial fishing operations to minimise unwanted catches

Thomas L. Catchpole*

Cefas, Pakefield Road, Lowestoft, Suffolk, UK

Fish provides billions of people with an important source of animal protein. In 2016, the value at first sale of fish from the worlds' capture fisheries was USD $130 billion (FAO, 2018). A recognised threat to the sustainable use of fish stocks, is the capture and discarding of unwanted fish, which results in fishing mortality with no economic benefit, as the catch cannot be sold or eaten, and cannot contribute to the fishery in future years. The magnitude of annual discards in global marine capture fisheries has been estimated at 10-30 million tonnes (FAO, 2018, Alverson et al., 1994, Kelleher, 2005).

Discarding is generally highest in bottom trawl fisheries that catch a mix of species simultaneously (Kelleher, 2005), and in these fisheries, species with the lowest quota or protected species may restrict the fishing opportunities for other commercial species. An objective in many fisheriesis to improve the selectivity of fishing, to minimise unwanted catches, in order to maximise fishing opportunities and meet sustainability objectives. Here, with a focus on bottom trawls, we discuss selectivity improvements in the broadest sense, that is, all aspects of the fishing process that enable the capture of targeted fish while avoiding the capture and mortality of non-targeted fish or other organisms.

Enhancing selectivity in fishing can be achieved through the application of new approaches and technologies at different phases of the fishing operation. Incentivising more selective fishing is a principal objective of the reformed fisheries policy of the European Union. Here we briefly describe European commercial fisheries in the context of the management of discards.

We present examples of the recently trialled and developing approaches and technologies from Europe and beyond, that could enhance selectivity at different phases of the fishing operation:

1. Deploying the fishing gear

2. Monitoring the fishing operation

3. Sorting the catch

4. Reporting and landing the catch

5. Deciding to fish

*thomas.catchpole@cefas.co.uk

Discards in global marine capture fisheries: the most recent update

Amparo Pérez Roda1 and Eric L. Gilman2*

1Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department, Fishing Operations and Technology Branch, Rome, Italy, 2Hawaii Pacific University, College of Natural and Computational Sciences, Honolulu, Hawaii, United States.

The Food and Agriculture Organization of the United Nations (FAO) considers bycatch and discards detrimental to the sustainability of ecosystem, fisheries and food security. Since the first report in 1994, two major updates were done with more and higher quality data and improved methodology. This presentation will provide methodology and key findings of the most recent update – A third update of global marine fisheries discards. This estimate adopted the 'fishery-by-fishery' approach employed in the second discards assessment published in 2005. The update included publicly available discard data in the last 20 years to establish a baseline of a time series of global marine fisheries discards. This is essential for monitoring the status and trends of discard management, which is the first step of the ecosystem approach to fisheries management cycle. The current study estimated that the annual discards from global marine capture fisheries between 2010 and 2014 was 9.1 million tonnes (95% CI: 6.7 – 16.1 million tonnes). About 46% (4.2 million tonnes) of total annual discards were from bottom trawls. The study included a synthesis of estimates of bycatch and discards of endangered, threatened and protected (ETP) species. The report also included a review of previous research on discard practices, related regulations and management measures, and methods for accounting and mitigating against pre-catch, post-capture and ghost fishing mortalities to understanding of the relative importance of factors affecting indirect fishing mortality estimating total fishing-induced mortality and for designing and implementing mitigation measures.

* EricLGilman@gmail.com

Progresses, challenges and preliminary results of REBYC-II LAC- The Sustainable Management of Bycatch in Latin America and Caribbean Trawl Fisheries

Raymon van Anrooy*, Carlos Fuentevilla, Mario Rueda, Daniel Aguilar, Tomas Willems, Nerissa Lucky, Cecilia Quiroga, Fabian Escobar and Nicholas Hopkins

Food and Agricultural Organization of the United Nations (FAO)

The GEF/FAO project on the Sustainable Management of Bycatch in Latin America and Caribbean Bottom Trawl Fisheries (REBYC-II LAC) seeks to improve the sustainability of these fisheries in Brazil, Colombia, Costa Rica, Trinidad & Tobago and Suriname.

These are tropical multi-species fisheries with significant biodiversity and a disproportionate impact on local livelihoods and food security, requiring simple and practical approaches. A core output of the project rests on the introduction of bycatch reduction devices and improved fishing practices. We present preliminary results of the introduction of various fishing gear improvements. In Suriname, tests of a flexible-TED for demersal fish trawl fisheries showed a 68-75% reduction in discards (mostly elasmobranchs). Fishers are not yet comfortable with the retention rate for marketable species, thus preventing voluntary uptake of the device. In the Colombian deep-water shrimp fishery, a prototype net showed a slight increase in target species catches, a 46% reduction in discarded bycatch and 24% reduction in fuel consumption. Results are preliminary and require replication across different seasons, but the fishing industry is already switching to the new nets. In Mexico, results of three research cruises remain inconclusive given the variety of nets and trawling systems evaluated. In T&T, a square mesh added to the codend showed a significant 24.5% reduction of discarded species. None of the nets and devices tested are innovative, but overexploited, under regulated and over-capitalized fisheries require simple gear solutions if fishers are to adopt new practices. The region continues to suffer from inadequate capacity to develop and properly evaluate alternative fishing gear and bycatch reduction devices. International funding and technology/knowledge transfer are urgently required. Alongside its partners, the REBYC-II LAC has fostered an enabling environment in project countries, that includes policy and normative changes as well as increased stakeholder participation in the decision-making process. Dialogue and participation have strengthened trust between policy makers and fishers, leading to desired management processes. Change will require expertise, time and patience. FAO is committed to expanding its support for bycatch management in trawl fisheries and is looking for partners for new initiatives in in the Near East and Africa and partners for follow-up activities in SE Asia and Latin America and the Caribbean.

*Raymon.VanAnrooy@fao.org

Do you really want to leave? The attractiveness of Square Mesh Panels as exit devices for cod

Juan Santos[1]*, Bent Herrmann[2,3], Bernd Mieske[1] and Daniel Stepputtis[1]

[1]Thünen Institute of Baltic Sea Fisheries, Alter Hafen Süd 2, 18069 Rostock, Germany, [2]SINTEF Fisheries and Aquaculture, Fishing Gear Technology, Willemoesvej 2, 9850 Hirtshals, Denmark, [3]Norwegian College of Fishery and Aquatic Science, University of Tromsø, 9037 Breivika, Tromsø, Norway

Square mesh panels (SMPs) are often applied as supplementary selectivity devices in the upper part of the trawl gears (e.g. extension or codend). To work efficiently, SMPs need to be attractive enough to induce fish attempts to contact with them. As for any other event taking place during the catch process, attractiveness to the SMP can involve complex behavioural mechanisms. However, this is often not properly assessed and can lead to wrong assumptions, e.g. fish contact is length-independent. Therefore, evaluating the primary attractiveness of the device is essential to develop more efficient selection devices. Based on catch comparison data collected with twin trawls, we assessed the attractiveness of top SMP on Baltic cod. Both trawls used non-selective codends, therefore the only escaping zone was an SMP inserted in the extension piece of one of the trawls.

The SMP was made of thin, single twine and very large mesh size (200 mm) netting to avoid mechanical size selection, and to establish a zone with high sensorial contrast relative to the net tunnel to enhance attractiveness.

The results show very little attraction from cod to the top SMP and no clear length dependency. Attractiveness increased only for larger individuals by applying devices to stimulate fish avoidance behaviour in the vicinity of the SMP. Our findings indicate top SMP's are not optimal devices for reducing by-catch of small cod in the Baltic Sea.

* juan.santos@thuenen.de

Test of a netting-based alternative to rigid sorting grids in the industrial Norway pout (*Trisopterus Esmarkii*) trawl fishery

Ole Ritzau Eigaard[1*&], Ludvig Ahm Krag[1&], Bent Herrmann[2,3&], Jordan P. Feekings[1] and Claus R. Sparrevohn[4&]

[1] DTU AQUA, Kemitorvet, 2800 Kgs. Lyngby, Denmark, [2] SINTEF Ocean, Brattørkaia 17C, N-7010 Trondheim, Norway, [3] The Arctic University of Norway, UiT, Breivika, N-9037 Tromsø, Norway, [4] DPPO, H.C. Andersens Boulevard 37.1., 1553 København V, Denmark

A new bycatch reduction device (BRD), termed "Excluder", is presented as an alternative to the traditional rigid sorting grids, which are mandatory in the industrial Norway Pout fishery in the North Sea. This fishery is a high-volume fishery with large demersal trawls and catches up to 200 tons per haul. The Excluder is a 24-meter long selective netting section with no rigid structures, developed to reduce bycatch and improving on-board gear handling. The Excluder (78 mm full mesh) was tested against a 1.6 x 3.6 meter standard grid (35 mm bar spacing) in a twin-trawl experiment on-board the commercial 70 m trawler "S364 Rockall" on the Fladen Ground in the North Sea in November 2018. The resulting 11 twin-trawl hauls formed the data basis of length-dependent catch comparison and catch ratio analyses of target and bycatch species. For the target species, Norway Pout, there was an estimated increase in the average catch efficiency of 32 % (3 – 95 %). However, when considering the confidence limits, this increase could be as low as 3 %. For all 6 bycatch species considered, we estimated that the Excluder substantially reduced catches, either length-based or on average. The catches, averaged over all length classes, by the Excluder were: herring (21 %; CI: 11-49 %),mackerel (5 %; CI: 2-14 %),whiting (6 %; CI: 4-11 %), American plaice (70 %; CI: 27-142 %), witch (15 %; CI: 0-27 %), and lesser silver smelt (71 %; CI: 54-95 %) when compared to the grid. Therefore, if the size distributions encountered during the experimental fishing are typical of the commercial fishery, the use of the Excluder would lead to a substantial reduction in bycatches. Potentially, bycatch reduction could be improved further in the Norway pout fishery through modifying the mesh size of the Excluder. We also highlight that the Excluder has a large potential for improving selectivity in a number of other trawl fisheries with bycatch issues.

* ore@aqua.dtu.dk [&] Equal authorship

Is two better than one? Predicting the performance of a combination of bycatch reduction devices in a Nephrops-directed fishery

V.Melli1*, B.Herrmann2,3, J.D.Karlsen1, J.P.Feekings1 and L.A.Krag1

1DTU Aqua, National Institute of Aquatic Resources, North Sea Science Park, DK-9850, Hirtshals, Denmark, 2SINTEF Ocean, Willemoesvej 2, DK-9850 Hirtshals, Denmark, 3University of Tromsø, Breivika, N-9037 Tromsø, Norway

Global efforts to reduce unwanted catches have led to the development of a vast array of bycatch reduction devices (BRDs), in particular for mixed demersal trawl fisheries. An example is the Nephrops (*Nephrops norvegicus*) directed mixed trawl fishery in the Northeast Atlantic, where modifications to most components of the gear have been tested and documented in literature. Since achieving the desired reduction of bycatch in these fisheries is rarely obtained via one single modification, some of these BRDs could be combined to further optimize selectivity. However, testing all possible combinations of documented BRDs would be prohibitive in terms of time and resources. So how do we identify potentially beneficial combinations? We can combine the species-specific, size-selectivity of each individually tested BRD and predict their combined selectivity and performance under different catch scenarios. For the Nephrops-directed fishery we considered a counter-herding device (FLEXSELECT), a modification of the netting in the trawl body, a horizontal separation and multiple codend configurations. From the pool of 100 possible combinations, we identified 15promisingBRD combinations that warrant experimental investigation. Moreover, the results highlighted that an anterior modification such as FLEXSELECT, that can be applied or removed at the haul-by-haul level, creates quickly interchangeable combinations that could lead to a more flexible and dynamic trawl selectivity.

*vmel@aqua.dtu.dk

The use of (electrified) benthos release panels in beam trawl fisheries targeting sole

Soetaert Maarten*, Klaas Sys and Heleen Lenoir

Institute for Agricultural and Fisheries Research (ILVO), Animal Sciences - Fisheries, Ankerstraat 1, 8400 Oostende, Belgium

Benthos release panels (BRPs) were studied in the early 2000's as a tool to decrease the bycatch of benthos and debris, with authors such as Revill & Jennings (2005) and Fontyne & Polet (2002) reporting reductions over 80% for invertebrates and non-commercial fish and over 50% for debris such as stones and litter. Unfortunately, this square meshed panels in the belly of the net also allowed over 20% of the commercial sole (*Soleasolea* L.) to escape, which was an unacceptable loss for fishermen so the BRP was never implemented. However, the importance of fish quality and discard survival, which may improve as a result of the smaller and cleaner catches, has increased a lot in recent years. Therefore, several experiments have been done on the R.V. Belgic a over the past 5 years to prevent the loss of commercial sole, testing and successfully optimizing (electrified) benthos release panels with two different approaches. The first focused on removing the slack previously observed in the panel. By implementing a stretched BRP in a net with rectangular footrope/square net, the BRP showed no more 'bagformation', eliminating horizontal escape possibilities for sole to zero in case of a 150 mm BRP. The second configuration used an electrified cramp stimulus of 40 Hz on top of the panel to immobilize sole and prevent active escapement. As a result, this so called electrified BRPs (eBRP) can use larger mesh openings, further increasing the loss of benthos and debris, to 200 mm without losing commercial fish.

*maarten.soetaert@ilvo.vlaanderen.be

Robbing Peter to pay Paul: Replacing unintended cross-taxa conflicts with intentional trade-offs by moving from piecemeal to integrated fisheries bycatch management

Eric Gilman[1*], Milani Chaloupka[2], Laurent Dagorn[3], Martin Hall[4], Alistair Hobday[5], Michael Musyl[6], Tony Pitcher[7], Francois Poisson[3], Victor Restrepo[8] and Petri Suuronen[9]

[1] Hawaii Pacific University and The Nature Conservancy, Indo-Pacific Tuna Program, [2] University of Queensland and Ecological Modeling Services, [3]MARBEC, Univ Montpellier, CNRS, Ifremer, IRD, [4] Inter-American Tropical Tuna Commission, [5]CSIRO Oceans and Atmosphere, [6] Pelagic Research Group, [7] University of British Columbia, [8] International Seafood Sustainability Foundation, [9] Natural Resources Institute Finland

Bycatch in fisheries can have profound effects on the abundance of species with relatively low resilience to increased mortality, can alter the evolutionary characteristics and concomitant fitness of affected populations through heritable trait-based selective removals, and can alter ecosystem functions, structure and services through food web trophic links. We challenge current piecemeal bycatch management paradigms, which reduce the mortality of one taxon of conservation concern at the unintended expense of others. Bycatch mitigation measures may also reduce intraspecific genetic diversity. We drew examples of broadly prescribed 'best practice' methods to mitigate bycatch that result in unintended cross-taxa conflicts from pelagic longline, tuna purse seine, gillnet and trawl fisheries. We identified priority improvements in data quality and in understanding ecological effects of bycatch fishing mortality to support holistic ecological risk assessments of the effects of bycatch removals conducted through semi-quantitative and model-based approaches. A transition to integrated bycatch assessment and management that comprehensively consider biodiversity across its hierarchical manifestations is needed, where relative risks and conflicts from alternative bycatch management measures are evaluated and accounted for in fisheries decision-making processes. This could be accomplished, for example, by adapting the current piecemeal International Plans of Action of the Food and Agriculture Organization of the United Nations into international guidance for integrated assessments and management of fisheries bycatch. This would enable managers to select measures with intentional and acceptable trade-offs to best meet objectives, when conflicts are unavoidable.

*EricLGilman@gmail.com

Bycatch reduction actions in scope of REBYC II -LAC /FAO in Brazil

Dérien Lucie Vernetti Duarte[1*], Bianca Bentes[2], Carlos Fuentevilla[3], Luiz Felipe Cestari Dumont[4], Rodrigo Medeiros[5], Vanildo S. Oliveira[6] and Fabio Hissa Vieira Hazin[6]

[1] Centro Nacional de Pesquisa e Conservação da BiodiversidadeMarinha do Sudeste e Sul do Brasil – CEPSUL/ICMBio, Av. Carlos Ely Castro, 195, Centro, Itajaí city, Santa Catarina state, Brazil, 88301-445, [2]Universidade Federal do Pará – UFPA, Rua Augusto Correia, S/N, Guamar, Belém city, Pará state, Brazil, 66075-000 , [3] FAO Subregional Office for the Caribbean, P.O. Box 631-C, Bridgetown, Barbados, [4]Universidade Federal do Rio Grande – FURG, Campus Carreiros, Av Itália, km 8, Carreiros, Rio Grande, Rio Grande do Sul, 96203-900, [5]UniversidadeFedearl do Paraná – UFPR, Av Beira Mar S/N, Pontal do Sul, Paraná, 83255-000, [6]Universidade Federal Rural de Pernambuco – UFRPE, Av. Dom Manuel de Medeiros, S/N, DoisIrmãos, Recife, Pernambuco, 52171-900

Shrimp trawling is one of the most important economic activities worldwide. The low selectivity of these gears results in a high bycatch ratio, and the lack of basic information on bycatch amount and composition in shrimp trawl fisheries hinders the management and conservation strategies.

In these contexts, the project REBYC II – LAC (Sustainable Management of Bycatch in Latin American and Caribbean Trawl Fisheries) from FAO (Food Agriculture Organizations) has, among its goals, to establish baseline information on the impacts of bycatch in shrimp trawling in Brazil, to develop and test bycatch reduction devices and use these technologies as part of management process. The project is being held in three regions of Brazil, namely: North (Bélem, Pará State), Northeast (Barra de Sirinhaém, Pernambuco State), Southern (Santa Catarina and Rio Grande do Sul States). The first goal of the project was to assess the bycatch composition and abundance for different shrimp fisheries, as well as investigating the temporal and spatial variation. For instance, interannual bycatch of legal (fyke net) and illegal (trawling) fisheries were assessed in order to understand the main factors influencing the bycatch composition. Results indicated that the bycatch from trawling is composed of a higher number of species (61), some endangered. The second goal is to improve the selectivity of shrimp trawl gears by using bycatch reduction devices. In Barra de Sirinhaém, South of Pernambuco, a series of 108 tests were develop using fisheye, square-mesh and Nordmøre grids. The tests showed positive results, and the BRDs were able to significantly reduce bycatch with very low shrimp loss. It is also important to highlight that the fishermen were involved in the process and their needs were taken into consideration to develop devices.

Additionally, the REBYC project is a novel possibility to adopt a participatory approach to fisheries management, and a successful case study in the Marine Protected Area of Anhatomirim is worth noticing. In this region, the management plan has involved different stakeholders, and the BRDs were used as a powerful tool for discussing the regulations, providing discard reduction and reducing ecological damage for these ecosystems.

*derienvernetti@yahoo.com.br

3.8 Session 5: Selectivity of fishing gear: Means and methods

Comparing the size selectivity of three different codend mesh orientations in the Icelandic Northern Shrimp (Pandalus borealis) trawl fishery

Zhaohai Cheng[1]*, Haraldur Arnar Einarsson[2], Shannon Bayse[1], Bent Herrmann[3], [4] and Paul Winger[1]

[1] Fisheries and Marine Institute, Memorial University of Newfoundland, P.O. Box 4920, St. John's, NL, A1C 5R3, Canada, [2]Marine and Freshwater Research Institute, Skúlagata 4, 101 Reykjavík, Iceland, [3]SINTEF Ocean, Fishing Gear Technology, Willemoesvej 2, 9850, Hirtshals, Denmark, [4]University of Tromsø, Breivika, N-9037 Tromsø, Norway

The size selectivity of a traditional T0 mesh codend was compared to experimental T45 and T90 mesh codends in the inshore Northern shrimp (*Pandalus borealis*) fishery of Iceland. Results showed that there was no significant difference in size selectivity of Northern shrimp between the T0 and T45 codends at lengths greater than 13 mm (Minimum references size; MRS); size selectivity for Northern shrimp less than the MRS was undetermined due to small catches at those sizes. Size selectivity was significantly different between T0 and T90 codends and T45 and T90 codends. The T90 codend retained less Northern shrimp between 9 and 19 mm than the T0 codend, and retained less between 15 and 19 mm than the T45 codend. In conclusion, the T90 codend had better size selectivity than the other codends, decreasing the catch of undersized Northern shrimp at 9-12 cm when compared to the traditional T0, however capture of commercial sizes 13-19 cm are also captured less.

*zhaohai.cheng@mi.mun.ca

Development and performance of selective trawl net prototypes for pink shrimp from Campeche, Mexico

Daniel Aguilar Ramírez*, José Alejandro Rodríguez Valencia and Luis Vicente González Ania

Instituto Nacional de Pesca y Acuacultura. México

The Campeche industrial shrimp fleet is the most important fishery in the Gulf of México. It fishes on endemic pink shrimp (*Farfantapenaeus duorarum*), producing in average 4,000 t/season over this decade with reduced nominal effort (248 trawlers in 2008and 102in 2017; average yield: <3.5 t/vessel/season). The fleet profitability is low, since old vessels continuously require repairs, fuel represents >85% of the total operative costs and local markets prefer juvenile shrimp. A prototype of a lighter and selective shrimp net was tested in that fleet during 2018, framed by the FAO-GEF project "Sustainable Management of Bycatch in Latin America and Caribbean Trawl Fisheries" (REBYC-II LAC). The net has a four panels design;50′ of head rope, buoy less, made with knotless Spectra™ webbing panel (4 ply); there is a mesh size gradient from 60 mm to 44.45 mm, connected to cod ends of P.E. 44.45 mm or 38.1 mm. It includes a turtle excluder device (Super shooter, downward exit), a fish excluding device (fish eye, 3.4 m forward from drawstring), and a second footrope as a drag train without tickle chain. The net performance was assessed using traditional wood trawl doors (8′x 40", 180 Kg/each.) and steel hydrodynamic doors (Polar™ Neptune of 1.3m², 230Kg/each.) in quad-rigs arrangement (2 nets by board). The use of Acoustic Notus™ sensors and tension meters in three 15-dayexperimental cruises undertaken at different moments of the shrimp season (April, August and December) allowed the characterization of the net behaviour and its catches. The prototype net showed good performance and efficiency for fishing larger shrimp, while reducing by 40 percent the bycatch of benthic species and offering lower resistance to the vessel advance. Vessels operating prototype nets operated at lower RPMs, implying reduced fuel consume. Steel trawl doors were difficult to operate in the third cruise and modifications in the drag train of prototypes during that cruise affected the catch and selectivity as well. A forth cruise will be undertaken during in summer 2019 for achieving 30 trials with strict statistical robustness. The local fleet has agreed on continuing testing the prototype net and fleets from other regions of Mexico are also requesting tests on board their vessels. This represents an opportunity for modernizing and improving Mexican shrimp trawling fishing and producing sustainable seafood.

*daniel.aguilar@inapesca.gob.mx

Study on the selectivity of stow net in the Haizhou Bay

Liuyi Huang*, Yuyan Li, Huiliang Gao, Qingchang Xu and Yanli Tang

College of Fisheries, Ocean University of China, Qingdao, 266003, China

The Haizhou Bay is one of China's famous traditional fishing grounds, and also marine spawning grounds, feeding grounds and migration field. Stow net is the main fishing gear in Haizhou Bay, and it mainly catches shrimp and small fish bycatch crab and other shrimps. It is of great significance to study on the selectivity of stow net for the admittance of stow net and the protection of marine fishery resources in this area. In this study, the selective tests of three mesh sizes of codends for the main economic varieties (*P.polyactis, T.curvirostrisand O.oratoria de Haan*) were carried out by the cover-net method. The result showed that when the mesh sizes were 30mm, 35mm, and 40mm, the 50% selection lengths L50 of *P.polyactis* were 7.920cm, 9.503cm and 11.229cm, while the selection ranges (SR) were1.975cm, 2.306cm, 3.775cm, respectively; the 50% selection lengths L50 of *T. curvirostris* were 5.400cm, 5.901cm, 7.404cm, while the selection ranges (SR) were1.283cm, 1.376cm, 1.709cm respectively; the 50% selection lengths (L50) of *O.oratoria de*

Haan were 7.844cm, 8.324cm, 9.602cm, while the selection ranges (SR) were2.680cm、2.719 cm、2.973cm respectively. The selective tests of four mesh sizes of square mesh escape windows for *Pseudosciaena polyactis* and *Trachypenaeus curvirostris* were carried out. The result showed that when the mesh sizes were 35mm, 40mm, 45mm and 50mm, the 50% selection lengths L50 of *P.polyactis* were 9.27cm, 12.54cm, 13.46cm and 15.94cm, while the 50% selection lengths L50 of *T.curvirostris* were 6.01cm, 6.15cm, 7.73cm and 8.66cm. The results can be used as reference to determine the minimum mesh and design the selective device for stow net in Haizhou Bay.

*huangly@ouc.edu.cn

Benefits of 120 mm diamond and 100 mm T90 codends in mixed demersal fisheries

Matthew McHugh[1]*, Daragh Browne[1], Martin Oliver[1], Cóilín Minto[2] and Ronán Cosgrove[1]

[1] Bord Iascaigh Mhara, New Docks, Galway, H91 HD92, Republic of Ireland, [2] Galway Mayo Institute of Technology, Dublin Road, Galway, Republic of Ireland.

The European Union landing obligation discard plans specify technical measures to increase gear selectivity and reduce unwanted catches. Scope exists to add more gears where equivalent selectivity for key species can be demonstrated. Ireland's commercially important Celtic Sea seine-net fishery is impacted by the technical measures. Seiners traditionally use a 100 mm diamond mesh codend with 120 mm square mesh panel (SMP), but also a 120 mm diamond mesh codend (T0 120) without a SMP which helps prevent fish meshing in the SMP when hauling the seine. The T0 120 is not included in the technical measures. This study aimed to compare selectivity between T0 120 and a gear which is included in the Celtic Sea technical measures, a 100 mm T90 mesh codend (T90 100).

A binomial logistic model with bootstrapping was used to statistically assess proportional differences in catches from alternate tows. Overall, less than 0.5% of total haddock and whiting, and 2% of cod catches were below minimum conservation reference size (MCRS), suggesting equivalent selectivity between the two gears. In relation to ≥ MCRS fish, T90 100 caught almost twice as much haddock and three times fewer whiting compared with T0 120. There are relatively low and high quotas for haddock and whiting respectively in the Celtic Sea. Hence, vessels in that area should have an option not to catch excessive quantities of haddock while maintaining reasonable whiting catches using T0 120.The results strongly support the case for T0 120 to be added to the Celtic Sea technical measures, and for T90 100 to be permitted in other areas where fishers target haddock and want to avoid whiting.

*matthew.mchugh@bim.ie

Selectivity of diamond and square-mesh codends in the East China Sea trawl fishery for *Parimichthys polyactis*

Hongliang Huang [1]*, Xuefeng Song1 and Taichun Qu[1]

[1]Key Laboratory of East China Sea Fishery Resources Exploitation, Ministry of Agriculture; East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Shanghai, 200090, China

A new mesh configuration trawl has been conducted in the East China Sea. Traditional diamond mesh and square mesh codends with 40mm, 50mm, 60mm, 65mm, mesh size were tested using the covernet method.

The catching data using different sets of network configuration, different mesh sizes was analysed, selective parameters were estimated by using the logistic equation with the maximum likelihood method and Significant differences of two mesh configuration deal with spss software. The results show that: 1) when the codend mesh size is 40mm, *P. polyactis* can't escape from the codend, neither is selective. The rest three meshes display that square mesh escape rate is slightly higher than diamond mesh, but square and diamond escape rate difference was insignificant (P>0.05). 2) when the mesh size was 60 and 65mm, square mesh configuration capsule 50% retention length (L0.5) than the corresponding diamond mesh bag large 16.8 percent, 7.3 percent, square mesh has a better selectivity on *P. polyactis*. 3) According to the *P. polyactis* 50% retention body length (L0.5), and the current catch standard together with capture fishery production, the appropriate trawl is diamond mesh size of 60mm or square mesh size of 55cm, both of two have the same selectivity and practical application effect.

*ecshhl@163.com

Cod-end selectivity for sole (*Solea solea*) and plaice (*Pleuronectes platessa*) in North Sea pulse-trawl fisheries

Pieke Molenaar* and Chun Chen

Wageningen Marine Research, Ijmuiden, The Netherlands

Electrified pulse trawls have replaced traditional tickler chain beam trawls in the North Sea fisheries for sole. This study investigates the mesh selection in pulse trawling of conventional cod-ends (80 mm cod-end mesh) used in the current pulse trawl fishery, and the effects of increasing the cod-end mesh size to 90 mm on catches of sole (*Solea solea*) and undersized plaice (*Pleuronectes platessa*). Cod-end selectivity was estimated for 79-80 mm and 87-88 mm codends during two experiments on a commercial pulse trawler using a cover cod-end. The results show that with a mesh size of 79-80 mm the length where 50% of the individuals are retained (L50) for sole is 19 cm with a selection range (SR) of 4.9 cm. Given the observed length distribution of sole on the fishing ground this results in a 10% loss of marketable sole catches in the 24-27 cm length range. Increasing the mesh size in experiment one to 87 mm resulted in a L50 for sole of 22 cm with SR = 4.9 cm and in experiment 2 to a L50 of 26 cm and SR = 4.9 cm was found for 88 mm cod-end, resulting in a loss of marketable sole of 24% and 38% in experiment 1 and 2, respectively. These losses were detected in the 24-33 cm length range. Compared to sole, plaice showed steeper selection curve with a L50 of 14.4 cm (SR 2.5) and 14.1 cm (SR 2.1) for the 79-80 mm cod-ends in experiment 1 and 2, respectively. In the 87 mm cod-ends, this L50 shifted to 15.6 cm (SR 2.5) for experiment 1 and 18.7 cm (SR 2.1) for the second experiment. The ratio of plaice discards per kg marketable sole caught was 0.4 in experiment one for 80 mm cod-ends, and increased to 0.5 in an 87 mm cod-end. In the second experiment this was 2.3 for 79 mm and 2.5 for 87 mm. Increasing the minimum cod-end mesh to 90 mm thus increases the discard quantities of undersized plaice when the sole total allowable catch (TAC) is fully exploited.

*pieke.molenaar@wur.nl

3.9 Session 6: New technologies for fisheries research and education

Development of acoustic catch monitoring methods for purse seine fisheries

Maria Tenningen*, Jan Tore Øvredal and Gavin Macaulay

Institute of Marine Research, P.O box 1870 Nordnes, NO-5817 Bergen

Control over catch size, composition and behaviour in relation to fishing gear is important for sustainable and economic fisheries. In purse seine fisheries targeted fish schools are acoustically evaluated before the seine is set. Despite this, unwanted fish may be caught by the net. It is then important to obtain school information before the fish densities inside the seine reach detrimental levels and it is still legal to release the catch. Currently, no suitable monitoring systems exist, mainly because of difficult observational conditions during fishing. The aim of the present work is to obtain a better understanding of the acoustic environment (obstructions between the seine and acoustic transducers, such as propeller-generated air bubbles and the seine itself) and to thereby develop improved catch monitoring methods for purse seine fisheries. Our studies indicate that propeller generated air bubbles and the seine net significantly interfere with the acoustic beams, making catch monitoring with vessel mounted instruments difficult. A new approach is now being developed, whereby an echosounder is deployed into the water enclosed by the seine net. Initial experiments were made in June 2018 in the North Sea, during the Atlantic herring fishery. The echosounder (Simrad ES200 – 7CDK transducer and WBT mini transceiver) was deployed from a flying drone, and acoustic data were transferred and visualized in real time onboard the fishing vessel. A single beam echosounder will not give as good an overview of the school as a vessel-mounted multibeam sonar, but has the potential to provide more detailed information on school density and vertical distribution. This system combined with sonar may also provide more accurate school biomass estimates if used before the seine is set.

*maria.tenningen@hi.no

Open source software for statistical models of gear selectivity

Mollie Brooks*, Tiago Veiga-Malta, Ludvig Krag and Jordan Feekings

National Institute of Aquatic Resources, Technical University of Denmark

Software for modelling gear selectivity has been limited in its general availability. To solve this issue, we present a new R package, selfisher, for modelling many common types of data obtained from selectivity experiments, including catch comparison, paired gear, covered codend, alternate haul (paired or not), trouser trawl, and twin trawl. The main requirement is that the design can be characterized by a binomial distribution, meaning that there are two possible outcomes for each fish.

The selectivity model is flexible such that, in addition to length, it can contain covariates such as total catch weight or environmental and vessel variables that may affect retention probability. Factors may also be incorporated in the selectivity model as random effects. It can also contain splines via the bs or ns functions from the splines package. Possible link functions for the selectivity model include "logit" (logistic), "probit" (i.e. normal probability ogiv), "cloglog" (i.e. negative extreme value), "loglog" (i.e. extreme value/Gompertz), or "Richards".

In paired gear designs, the relative fishing power can be modelled by specifying psplit=TRUE in a selfisher model. Then the probability that a fish entering the gear enters the test codend is p where retention probability is being tested; and 1-p is the probability of entering the control codend where retention probability is 1. In a selfisher model with psplit=TRUE, the default is to model p as an intercept-only model (pformula=~1) with a logit link. Relative fishing power can be fixed at 0.5 by specifying pformula=~0. Or it can be a function of covariates, e.g. if p depends on x, one could specify pformula=~x.

With selfisher, statistical inference and hypothesis testing can be done via Wald z-tests, likelihood ratio tests, information theory (e.g., AIC), and bootstrapping. A double bootstrapping method, named bootSel, which can resample hauls is available in the package. There is also a predict method which allows calculation of expected retention probabilities and can be combined with bootstrapping to obtain confidence intervals.

Examples will be demonstrated in the talk. More information and installation instructions for the selfisher package can be found at https://github.com/mebrooks/selfisher. The selfisher package is an open source software that is continuously being developed, where additional analyses are being incorporated and a user-friendly interface is being developed.

*mollieebrooks@gmail.com

Open Scientific Measurement Board (OpenSMB)

Andreas Hermann[1]*, Daniel Stepputtis[1]*, Marcellus Rödiger[2] and Joachim Hensel[3]

[1] Thuenen Institute of Baltic Sea Fisheries, Alter Hafen Süd [2]; Rostock; Germany, 2Thuenen Institute of Sea Fisheries, Herwigstraße 31, 27572 Bremerhaven; Germany, [3] Hensel Elektronik GmbH, Hinrichsdorfer Straße 7c, 18146 Rostock; Germany

Taken into account the way of data acquisition, fishery scientists seem to be very conservative and often stick to a simple length measurement board, paper and pen (the analogue way) - resulting in quite inefficient data sampling procedures (e.g. every single datum passes through, at least, 3 people/work steps). Although, several digital data acquisition tool/electronic measuring boards for use in fishery science were developed over the last years, these are not widely used. We have figured out some major issues: a) lack of adaptability to own needs and future requirements (mostly proprietary solutions), b) restriction to one computer-platform and c) lack of modularity (use of standard hardware). In a nutshell: a system is needed, which is more "future safe".

Sustainable Ocean research (including fishing gear research), requires sustainable data acquisition technology. Open Source-solutions are obvious key elements to achieve this ambitious goal. Ideally, these solutions can

- make intensive use of user expertise and requirements,

- extend the life-time of such tools due to independence of manufacturer-product cycles and sufficient documentation for further development, reproduction and repair,

- make efficient use of resources (available in the different institutions), when working on a joint solution, rather than spending money and effort in institution-specific solutions.

Under this premises, the 'open scientific measurement board' (openSMB) was developed, a scientific Open Source data acquisition system to be used in fisheries sciences (e.g. in Lab, at sea, at commercial vessels). The system includes a highly flexible, modular and future-proof software and hardware, which is easily adaptable to future needs in fisheries science (or even in other scientific fields, such as agriculture).

Key design criteria are platform independency, use of standard industrial components, standard formats (e.g. JSON) and interfaces for data and scalable hardware. Due to the integrated SBC (single board computer) the openSMB is far more than a simple fish length measurement device with 1 mm resolution. Moreover, it can act like a complete data acquisition system, managing user defined and complex sampling schemes, interact with other devices (e.g. scales, callipers, internal and external databases, other openSMB, external display devices). The device‘s interface can be accessed remotely via Wi-Fi or Ethernet using the fully documented API in JSON-format.

The 'open scientific measurement board' (openSMB) – development will be presented.

*daniel.stepputtis@thuenen.de *andreas.hermann@thuenen.de

Infrared Fish ObservationiFO

Andreas Hermann, Daniel Stepputtis* and Jerome Chladek

Thuenen Institute of Baltic Sea Fisheries, Alter HafenSüd 2; Rostock; Germany

A sustainable ocean monitoring strategy needs sustainable technology and measurement devices because that is its primary fundament. What we derived from our long experience is: to achieve this ambitious goal, the most promising way is to follow an open source approach. On the one hand there are plenty of good solutions published under an open source license that can be re-used and adapted to our scientific needs and on the other hand it might be useful for others to participate in the improvements.

The use of infrared video surveillance at night is very common for onshore applications and therefore hardware became efficient and cheap. Nevertheless, the observation in a dark environment is also a frequent task in fishery science. In many cases the use of visible light is inacceptable to avoid bias of fish behaviour. Available acoustic cameras reach a high resolution at a medium range, but those are complex and expensive systems. Like humans, various fish species cannot see infrared light. So far underwater infrared video observation is not very common. One major obstacle is the relative high attenuation compared to visible light. But with the increasing effectivity of LED technology, even very cheap CMOS cameras can cover acceptable ranges suited for many application scenarios. Our task was to observe the behaviour of cod at the entrance of different fish traps. After first tests with IR-cameras, we developed our own infrared camera and light system from standard components. It delivers underwater videos in darkness at a distance up to 1.8m. We use a consumer single computer board (Raspberry Pi) and standard industry parts. A system consists of one camera and two lights, where as parts are below 250€ including 100m depth rated housing. It uses open source software tools running on a Linux platform. The system offers a webserver, a comfortable scheduler, a motion detection unit, and can store internally more than one week’s continuous video data.

Additionally, we added an LTE router with internal NAS (FritzBox 7890) to be used with up to four camera systems and an external hard disk. This allows storing video data for several weeks and gains full access via VPN and LTE to the whole system. It gives remotely live videos, access to the camera‘s webserver for adjustment and setup, for instant download of data and to the camera‘s operating system for maintenance.

*daniel.stepputtis@thuenen.de, andreas.hermann@thuenen.de

The SeSAFE learning management system: application and potential to provide training and build capacity in fishing technology

Stephen Eayrs*

Smart Fishing Consulting., 501/17 Gibbon St. Woolloongabba. Queensland, Australia. 4102

This presentation will describe the SeSAFE project (www.sesafe.com.au) and how readily available software used to train fishers in safety awareness at sea can be adapted to build capacity in fishers, researchers, and others in a variety of other relevant topics.

Over recent decades training opportunities for individuals working in the commercial fishing industry have become increasingly rare. This includes opportunities for fishers to obtain vocational training in nautical knowledge and seamanship and for researchers (and others) to receive academic training in fishing technology. Subsequently, prior to going to sea for the first time, many in experienced fishers receive little training in occupational health and safety, fishing gear design and operation, and other relevant skills, with training often provided on-the-job, informally, and when time permits. Furthermore, many researchers receive limited formal training in fishing technology, such as gear design, operation, and rigging, and field work planning, execution, and analysis, despite being employed in positions that require competence in these topics.

Following several high-profile tragedies in recent years on Australian commercial fishing boats, resulting in loss of multiple lives and several boats, a learning management system (LMS) using online software has been developed to provide safety training to fishers in the Australian fishing and aquaculture industry. Funded by the Fisheries Research and Development Corporation (FRDC), the commercial fishing industry, and the Australian Maritime Safety Authority (AMSA), the LMS comprises multiple brief training modules that can be accessed by fishers at home, at sea, or elsewhere. Modules currently include training in workplace health and safety policy, risk assessment, emergency response, personal health and safety, operational safety, and fishery-specific safety hazards. They are specifically designed for the commercial fishing industry and each concludes with several brief questions that a fisher must complete and pass to an acceptable standard, thus filling an overlooked void in their safety training.

The SeSAFE project will be described, including software and module delivery options and industry uptake. An example of an LMS module will also be presented, followed by a discussion describing how an LMS could be developed by the FAO, academic institutions, or others to serve training needs and build capacity, such as appropriate fieldwork techniques to test and evaluate fishing gear performance.

*smartfishing1@hotmail.com

3.10 Session 7: Energy, technology, analysis and simulation

Energy use in fisheries and development of eco-driven fishing techniques

Antonello Sala* and Emilio Notti

Italian National Research Council, Ancona (Italy)

Recently the climate-abusing effects of exhaust gases from combustion processes have been increasingly focused. This is underlining the importance of improving the energy efficiency. Nowadays, fishing fleet is in most cases not efficient because of outdated technology. Maintaining an adequate level of energy efficiency requires a continuous monitoring of the energy profile of the vessel. Any causes of energy inefficiency can be identified, being able to act on them promptly and effectively.

Individual technological adaptations offer energy savings mostly in the range of 10-30%. Examples are given on reducing the drag of towed fishing gears, potential changes in trawl design as well as replacement by more efficient otterboards.

Measurement of energy consumption during vessel operations in different working conditions (sailing to and from the fishing ground, fishing operations or fish processing) might also lead to identify the potential for fuel-saving by improving vessel's operating conditions. A proper system of energy use monitoring is therefore essential for maintaining high-energy efficiency. Once energy use has been related to each operating condition, fishers can minimize fuel use. Energy efficiency in fisheries can be investigated through Energy Audit, which allows obtaining an extensive energy profile of the fishing vessels monitored. Vessel Energy Audit assesses the energy consumption of each energy user (e.g. propulsion system, electric- and hydraulic-user). Energy audits have been conducted for fishing vessels, which lead to recommendations for improved efficiencies to solve present and possible future fuel cost increases.

With regard to greenhouse gas (GHG) emissions, insufficient attention has been paid to the fisheries sector as a whole and to fishing operations in particular. Consequently, it is difficult to rank fishing gear and practices in terms of GHG emissions. However, using the consumption of fuel as a proxy for total GHG emissions can provide a good estimate. The fishing sector should strive to further lower its fuel consumption and decrease ecosystem impacts. Despite a growing number of initiatives and experimentation with energy-reducing technologies, there is currently no viable alternative to fossil fuels for mechanically powered fishing vessels. However, it is well demonstrated that, through technological improvements, gear modifications and behavioural change, the fishing sector can substantially decrease the damage to aquatic ecosystems, reduce GHG emissions (which is a legal obligation for governments under existing international conventions) and lower operational costs for fuel without excessive negative impacts on fishing efficiency.

*antonello.sala@cnr.it

CRISP - Eight years of innovation in fisheries technology

Aud Vold*

Institute of Marine Research, Bergen, Norway.

For nearly 8 years CRISP (the Norwegian Centre for Research-based Innovation in Sustainable fish capture and Processing technology) has developed smart technologies for more responsible trawl and purse seine fishing. The CRISP consortium consists of innovative industry companies and research institutes working together to increase value creation through developing "green" technologies and fishing methods. It has responded to several global challenges faced by the fishing industry. The philosophy of CRISP has been to develop technologies and tools that enables fishermen to take informed decisions on how to harvest the ocean in an eco-friendly manner and at the same time improve catch quality and value.

This has been done in several ways: by developing instruments for pre- and early-catch identification of fish species, size and school volume and for monitoring the fishing gear during capture; by development of environmentally friendly and selective fishing gears, as well as developing gentle capture and handling methods which improve catch quality and income. The pre-catch identification systems developed enables fishermen to avoid catching non-target species or sizes. Monitoring systems that visually and automatically identifies the catch inside the gear may be linked to active selection devices and thereby reduce bycatch and discarding. Gear modifications and new handling methods may substantially affect fish welfare and thereby also the potential survival of released catch and improved quality of landed fish.

*aud.vold@hi.no.

Large scale pontoon trap in cod fisheries, a retrospect

Peter Ljungberg*

Swedish University of Agricultural Sciences, Turistgatan 5, 453 30, Lysekil, Sweden

Swedish coastal fisheries are severely affected by the steady increasing seal populations. In addition, the EU's landing obligation makes coastal fisheries even more complex due to their simultaneous targeting of multiple species. A stronger focus on the advancement of both selective and seal-safe gear is therefore of great importance to sustain coastal fisheries. In Sweden, more than 300 pontoon traps are used in the salmon (*Salmo salar*) and whitefish (*Coregonus lavaretus*) fisheries.

Since 2014, modified pontoon traps have been evaluated within the Swedish coastal fisheries both targeting cod (*Gadus morhua*) but also for multi species fisheries. Beside catch efficiency our evaluation includes studies on seasonality aspects, fish house positioning within the water column, size selectivity trials, attraction, target species behaviour in regards to the gear, discard survival analysis and comparison with gillnet fisheries and catch value evaluation. We put our results in a broader perspective of costal fisheries and show how pontoon traps may be used as a complement within the coastal fisheries in changing environments.

*peter.ljungberg@slu.se

Some Relationship of the Characteristics of trawl net, Otter Board and trawlers in Thailand

Isara Chanrachkij[1]*, Tanut Srikum[2], Nakaret Yasook, Santipong Putsa, and Narong Ruang-sivakul1

[1] Southeast Asian Fisheries Development Center/ Training Department, [2]Deep-sea Research and Exploration Group, Marine Fisheries Research and Development Division, Department of Fisheries Thailand

The study on Some Relationship of the Characteristics of Trawl Net, Otter Board and Trawlers in Thailand is carried out by the survey for gathering data of trawl gear and trawler along the coast of the Gulf of Thailand, in year 2015. The survey conducted in collaboration between Training Department of Southeast Asian Fisheries Development Center, Marine Fisheries Research and Development of Department of Fisheries Thailand and Thai local trawl fishers. Forty-six (46) bottom trawl nets of thirty-seven (37) otter board trawlers were surveyed and collected technical data, i.e. length overall (m), gross tonnage (GT), engine power (kW), otter board area (m^2), otter board height (m) and head rope length (m).

Result of the study reveals that gross tonnage, engine power, height of otter board, area of otter board, head rope, and ground rope, shows correlation among them, between 0.73 - 0.99 at confident level 95% The very high correlation, 0.986, is found in the comparison between height of otter board and length of otter board. The lowest correlation, 0.727, is found in the comparison between gross tonnage and head rope. The study on the influence of independent variable i.e. length overall (m), gross tonnage (GT), engine power (kW), otter board area (m^2), otter board height (m), and head rope length (m) to dependent variable shown by R-square value at confidence level 95% Range of R-square value between 21% - 91%. The highest R-square value, 90.94 found in comparison between area of otter board and length of otter board. The lowest R-square value, 21.88, found in comparison between engine power and head rope length.

Fisheries manager can apply the study result to control efficiency of trawl net. Management measure on trawl gears and trawler can apply through fishing gear inspection on the trawl parts which can be selected from the study result, such as area of otter board, engine power, ground rope, etc. According that trawl net and trawler collected in this survey was less in number compare with total trawl net of Thailand, further data collection should be continue undertaken to generate more accurate result to serve better management.

*isara@seafdec.org

Numerical Simulation on the Mechanical Properties of Marine Float

Wenhua Chu[1,2,3]* and Xuchang Ye[1]

[1] College of Marine Sciences，Shanghai Ocean University, Shanghai 201306, [2] National Engineering Research Center for Oceanic Fisheries, Shanghai 201306, [3] Laboratory of Sustainable Exploitation of Oceanic Fisheries Resources, Ministry of Education, Shanghai 201306

As the key structure of buoyance and dynamic lift generation, the float is one of the most important attachments of the fishing gear in ocean fishery. For the special work environment, the float may deform and move under the hydrodynamic force when it works. At the same time, the motion may cause the impacting action from fluid and structures around.

Then the investigation of the mechanical behaviour of the float is of important significance for the structural design and performance optimization of the fishing gear, and even for the development of the ocean fishery. The three-dimensional numerical model of marine float working in the flow field was established based on the smooth particle hydrodynamics (SPH) method and the finite element (FEM) method according to the structural form and the mechanical characteristics in operation. The hydrodynamic performance and impact resistance were analysed, and the response mechanism of float structure under the action of hydrodynamic load and impact load was summarized. It aims at providing basic theory support for the structure design and optimization of marine float and the related fishing gear.

*whchu@shou.edu.cn

Numerical and experimental investigations on twisted ropes with regard to their hydrodynamic behaviour

Stephan Schacht* and Mathias Paschen

Chair of Ocean Engineering, University of Rostock, Justus-von-Liebig-Weg 2, 18059 Rostock,Germany

It is known that currents induce a hydrodynamic transverse force on twisted ropes. This transverse force is perpendicular to the plane spanned by the tangent of the rope and the direction of flow. Its direction of action results from the twisting of the rope (z / s). The amount of this force obviously depends on the local angle of attack, the rope characteristic and the Reynolds number. If it is possible to increase this force in a targeted manner, this effect could be used to support the effect of the trawl doors for opening of pelagic trawls by a decreasing drag of the doors.

In the context of a current PhD thesis the emergence of the flow induced transverse force is researched. The influence of the lay angle as well as the incident flow angle on the pressure distribution on the surface of a twisted rope is investigated. Both numerical and experimental investigations in a wind tunnel were carried out and a suitable measuring concept was developed. On the basis of these and further investigations, the design of ropes can be further optimised in order to influence desired effects in a targeted manner.

*stephan.schacht@uni-rostock.de

Flow simulation in and around a North Sea brown shrimp beamtrawl

Karsten Breddermann*and Mathias Paschen

Chair of Ocean Engineering, University of Rostock, Justus-von-Liebig-Weg 2, 18059 Rostock,Germany

Shrimp beam trawls to fish brown shrimp (*Crangon crangon*) are made from small mesh size netting. To reduce unwanted by-catch and debris, sieve nets of large mesh size are used in the trawls which guide unwanted objects out of the trawls. In order to improve the size selectivity on brown shrimp, investigation is being done into the application of sorting grids. Furthermore, it is expected that guiding panels of small mesh size, which are rigged in front of the sorting grid, maximize contact probability between catch and grid and hence improve the sorting capability of the grid. However, sieve net and guiding panel obstruct the flow, slowing the flow in the trawl down, possibly resulting in a reduced sorting capability of the grid.

Therefore, to investigate the effect of the sieve net and the guiding panel on the fluid flow in front of the sorting grid, the flow through and around a shrimp beam trawl was simulated using "Reynolds averaged Navier-Stokes" (RANS) methods.

The dimensions of a trawl with a sorting grid section were provided by the Thünen Institute of Baltic Sea Fisheries. The width of the beam trawl is 7 m and the total length is approximately 20 m.

For the flow simulation, the beam trawl has been assumed to be rigid. The mesh sizes of the guiding panel and the sieve net were varied and the effects of the variations on the flow field are discussed.

*karsten.breddermann@uni-rostock.de

3.11 Session 8: Chinese fisheries – Status, challenges and future

Moderator: Liuxiong Xu (Shanghai Ocean Univ., China)

Research on fishing gear selectivity and its application in China

Liuxiong Xu*, Jian Zhang and Zhongqiu Wang

Shanghai Ocean University, Shanghai China

China's Marine fishing output ranges from 12 million tons to 13.28 million tons between 2010-2016, of which the yellow and Bohai seas account for about 28 percent, the South China sea for 32% and the East China sea for about 40 percent. Most of China's offshore fishing grounds are multi-species fishing ground, the body shapes of the main targeting species in different waters vary greatly. Trawl nets, gill nets, stow nets and Seine nets account for about 90 percent of China's total catch of 12 categories of fishing gear, and the main targeting species of the same type fishing gear varies with the fishing waters. The fishing gear selective study in China began in the 1950s and has been paid more attention to due to the decline of offshore fishery resources in the 1980s, and strengthened with the emphasis on fisheries management after 2000. The selective research on fishing gear in China mainly involves bottom trawl, shrimp trawl, stow net and gill net, etc. The research results mainly serve for the establishment of the minimum mesh size of fishing gear, especially provide scientific basis for the establishment of the fishery access system and the minimum mesh size of fishing gear. Cover net method is the main method used in the comparative study of codend mesh selectivity of both trawl net and stow net at sea, research contents involved the effect of change in mesh size, mesh shape and structure， such as diamond mesh, square mesh and T90 on the selective performance of main target species for the trawl net, and the selectivity research of the shrimp beam trawl has also related to shrimp-fish separation device, such as separation netting, vertical separation codend and rigid grid inside the codend. In addition, some preliminary survival rate of catch escaped through the mesh size of the codend was also studied. The aim of gill net selectivity research is to determine not only the minimum mesh size for catching traditional economic species, but also the optimal mesh size for newly developed species. Some basic results have been realized, such as the selective parameters of the main targeting species and theoretical minimum mesh size of the codend, those research results have been used as the scientific basis for the implementation of fishing gear admittance system in China. Research funding mainly comes from national natural fund, public welfare industry (agriculture) research projects, Special finance projects of both the Ministry of Agriculture and Rural Affairs and provincial government, as well as the specialized research fund for the doctoral program, and provincial key discipline construction project funds, etc.

Compared with developed fisheries countries, China's research on fishing gear selectivity is generally not systematic and in-depth, and the test comparison method is relatively simple. With the strengthening of China's fishery management system and the implementation of the fishing gear access system in the offshore waters of China, research on fishing gear selectivity will be strengthened.

*lxxu@shou.edu.cn

Monitoring and assessment of China’s coastal fisheries

Yiping Ren[1, 2]*, Binduo Xu[1, 2], Chongliang Zhang[1, 2] and Ying Xue[1, 2]

[1]College of Fisheries, Ocean University of China. 216, Fisheries Hall, 5 Yushan Road, Qingdao, China, 266003. [2]Pilot National Laboratory for Marine Science and Technology (Qingdao), 1 Wenhai Road, Qingdao, China. 266000

Stock assessment and fisheries management are developed on the basis of qualified data collected from both fishery-dependent and fishery-independent surveys, for which optimization of sampling design is desired for cost-effective sampling efforts given multiple objectives. Our studies developed a simulation approach to evaluate the fishery-independent survey design, targeting on estimation of abundance indices of fish species, species diversity indices and mean size of fish species. We illustrated proper stratification to improve precision of estimates, and the stratification scheme performed stably over years. We showed that sampling efforts could be reduced while remaining relatively high precision and accuracy for most abundance and biodiversity measurement, which might contribute to reduce the cost and negative ecological impacts of trawling surveys. Basing on the fisheries survey data, we developed a range of population and ecosystem models (such as data-limited stock assessment models, Ecopath, and size-spectrum model) to evaluate the current status of fish stocks and predict the effects of fishing on the whole ecosystem. The assessment results showed that the many fisheries stocks of Haizhou Bay suffered from overfishing, and simulations suggested that a considerable period was needed to recover the marine ecosystem.

*renyip@ouc.edu.cn

China's distant water fisheries –status, management and challenges

Liming Song[1,2,3,4]* and Di Wang[1]

[1]College of Marine Sciences, Shanghai Ocean University, 999 Huchenghuan Road, Lingangxincheng Shanghai 201306, China, [2]National Engineering Research Centre for Oceanic Fisheries, Shanghai Ocean University, 999 Huchenghuan Road, Lingangxincheng Shanghai 201306, China, [3]The Key Laboratory of Sustainable Exploitation of Oceanic Fisheries Resources, Ministry of Education, College of Marine Sciences, Shanghai Ocean University, 999 Huchenghuan Road, Lingangxincheng Shanghai 201306, China, [4]Collaboration Innovation Center for National Distant-water Fisheries, Shanghai 201306, China

The status of distant water fisheries of China is reviewed in this report. In 2017, there were 2,491 fishing vessels approved for the fishing operation, involving159 fishing companies. The total catch reached 2.09 million tons. The challenges to China's distant water fisheries are: (1) The main tasks of fisheries administering authority of China are protecting the marine ecological environment, maintaining sustainable resource utilization, implementing responsible fisheries management, and combating IUU fisheries activities; (2) The capacity to comply with the international regulation needs to be improved;(3)The comprehensive oversea fishery base is relatively simple and shortage; (4) The recruitment of fisherman engaged in distant water fisheries is decreasing.

The technical level of the fisherman is declining; (5) The industrial structure is still relatively simple, the industrial chain is short, and the domestic market is not fully developed; (6) The scientific and technological support and comprehensive development capability need to be improved. The following strategies are proposed:(1) The capacity to comply with the international regulation should be improved by heavy training; (2) The domestic and international market, and industry chain construction should be developed and adjusted; (3) The intergovernmental fisheries exchange and cooperation should be strengthened; (4) The fishing capacity should be reduced or effectively controlled in the near future; (5) The profits of the industry should be increased by improving the management, employing the foreign fishermen, using the energy saving fishing strategy, etc; (6)The technical training should be implement to improve the fishing technical level of the fishermen.

*lmsong@shou.edu.cn

China's policies and practice on combating IUU in distant water fisheries

Huihui Shen[1]* and Shuolin Huang[2]

[1]Institute of Marine Policy and Law, Shanghai Ocean University, [2]Marine Research Institute, Shanghai Ocean University

China's distant water fisheries (DWF) have made considerable progress since its entering into this industry in the 1980s. Though great efforts have been made to combat illegal, unregulated and unreported (IUU) fishing activities, there are still repeated IUU cases reported or documented by regional fisheries bodies and coastal countries. This article starts with an introduction to the latest development in China's policies and practices in the past three decades, followed by an attempt to explore the reasons behind this haunting IUU problem. It is found that lack of concrete regulatory measures, ineffective policy implementation, and insufficient supervision and control are the main impediments to eliminate the on-going IUU problem. Therefore, the authors suggest fishery authorities in China have stronger willingness and determination to impose stricter supervision and control on DWF industry, but at the same time, gives more concern to fishermen by offering training courses to raise their awareness of law compliance and mitigate motivations to commit infraction. Only in such way would China promote healthy and sustainable development of DWF, and become a responsible major fishing nation as it aims to be.

*hhshen@shou.edu.cn

IUU-related International Law Issues and China's facing challenges and Countermeasures

Ying Dai [1, 2, 3]* and Naizhong Liu [1]

[1] Dalian University of Foreign Languages, Dalian, China, [2] National Marine Data and Information Service, Tianjing, China, [3]Law School,Ocean University of China, Qingdao, China

In the past 20 years, IUU Fishing on the high seas has become increasingly rampant, which has caused serious impacts on the sustainable development of fish resources. The continuous increase in IUU fishing indicated the complexity of world fishery resource management and the development trend of globalization, prompting the international community to solve the existing fishery management issues in a global manner. By analysing the case of fishing vessel "Fu Yuan Yu Leng 999" of China which transferred unauthorized fishery species on the high seas outside the approved sea area, this article points out that challenges of combating IUU Fishing which China face, analyses international law-related issues and proposes countermeasures on the regulation of IUU fishing in China.

* 286143216@qq.com

Experiences of Liancheng Overseas Fishery (Shenzhen) Co. Ltd transitioning from Fishery Improvement Projects to Marine Stewardship Council Certification

Eric Gilman1, 2 *

1Liancheng Overseas Fishery (Shenzhen) Co. Ltd., 2 Hawaii Pacific University

The Liancheng Overseas Fishery (Shenzhen) Co. Ltd.operates locally-based pelagic longline fisheries in several Pacific Island countries. In collaboration with domestic management authorities, other companies in the supply chain, environmental non-governmental organizations and other stakeholders, Liancheng established Fishery Improvement Projects (FIPs) to gradually address deficits with an aim to improve the management and practices of the fisheries to a point where they would pass an assessment against the Marine Stewardship Council's (MSC's) fisheries standard. Here we describe the experiences of these Chinese longline companies with establishing and implementing FIPs, and making gradual improvements, including the introduction of electronic monitoring programs; ecological risk assessments of the effects of fishing on endangered, threatened and protected (ETP) species; gear technology research to mitigate ETP bycatch; research on shark post-release survival; skipper training; and through participation in a regional alignment group, improvements to regional harvest strategies for principal market species of tunas. We describe the transition into the MSC program, and current improvement priorities to address conditions of MSC certification. Lessons learned demonstrate how other Chinese fishing companies can improve their environmental performance through participation in FIPs and MSC.

* EricLGilman@gmail.com

3.12 Posters

Degradability evaluation of natural material ropes potentially used on fish aggregating devices (FADs) in tuna purse seine fishery

Cheng Zhou[1]*, Yucheng Wang[2], Xuchang Ye[2], Hao Tang[2] and Liuxiong Xu[2]

[1]Fisheries College, Ocean University of China, Qingdao 266003, P. R. China, [2]College of Marine Sciences, Shanghai Ocean University, Shanghai 201306, P. R. China

Purse seiners deploy thousands of drifting fish aggregating devices (DFADs) in all tropical oceans to catch tropical tunas. Nowadays these FADs were constructed with synthetic netting, which are explicitly considered responsible for incidental mortality of sea turtles and sharks through entanglement, even causing ghost fish if they are lost and abandoned. The use of natural and/or biodegradable materials to build FADs can effectively mitigate marine pollution and bycatch issues so that they are currently made efforts to promote by fisheries management organizations. This paper presents some fragmentary results on degradability of three natural material ropes (3-ply 96-thread cotton, 3-ply 13-thread jute, and 3-ply 8-thread sisal) on the basis of an experiment measurement (currently ongoing). These samples were deployed at China's off shore waters attached to the floating frame of net cage in Dec 2018 and retrieved per month for testing breaking strength (N) in the laboratory. Results showed the maximum initial strength was from Jute rope with a linear density of 46898 tex, which however experienced the rapidest reduction

of all in breaking strength over the first month. Cotton rope exhibited the most inertial degradation behaviour with the reduction ration by the third month at 58% of initial strength, compared to 3.5% and 12% for jute and sisal, respectively. Preliminary judge concluded that, in terms of limited data, jute and sisal rope are unable to satisfy the application criterion that is thought to vary from 5 months to 1year for their life span serving fishing.

*zhoucheng286@126.com

Development of biodegradable resin for fishing gear and the outstanding characteristics of biodegradation

Subong Park, Yongsu Yang* and Hyunyoung Kim

Fisheries Engineering Division, National Institute of Fisheries Science, 216, Gijang-haeanro, Gijang-eup, Gijang-gun, Busan, 46083, Korea

Among different biodegradable resins used in fishing gear, the PBS (Polybutylene succinate) lacked flexibility and had problems such as deterioration of fishing performance and swelling. and PBSAT (Polybutylene succinate adipate-co-terephthalate) resin was developed as an improved solution to these problems. The PBSAT resin improves flexibility; however, it has limited applications owing to its very rapid aging and decomposition rate, while in use. Therefore, it is necessary to develop a new resin to solve the problems of existing biodegradable resins used in fishing gears. In this study, a new resin for biodegradable fishing gear was developed by applying optimal values of reaction elements. A biodegradation net was made from the new resin and physical characteristics such as breaking strength, flexibility, elongation, and fishing performance were tested. The biodegradable fishing gear produced through the new resin showed similar physical properties to nylon fishing gear. In addition, the fishing performance of nylon net was 90% of the fishing performance of the resin, and the catch rate was lower than that of the nylon net.

Biodegradable fishing gear made of the new resin developed in this study is expected to solve the problem of marine litter and ghost fishing by replacing the nylon net and resource loss.

UV Illumination to reduce sea turtle bycatch in Mediterranean set net fisheries

A. Petetta[1]*, M. Virgili1 C. Vasapollo[1], G. Bargione[1,2] and A. Lucchetti[1]

[1] National Research Council (CNR), Institute for Biological Resources and Marine Biotechnologies (IRBIM), Largo Fiera dellaPesca, 1, 60125 Ancona, Italy, [2] Department of Biological, Geological and environmental sciences, University of Bologna, Piazza di Porta San Donato 1, 40126 Bologna, Italy

Incidental interaction between sea turtles and fishing activities often results in unwanted bycatch of these protected species by commercial fisheries, that is considered as the main threat to their conservation. In the Mediterranean Sea, an important bycatch of loggerhead turtles *Caretta caretta* is caused by fixed nets, common gears traditionally used in small-scale fisheries (SSFs). The bycatch rate due to fixed nets is estimated to be high and similar to that of trawl nets and longlines, but seems to be associated with higher mortality rates. Technical solutions aiming at reducing interactions with sea turtles through gear modifications (BRDs) have been developed mostly for large-scale commercial fisheries, i.e. longlines and trawls, while a few experiments have been carried out with set nets. In recent years, a potential strategy to reduce sea turtle bycatch in passive net fishery has been based on altering visual perception of turtles through the use of lights. Ultraviolet light-emitting diodes (LED) have already proved to be effective along the Northern and Southern Pacific coasts. In the present study ultraviolet LED lamps, were mounted on fixed nets set offshore (targeting Thornback ray *Raja clavata*) and inshore (targeting sole *Solea* spp.) in the Adriatic Sea. Their ability to reduce the loggerhead turtle bycatch and the catch performance of both traditional and illuminated net were assessed. No turtles were caught in the illuminated net, whereas 18individuals were captured by the traditional net with a direct mortality rate of 28%. There were no significant differences in the catch rates of target species. Abroad diffusion of these bycatch reducer devices would provide a significant contribution to the conservation of loggerhead turtles while enabling large-scale production and cost reduction. However, a cost-benefit analysis currently makes the use of this technique not suitable for commercial purpose by SSF fishermen operating with passive nets.

* a.petetta@irbim.cnr.it

Study on the structure and properties of HDPE/ starch composites for fishing

Fei Yan* and Min Zhang

College of Marine Sciences, Shanghai Ocean University

There is a large amount of abandoned fishing gear around the world every year. The fishing nets made of polyethylene, nylon and other non-degradable synthetic fibers still cannot be degraded after decades in the seawater environment, becoming "ghost fishing gear" and causing great harm to fishery resources and ecological environment. Research and development of biodegradable materials for fishing is one of the effective approaches to reduce the phenomenon of "ghost fishing", protect marine fishery resources and ecological environment. Only in this way can sustainable development be realized. Starch based materials, polylactic acid (PLA), polycaprolactone (PCL), poly (butylene succinate) (PBS) have so many good properties such as full biodegradability, good thermal processibility, renewability, high mechanical performance and so on. It is an inevitable trend to replace the non-biodegradable synthetic fiber materials for fishing. Their appearance opens up a new way for the application of biodegradable polymer materials in the field of fishery. However, the mechanical properties of most biodegradable materials decline when they are used in seawater and high price are obstacles for the application and development of them. All of these result in attracting much attention in the research of modification of biodegradable materials for fishing. In this paperthe performance, application status and research progress including blending with natural polymer and synthetic polymer of four kinds of biodegradable materials for fishing with starch-based materials, PLA, PCL, PBS are focused. The effect of processing technology, surface treatment and additives on the composite material is presented. Finally, the development prospect of biodegradable materials is analysed in this paper to provide references for the research and development of biodegradable fishing gear materials with low price and excellent comprehensive performance.

*279600721@qq.com

Tracking of *Coregonus peled* in large scale set net by using ultrasonic biotelemetry

Leiming Yin, Binbin Xing, Hongquan Li, Jing Liu and Yong Tang*

College of Marine Sci-Tech and Environment, Dalian Ocean University, China

Sayram Lake is the largest cold-water lake in Xinjiang Uygur Autonomous Region of China. The area of the lake is 458 km^2, the maximum depth of the lake is 102 m, and the altitude is 2071 m.

The main commercial fish in Sayram Lake is *Coregonus peled* that was imported from Russia in 1998. *Coregonus peled* is a fish with high oxygen consumption living in cold water. The main fishing method of the fish in the lake were gill nets and small set nets before 2017. In order to protect the environment of this lake and the juvenile of this species, only the large set net was available as a fishing gear from 2017. Therefore, the behaviour characteristics of the fish around the set net is an important information for the structural design and improvement of the fishing gear. In order to grasp the fish behaviours in migration and swimming depth changing around the set net, the ultrasonic biotelemetry experiment was conducted during Jun.23-Jun.29,2018. In this study, 10 fish were attached ultrasonic pingers for tracking 24 or 48 hoursby10 mooring receivers from Aqua Sound Inc.

The results show that four fish remained at a stationary depth which meant that the fish died or the pingers dropped from the fish's body. Six fish escaped from the set net and swam toward toon side orientation which faces the lakeshore. All the fish swam at depth of 2m-10m mainly. Moreover, some of the fish came in and out repeatedly at the entrance of the set net. In this experiment, the test fish were not captured in large scale set net. It means that there is still some improvement in this fishing gear.

Size selectivity of combined square and diamond mesh codends of shrimp beam trawl for banded scad Caranx (Atule) kalla in the northern South China Sea

Bingzhong Yang*, Lin Yang, Yongguang Tan, Lei Yan, Peng Zhang and Jie Li

South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences; Key Lab of South China Sea FisheryResources Exploitation & Utilization, Ministry of Agriculture, Guangzhou 510300, China

The shrimp beam trawl fishery in the northern South China Sea is characterized by high bycatch and poor selectivity problems. Among by-catch species, banded scad (Caranx (Atule) kalla is economically the most important one. The aim of this study is to improve the selective properties of codends for banded scad. Size selectivity of 2 traditional diamond mesh codends, with mesh size 25 and 30 mm (defined as D25 and D30, respectively), and 4 new combined square and diamond mesh codends, with25 mm square-mesh and 25 mm diamond-mesh (S25+D25), 30 mm square-mesh and 25 mm diamond- mesh (S30+D25), 35 mm square-mesh and 25 mm diamond-mesh (S35+D25), and 35 mm square-mesh and18 mm diamond-mesh (S35+D18), were tested for banded scad in shrimp beam trawl fishery of the South China Sea. A total of 54 valid hauls were finished using the covered codend method, and 5750 banded scad were caught. Selective parameters were obtained using the logistic equation with the maximum likelihood method, by incorporating the between-haul variation. The results show that the present minimum mesh size for shrimp beam trawl in the South China Sea, 25-mm diamond mesh size, is insufficient to release immature banded scad.

The S35+D25 codend is proved to be the most effective codend to release immature banded scad, and its 50% retention length (L50) is larger than the minimum landing size (MLS=63.5 mm) of banded scad. However, the 95% confidence intervals of L50 overlap among the three combined mesh codends, theS25+D25, S30+D25 and S35+D25 codend. For a sustainable exploitation of banded scad, larger mesh sizes are suggested to be investigated for the combined mesh codends.

*ybzaaa@163.com

Effect of location of escape vents on size selectivity of crab pots for swimming crab *Portunus trituberculatus* in the East China Sea

Jian Zhang*

College of Marine Sciences, Shanghai Ocean University, NO.999 Huchenghuan RD. Pudong New District, Shanghai, 201306

The increasing fishing effort of the crab pot fishery in the East China Sea has brought great pressure on swimming crab *Portunus trituberculatus* resources. There is thus an urgent need to implement conservation measures to release juvenile crab so as to increase recruits. One of the measures being considered is the installation of escape vents on crab pots. In most of existing studies on escape vents of swimming crab pots, to facilitate the escape of juvenile crabs, the vents were always mounted at the lower edge of the side panels of the cylindrical pots. However, in actual longlining fishing method, it cannot be assured that the escape vents remain at the bottom edges because of the symmetric structure. In order to test the effect of location on size selectivity of the escape vents, by comparing the results of sea trial experiments, we analysed the size selectivity of crab pots for swimming crabs (*P. trituberculatus*) with two different kinds of locations of escape vents, i.e., one is on the single side (SS, at top or bottom edge) and another on both sides (BS, at top and bottom edges). The results show that: the selectivity indexes, 50% selectivity carapace widths (CW50s) and the selective ranges (SRs), of BS escape vents crab pots are little larger than those of SS escape vents pots. However, the 95% confidence intervals of CW50s and SRs are basically overlapped, which means that their discrepancy is small. Then, in the mixed effect model, locations are taken as the fixed effect, the influence on selectivity parameters and indexes is analysed by hypothesis testing. The result shows that null hypothesis of SRs of SS and BS, and null hypothesis of CW50s of SS and BS escape vents crab pots are both accepted, which indicates that there is no significant difference in size selectivity between the two locations of escape vents for *P. trituberculatus.*

*j-zhang@shou.edu.cn

Stock Status and Fishery Management of China in the South China Sea

Yongsong Qiu*

South China Sea Fisheries Research Institute

Marine fishing by south China provinces mostly takes place in the northern South China Sea (NSCS). Fish stocks in the coastal and shelf waters are in a status of depletion and overfishing, respectively, because of rapid growth in fishing capacity from 1980s to 1990s. It was estimated that the current fishing capacity is more than 2times higher than the optimal level and fishing pressure in the coastal waters is especially high because of large numbers of small-size fishing boats.

The management measures of China in the NSCS include fishery zoning to limit trawl fishing in the inshore waters of <40m depth, and the closed fishing areas/seasons were established in the estuarine and coastal waters to protect breeding and nursery stocks. Fishing boat licensing system and policy of limiting fishing capacity has been in place since the late 1980s and fishing capacity has tended to level off since the late 1990s. A2-months (June/July) summer closed fishing season applying to trawl, purse seine and trammel gillnet in the NSCS has been implemented since 1999, and in 2018, the closed fishing season was extended to 3.5 months (form May 1 to August 15) and all fishing except hook-and-line are closed.

The major problems in the NSCS fishery include overcapacity and capture of under-size fishes. The summer closed season was intended to reduce the capture of juveniles, and to certain extent, reduce fishing pressure. The fishing closed season has been successfully implemented. However, after the closed season, the catches were yet dominated by juveniles and trash fish because of non-selectivity of fishing gears. The use of small mesh size is also encouraged by demand for forage fish from aquaculture of high-value fishes. It is recommended that, in addition to a closed fishing season, mesh regulation and/or size-at-first-capture be enforced.

To reduce fishing capacity, a program of fishing boat decommissioning through buyback by the government was ever started in 2000. However, the buyback was on the basis of volunteers and very limited number of fishing boats was decommissioned. Expanding fishing further offshore to the open SCS would be a way to reduce fishing pressure in the inshore waters. There is certain potential of open-sea fishing for pelagic fishes and oceanic squid in the SCS basin. Assuming continuation of the current policy of strict limits on the number of fishing licenses and total fishing horsepower, promoting pelagic fishery in the open SCS would lead to partial relocation of fishing capacity away from the heavily fished waters. This would correspond to a reduction in fishing pressure and a recovery growth in the fishery in the NSCS.

*qys@scsfri.ac.cn

Using controlled in-situ aquariumto reveal thermal and saline tolerance of Antarctic krill (*Euphausia superba*)

Zijun Liu[1, 2], Guoping Zhu[1, 2, 3]*, Yang Yang[1, 3], Zhen Wang1, Wenjie Yang[1] and Liuxiong Xu [1, 2, 3]

[1] College of Marine Sciences, Shanghai Ocean University, Shanghai 201306, China, [2] National Engineering Research Center for Oceanic Fisheries, Shanghai 201306, China, [3] Polar Marine Ecosystem Group, The Key Laboratory of Sustainable Exploitation of Oceanic Fisheries Resources, Ministry of Education, Shanghai Ocean University, Shanghai 201306, China

As a key species of the Southern Ocean ecosystem, the thermal and saline tolerances of Antarctic krill (*Euphausia superba* Dana) are relatively unknown because of the challenging environment and complicated situations needed for observation have inhibited in-situ experiments in the field. Hence, the thermal and saline tolerance of krill were examined under in-situ aquarium conditions with different controlled scenarios. According to the experiments, the critical lethal times of krill were 24 h, 2 h and 0.5 h under 9 °C, 12 °C, and 15 °C, respectively, and the estimated 50% lethal times were about 17.1 h and 1.7 h under 12 °C and 15 °C, respectively. Additionally, the critical lethal times (the estimated 50% lethal times) of krill were approximately 14 h and 0.5 h (about 22.9 h and 1.7 h) under 19.7 ppt and 15.9 ppt, respectively. The observed critical and 50% lethal times of krill were 0.5 h and approximately 1.4 h, respectively, under 55.2 ppt. The critical and 50% lethal temperatures of krill were 13 °C and approximately 14.2 °C, respectively.

Additionally, the critical and 50% lethal salinity were 19.6 ppt and approximately 17.5 ppt for the lower saline (below normal oceanic salinity [34.4 ppt]) environment and 50.3 ppt and approximately 53.2 ppt for the higher saline (above 34.4 ppt) environment, respectively. The upper thermal and saline preferences of krill can be considered 6 °C and 26.8 to 41.2 ppt, respectively. These results can provide potential scenarios for predicting the possible fate of this key species in the Southern Ocean.

* gpzhu@shou.edu.cn

The vertical influence of temperature and salinity on small pelagic CPUE in different depth in Mauritanian waters: an analysis based on oceanic survey

Narcisse Ebango Ngando [1], Liming Song [1,2,3,4]* and Shuangquan Xu[1]

[1]College of Marine Sciences, Shanghai Ocean University, Shanghai 201306, China, [2]National Engineering Research Centre for Oceanic Fisheries, Shanghai Ocean University, Shanghai 201306, China, [3] Key Laboratory of Sustainable Exploitation of Oceanic Fisheries Resources (Shanghai Ocean University), Ministry of Education, Shanghai 201306, China, [4]Collaboration Innovation Center for National Distant-Water Fisheries, Shanghai 201306, China

In the upwelling system, environmental conditions can cause large changes on small pelagic fish distribution at very short time scales, with significant implications on fisheries. Spatial and temporal distributions of marine environmental factors are commonly believed to influence the vertical and horizontal distributions of small pelagic species. Small pelagic species are the main target species of light fishing in the commercial fisheries. Our main goal was to analyse the habitat characteristic of three dominant small pelagic species during the survey in waters near Mauritania by evaluating the relationship between CPUEs and environmental factor that can influence their vertical distribution. Our study evaluated in detail the quarter catch depth distribution in relation to the environmental conditions (temperature and salinity) to assess the influence of environmental factors on catches of small pelagic fish. To address this, we implemented geostatistical analysis and nonlinear statistics GAM model on chub mackerel (*Scomber japonicus*), horse mackerel (*Trachurus trachurus*) and round sardinella (*Sardinella aurita*).The results showed that (1) changes in environmental factors in terms of distributions, the temperature has a major impact on three target small pelagic species abundance than salinity which has no significant influence on the target small pelagic species in waters near Mauritania; (2) the fluctuation in CPUE seem to be high at 30-50 m following by 0-30 m and 50-70 m related to the tolerance of a similar range of environmental factor of three species; (4) the temperature is a major factor to explain the fluctuations or to predict the vertical distribution of target small pelagic CPUE in this area.

* lmsong@shou.edu.cn

Performance analysis of Chilean jack mackerelmid-water trawl based on the field test

Yuwei Li[1,2,3,4] and Xiaorong Zou[1,2,3,4],*

[1] Shanghai Ocean University, College of Marine Sciences, Shanghai 201306, China, [2] Key Laboratory of Sustainable Exploitation of Oceanic Fisheries Resources (Shanghai Ocean University), Ministry of Education, Shanghai Ocean University, Ministry of Education, Shanghai, 201306, China, [3] National Engineering Research Center for Oceanic Fisheries, Shanghai, 201306, China

Study on the net performance and structure adjustment can improve the fish catch, and is also the key point in the fishery research. In this paper, according to the survey data from the fishing operation of Chilean jack mackerel trawl fishery in 2014 in southeast Pacific Ocean, we analysed the performance of the mid-water trawl. The data mainly came from the Scanmar System rigged on the net and the data of fishing operation at sea. We used these data to explore the relationships between the towing speed and net mouth height, towing speed and drag, towing speed and net horizontal opening, towing speed and the depth of net mouth, warp length and warp resistance, the depth of two otter boards and the horizontal opening of otter boards. By data processing and numerical analysis to get these parameters such as vertical opening coefficient, energy consumption coefficient, hydrodynamic performance and so on. When the towing speed ranges from 4.4kt to5.8kt, the formula of net drag was Fs= 0.055833 (d/a) LCV 1.149116by the non-linear model. The correlation coefficient between predicted net drag and actual net drag was 0.835(P=0.000) by correlation analysis. The average energy consumption coefficient of 1768 net was 0.088 kWh/104m^3 less than them of the other nets. And the ratio between length and circumference was 0.268, and the hydrodynamic performance was 31.93, which was the highest in the same type of nets. The vertical opening coefficient is also larger than the other net. Through the relationships between these parameters, we could understand and analyse the operation performance of the 1768 net to improve the fishing gear design and achieve effective energy saving.

*xrzou@shou.edu.cn

Effects of spatiotemporal and environmental factors on the fishing ground of *Symplectoteuthis oualaniensis* in the South China Sea based on generalized additive model

Lei Yan*, Jie Li, Bingzhong Yang and Peng Zhang

South China Sea Fisheries Research Institute, Chinese Academy Fishery Sciences, Key Lab. of Open-Sea Fishery Development, Ministry of Agriculture, Key Lab. of South China Sea Fishery Resources Exploitation & Utilization, Ministry of Agriculture, Guangzhou 510300, China

Abstract: Based on light falling-net fishery production data collected from 2013 to 2016in the South China Sea, combined with the data of environmental factors obtained by satellite remote sensing, the fishing ground distribution of *Symplectoteuthis oualaniensisand* its relationships with the spatiotemporal and environmental factors in the South China Sea using generalized additive model (GAM). The results showed that the rate of the cumulative deviance explained about catch per unit effort (CPUE) is 66.40%. The four factors, including longitude, latitude, sea surface temperature(SST) and chlorophyll a concentration(CHL),have significant effects on the CPUE ($p<0.05$), the relative important of the four variables that affect the fishing ground of *S. oualaniens* is can be followed with the order of longitude, latitude, CHL and SST. On the contrary, the other factors, such as year, month and sea surface salinity (SSS) did not have significant effects on the CPUE ($p>0.05$).

The CPUE of *S. oualaniensis* in 2013-2015 shows a stable trend. And the CPUE in 2016 shows a significantly declining trend affected by El Niño. The fishing ground of *S. oualaniensis* in the South China Sea was mainly located in the waters of 10°N~12°N and 114°E~116°E. The suitable SST ranged from 28°C to 30°C. And the suitable CHL ranged from 0.10mg/m^3 to 0.15mg/m^3.

*yanlei@scsfri.ac.cn

Gear alternatives after the European restrictions on North Sea pulse-trawl fisheries

Pieke Molenaar*

Wageningen Marine Research, Ijmuiden, The Netherlands

Electrified pulse beam trawls have replaced traditional tickler chain beam trawls in the North Sea demersal fisheries for sole. However, recently the European parliament has decided to limit and possibly ban pulse trawling in European Waters in 2021. Compared to the traditional thicker chain beam trawl gear the shift to pulse trawl gear resulted in fuel savings, reduced bycatch and improved fish quality. As the ban might be in effect by 2021 the fishing industry is aiming to find alternatives that perform comparable to the pulse trawl gear with similar fishing efficiency and fuel savings. Several initiatives were tested in lab experiments or in practice. This talk will provide an overview on the current development towards alterative gears for demersal flatfish species.

*pieke.molenaar@wur.nl

SORTEX: a first step towards dual-species selectivity for the Baltic bottom trawl fishery

Juan Santos[1]*, Bernd Mieske[1], Saeid Gorgin[2] and Daniel Stepputtis[1]

[1]Thünen Institute of Baltic Sea Fisheries, Alter Hafen Süd 2, 18069 Rostock, Germany, [2]Gorgan Fishing and Exploitation Department, University of Agricultural Sciences and Natural Resources, Gorgān, Golstan, Iran

BACOMA and T90 codends have been applied since 2005 in the Baltic Sea to shape the exploitation patterns of cod. While being highly selective for the target species, both codends provide poor size selectivity properties for flatfish co-habiting the fishing grounds exploited by the Baltic bottom trawl fishery. Consequently, the high bycatch rates of flatfish often observed in the fishery could be potentially mitigated by addressing this mismatch in selectivity. A strategy to increase the overall selectivity of Baltic trawls could be to split flatfish and roundfish into separated codends during the catch process, enabling technical strategies to establish size selection patterns optimized for the different groups of species. SORTEX is an experimental SORTing EXtension developed to achieve such catch separation, by utilizing observed differences in species swimming behaviour at the aft of the trawl. This study experimentally quantifies the sorting efficiency of five different SORTEX designs, varying either in construction details or the stimulation devices applied. The results obtained indicate high separation rates independently from the design applied. The separation efficiency is at least 80% for cod, as well as for flatfish-species. No clear length-dependency was found in any of the designs for both flatfish and cod. Our experimental results open the possibility to use double-codend trawls to establish dual-species selectivity patterns in the Baltic Sea.

*juan.santos@thuenen.de

Acoustic estimation and swarm characters of *Euphausia superba* in the South Orkney Islands in austral spring 2017

Teng Wang [1], Guoping Zhu[2,3,4], Jianfeng Tong[2,3,4] and Liuxiong Xu[2,3,4]*

[1]South China Sea Fisheries Research Institute, CAFS, Guangzhou 510300, China, [2]College of Marine Sciences of Shanghai Ocean University, Shanghai 201306, China, [3]The Key Laboratory of Sustainable Exploitation of Oceanic Fisheries Resources, Shanghai Ocean University, Ministry of Education, Shanghai 201306, China, [4]National Engineering Research Center for Oceanic Fisheries, Shanghai Ocean University, Shanghai 201306, China

Antarctic krill (*Euphausia superba*) is a key species in the Southern Ocean ecosystem, knowledge about its biomass and swarm dynamics are essential to understand the ecology and distribution of krill. The acoustic data was collected across extensive gradients in the South Orkney Islands based on commercial fishing vessel Long Teng. Krill targets were identified in acoustic data using a multi-frequency identification window and converted to krill density using the Stochastic Distorted-Wave Born Approximation target strength model. The average krill length was 33.01±4.06 mm, with a maximum length of 49.21 mm and a minimum length of 25.50 mm of this area. There was no significant difference between male and female krill length. The whole ecogram could be divided into 1338 integration units, of which 586 units were in daytime, 752 units were at night. The maximum krill density was 554.07 g/m^2 and the minimum density was 0 g/m^2. The Antarctic krill were mainly aggregated with 87.90% integration units had no biomass. There was no significant difference in diurnal NASC and SV values of the 9 transects, which suggested that the diurnal vertical movement had no effect on krill biomass estimate. The average krill density was 71.01 g/m^2 and the total biomass was 1.77×106 t in this area. The krill were mainly aggregated in the 60~180 m water depth in the daytime and gradually moved upwards or downwards at night. Light intensity is one of the factors that influence the krill diurnal vertical movement. However, a proportion of the Antarctic krill were sunk to deeper water at night, which may be prey the deep-water foods. A total of 2539 krill swarms with swarm characters including swarm height and length, packing density, swimming depth, and inter-swarm distance were extracted, of which 1389 were daytime swarms and 1150 night swarms. Compared with those of the night swarms, krill aggregated in deep waters during the daytime with lower packing density and smaller inter-swarm distance. There were significant differences between day and night krill swarms. Through the multivariate analysis, the krill swarms were divided into three categories, which differed in both their dimensions and packing density. Group A presented the highest swarm density (19.24±27.00 ind·m^{-3}), Group B swarms presented the deepest distribution depth (174.74±53.30 m), Group C presented the largest swarm area (2868.62±2149.75m^2) with the longest swarm length (258.76±322.88 m). There was no significant difference in swarm length between Groups A and B and no significant difference in swarm depth between Groups A and C. Group A swarms were mainly distributed in deep water areas in the north and northwest regions of the South Orkney Islands at a depth of > 1000 m, and mainly occurred during daytime. Groups B and C swarms were distributed throughout the survey area; Group B swarms were aggregated in the continental shelf at a water depth of < 200 m. The results suggest that the majority of krill were contained within a minor fraction of the total number of swarms, and there was a positive correlation between packing density and inter-swarm distance. The results of this study provide abundant information on the krill distribution and its swarm characters in this area and basic data for the current feedback krill resource management of CCAMLR. In the future, the research on the correlation between krill biomass and external factors (environmental factors, predators) can help us understand the population structures more accurately and predict the distribution of krill resources.

* luxx@shou.edu.cn

Analysis of trips and hauling net hours for swimming crab gillnets based on BDVMS

Shengmao Zhang [1,2], Xuesen Cui [1], Wenbin Zhu [2*], Fenghua Tang [1], Shenglong Yang [1], Heng Zhang [1] and Wei Fan [1*]

[1]Key Laboratory of East China Sea Fishery Resources Exploitation, Ministry of Agriculture and Rural Affairs; East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Shanghai, 200090, China, [2]Marine Fisheries Research Institute of Zhejiang, Key Laboratory of Sustainable Utilization of Technology Research for Fishery Resource of Zhejiang Province, Zhoushan, 316021 China

Gillnets is one of the most widely used fishing gear in the world, and there are nearly 97 thousand gillnets in China offshore. With the decline of resource Fisheries, fishing quota has always been a topic of concern for the world's fishing nations. At the beginning of 2017, the Ministry of agriculture and Rural Affairs of the People's Republic of China implementing the total management of marine fishery resources and begin to launch the quota fishing experiment. Vessel monitoring system (VMS) provides a new data source for fisheries scientific research. In China, Shipboard Beidou satellite navigation system terminal (SBNST) was installed on demonstrated fishing vessel. It sends vessel identification and location information at 3 min interval and with 10 m spatial resolution. In this paper, through the analysis of spatial intersection relations between port area and fishing vessel trajectory, more than 15 hundred fishing trips of 56 vessels were extracted. The duration of the trips 16.91 % were within one day, 38.87 % were 1(include)-2 day, 12.65 % were 2-3 days. 80.80 % were within 4 (not include) days. There were some long trip days at Linhai, Sanmen, Shengsi and Taizhou, and there were few long trip days at Wenling, Xiangshan and Zhoushan. The maximum density was at Shengsi. Speed threshold was used to select the state of hauling nets. The speed thresholds of vessels were from 1.7 to 2.4 m/s. Hauling hours of 56 vessels were distributed in 8 fishing grounds in 2017.The Average hauling hours was 1.7 h, and the maximum value was 41.5 h. There were about 514 thousand Net hauling points, and the catch weight was assessed of about 4.7 million kg in 2017.

* Wenbin Zhu foolse@126.com, Wei Fan fanwee@126.com

Variations in hydrodynamic characteristics of netting panels with various twine materials, knot types, and weave patterns at small attack angles

Hao Tang [1], Fuxiang Hu[2], Cheng Zhou [3] and Liuxiong Xu[1*]

[1]College of Marine Sciences, Shanghai Ocean University, Shanghai 201306, P. R. China, [2] Faculty of Marine Science, Tokyo University of Marine Science and Technology, Minato, Tokyo 108-8477, Japan, [3]Fisheries College, Ocean University of China, Qingdao 266003, China

It is essential to conduct hydrodynamic experiments for fishing gear at small attack angles along the flow direction to better understand the hydrodynamic characteristics of netting and application of gear. The hydrodynamic characteristics of netting panels made of different materials at small attack angles were investigated by a self-designed setup; this is essential for the effective use of netting on different types of gears. As confirmed by experiments, the measured drag of designed frame without netting accounted for less than 20% of the total setup drag including experimental netting and remained in a steady state under various current speeds and small attack angles, indicating that the self-designed frame setup is suitable for such trials. The drag coefficient was determined by varying the attack angle, solidity ratio, Reynolds number, knot types, weave pattern, and twine materials at small attack angles.

The results indicate that the drag coefficient increased as the attack angle increased, but decreased as the solidity ratio and Reynolds number increased. The drag generated by knot accounted for 21% of the total drag of nylon (PA) netting. For braided knotless netting, the drag coefficient of PA netting was about 8.4% lower than that of polythene netting (PE) and 7% lower than that of polyester netting (PES). Compared with twined netting, the braided netting exhibited a higher resistance to flow, corresponding to higher values of drag coefficient.

* lxxu@shou.edu.cn

Seasonal distribution patterns of Crimson Seabream (*Parargyropsedita*): implications for marine protected area in Beibu Gulf, northern South China Sea

Xuefeng Wang[1]*, Lifei Wang[2], Chunhou Li [3] and Xiaoping Jia[3]

[1]College of Fisheries, Guangdong Ocean University, Zhanjiang, Guangdong 524088, China, [2] Gulf of Maine Research Institute, Portland, Maine 04101, USA, [3] South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Guangzhou, Guangdong 510300, China

Understanding the distribution patterns and habitat characteristics of ecologically or economically important species in marine protected areas is critical for identifying the ecological boundaries and optimizing the management strategies. However, studies on groundfish resources around marine protected areas are often limited because of economic, geographic, or jurisdictional constraints. This study investigated the seasonal distributions of Crimson Seabream(*Parargyropsedita*), an important demersal fish species in the Beibu Gulf, northern South China Sea, based on bottom trawl surveys inside and outside the experimental zone of marine protected area, and examined the habitat preferences of Crimson Seabream in terms of eleven abiotic and biotic factors (sea bottom temperature, salinity, dissolved oxygen, pH, depth, transparency, zooplankton biomass, eastings, northings, season, and zone) using generalized additive models (GAMs). The density of Crimson Seabream was highest in spring with a mean density of 50700 (±15100) ind./km^2 (± indicates standard deviation) and an occurrence frequency of 92.3%, and lowest in winter with a mean density of 20 (±39) ind./km^2 and an occurrence frequency of 30.8%. Crimson Seabream was most aggregated in summer and least aggregated in winter. Results suggested that the distributions of Crimson Seabream were most influenced by season, sea bottom temperature, and salinity. Crimson Seabream was most likely to be distributed in area with sea bottom temperature of 22.8–25.0 °C, salinity of 31.5–32.0, dissolved oxygen of 4.4–6.8 mg/L, and zooplankton biomass of 114.0–2717.5mg/m^3. Results from this study suggested that dynamic management strategies with more efforts on minimizing human activities around the marine protected area in winter and spring may provide more effective support for Crimson Seabream recruitment. The statistical approaches applied and related findings could serve as a basis for determining the spill over effects of marine protected areas and enhancing fishery management units.

*xuefeng1999@126.com

Movement and habitat utilization of yellowfin tuna (*Thunnus albacares*) in the nearby waters of West Pacific Ocean recorded with the pop-up archival tags

Heng Zhang*, Yang Dai and Shenglong Yang

East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Shanghai 200090

Pacific yellowfin tuna (*Thunnus albacares*) is widely distribute in subtropical and tropical waters, extending to 40°N in the North Pacific Ocean. Understanding the biology of tunas requires knowledge of where it lives and of its various movements between different habitats. But, the movement and habitat of yellowfin tuna in the West Pacific Ocean have been poor understood in the world. A total of 36 yellowfin tunas *Thunnus albacares* were tagged using Pop-up Satellite Archival Tags (PSATs) and released in 2010-2012 to examine their vertical movement patterns. The results showed that the return rate of 8tunasdeployed from purse seine fishery was 100%, but the recorded period of tags was only 0.5~5 days. The return rate of those tunas deployed from handline fishery was 75%, while the recorded period of tags was 0.5~91 days and the tag of 2 tunas were normally popped up. In this study, the recorded period was lower than 10days for 18 tags, was 10~20days for 3tags and was longer than 20 days for 8tags. The longest recorded time of fish ID 33339 was 91 days and its straight-line distance was 822 km from the deployed site. The second longest recorded time of fish ID 33869 was 89 days because of the 3 months set time, while its straight-line distance was only 10 km. The tunas deployed from handline fishery provided loner-time information. About 85.9%of time for yellowfin tunas lived in the 0~149.9 m depths,13% of time in 150～249.9 m and only 1.1%of time lived the ≥250m depths. As for as water temperature, 81.7% of time yellowfin tunas lived in ≥24°C, 16.2%of time in 16～24°C and only 2.1%of time lived in ≤16°C. In 0～49.9m depth, the occurrence frequency of yellowfin tunas in night was 2 times higher than that in day, while the occurrence frequency of them in day was larger than that in night in 50~500m depths. From most tags data, we found that the yellowfin tuna can go up to surface water layer (<10m) and the maximum habitat depth of 53.3% individuals both above 300 meters. For example, the fish (tag 33869) have reach to 1100 water depth and the corresponding temperature only was 4.9°C. In the activity layer of yellowfin tunas, the minimum temperature of 80% of tuna were above 10 °C, while the maximum temperature of tuna were both >26°C. As a whole, the daily depth of yellowfin tuna was obviously deeper 23.5m than the nightly depth. About 87.5% individuals have the phenomenon of obvious diurnal vertical migration. In the whole, about 68% of individuals begun to move the shallow waters at dusk (18:00), and then they dived to relative deep water at dawn (06:00). For example, data of tag 33869 and 33882 showed that these two tunas have similar movement patterns in 24 hours. They both begun to dive deeper water layers from 5 to 6 clocks in the early morning, then maintain at the 60-160m layer, and begun to rise to 20-50m layer to habitat at dusk (17-18 p.m.). In general, this preliminary study on the tag and release of yellowfin tuna has proved to be successful and can be used as a protocol for tagging study of tunas in the future.

*zhangziqian0601@163.com

Fish collective behaviour: New research field and new progress

Ying Liu* and Zhen Ma

Aquaculture Facilities and Equipment Engineering Research, Dalian Ocean University, Dalian 116023

Animal collective motion arises from the intricate interactions between the natural variability among individuals, and the homogenizing effect of the group, working to generate synchronization and maintain coherence. A group is defined as a collection of two or more individuals that interact and interdependent to achieve specific goals.

The observation and study on fish collective behaviour will contribute to understand the mechanism of information transmission and collective motion of fish, to deepen the knowledge of the interaction between fish and environmental factors, to enrich the aquatic ethology and bionics, to provide theoretical support for intensive aquaculture system.

We describe a computer vision-based method for measuring the feeding activity of an Atlantic salmon (*Salmo salar* L.) shoal. Feeding activity analysis was based on the intensity summation of the difference frame due to the motions of the fish. An overlap coefficient was defined to calibrate the error of calculation caused by the overlaps among fish bodies in images. Based on these data, a computer vision-based feeding activity index (CVFAI) was determined for measuring the feeding activity of the fish in arbitrary given duration. To assess the reliability of CVFAI, a manual observation feeding activity index (MOFAI) was determined by scoring each kind of feeding behaviour in the same recordings. The CVFAI and MOFAI presented a linear relationship at a correlation coefficient of 0.9195. CVFAI is therefore a potential indicator for measuring the feeding activity of an Atlantic salmon shoal, in a low-cost and rapid way.

In order to study the fond habit of juvenile turbot to different colour backgrounds, the experiment of 9 colour backgrounds selection was conducted and fish body colour response to different colours was analysed. The results showed that the appearance frequency of juvenile turbot in purple and pink backgrounds was significantly higher than that in black and red ones, and body brightness change rate under black and red backgrounds was more drastic and intensive than under pink and purple backgrounds. Results indicated that fish needed more physiological response to adapt black or red background and it is better to use lighter colour as the background rather than black or red colour. This research provides reference for aquaculture system designs and operations.

We also examined the effect of *Aeromonas salmonicidon* infection on the swimming behaviour and physiology of Atlantic salmon (*Salmo salar* L.). Compared with the control group, the pathogen injected group significantly impaired the critical swimming speed (Ucrit) and exhausting time ($P < 0.05$), which were reduced by 37% and 39%, respectively. Furthermore, the blood parameters related to their swimming behaviour were also influenced significantly by pathogen injection ($P < 0.05$). The results showed that the high-density lipoprotein (HDL), haemoglobin and total protein decreased by about 63%, 49% and 74% at the end, respectively, while lactate increased by about 29% on day 6. The results suggested that the swimming performance of Atlantic salmon might be a useful indicator of disease, and it was feasible to warn the outbreaks of acute disease by fish behaviour.

How do the characteristics of the individual's behaviour differ when alone or when in a group? Which traits of the individual are adjusted for it to become part of the synchronized group, which are retained unchanged, and how are they manifested within the swarm?

Based on these questions, we think future research mainly focused on how to quantify the characteristics of fish collective behaviour, how to identify the ways of information transmission between cooperative group activity, how to determine the social hierarchy of group, and to clarify the interaction mechanism between fish behaviour and environmental factors.

*yingliu@dlou.edu.cn

Application of a Pipe-based Automated Net-hauling System in Set Net Fishery

Junbo Zhang[1], Chunyi Zhong[1*], Daisuke Kitazawa[2] and Yoichi Mizukami[2]

[1]College of Marine Sciences, Shanghai Ocean University, [2]Institute of Industrial Science, The University of Tokyo

As a passive fishery as well as a sustainable fishery, set net fishery has a few hundreds of histories and plays an important role in coastal fishery. In a net-hauling system, migratory fish are guided to a box chamber net by leader net and related net. Fish harvest requires lots of workers to visit the set-net and haul the box chamber net every dawn, however working in early morning is hazardous. A pipe-based automated net-hauling system is developed to reduce labour costs and risks. The system utilizes high density polyethylene pipes in which compressed air is injected or exhausted through water tank testing. Models of set net and four high density polyethylene pipes are made based on the similarity law (for stiffness and force), and they are installed in water tank. Air is injected and exhausted in the pipe models, and the motion of pipes and the formation of the box chamber net are examined by underwater video camera. In the experiment, the similar motion of pipes can be observed. Then the first and second high density polyethylene pipes were made and tested. In addition, the pipe made of PE materials can be used safely because it will not break due to bending. The detail of the motion of pipes need to be analysed in the future. The third and fourth high density polyethylene pipes will be tested in the actual sea.

*chunyiz0906@sina.com

The Seals and Fisheries Program

Peter Ljungberg*

Swedish University of Agricultural Sciences, Turistgatan 5, 453 30, Lysekil, Sweden

An increasing threat to the Swedish coastal fisheries is the growing seal populations. Seals damage fishing gear and catch which causes significant economic losses for fishermen. The Seals and Fisheries Program (SFP), is a research group that produce a scientific base for the support and implementation of seal-safe fishing gears. Together with fishermen and manufacturers, we have been developing seal-safe fishing gears since the 1990's.

*peter.ljungberg@slu.se

4 TOPIC GROUP: Passive fishing gears (Passive)

4.1 Introduction

A WGFTFB Topic group convened by Peter Ljungberg (Sweden), Isabella Kratzer (Germany) and Lotte Kindt-Larsen (Denmark) on passive gears was formed in 2019. The group met on two days on 11 and 12 April in Shanghai, China and kept a focus on pots and trap development in the first year.

Terms of Reference:

1. Summarize current and past work in relation to fish pot and trap development, plus gillnet and longline modifications in order to avoid bycatch of protected species (hereunder marine mammals, sea birds and sea turtles).
2. Discuss and describe methods and their limitations, hereunder catch efficiency and depredations risks. Furthermore compare newly developed bycatch mitigation efforts and their efficiency to standard gear and compare different types of passive gears (e.g. gillnets vs. fish pots/traps) and the processes of depredation.
3. Identify and make recommendations on how to improve passive gears including unwanted bycatch, high variability in catches and mitigation of depredation from different predators.
4. Identify potential synergies in developing new approaches to promote sustainability (economically and ecologically) of passive gears

Justification

Passive fishing gears such as gillnets, longlines, traps and pots, belong to the most common fishing methods worldwide. These methods have naturally advantages like efficiency, simple use and size selectiveness. Nevertheless, they have been criticized due to bycatches of higher taxa like sea turtles, sea birds and marine mammals, ghost fishing and their vulnerability to depredation by marine mammals. In recent years, a lot of effort has been put into the optimization of fish traps and pots, mainly due to gillnet-raiding seals and studies on how to mitigate bycatch in gillnet and longline fisheries have been carried out with differing success, but a scientifically proven management tool or technical solution working across taxa has yet to be developed.

The "Passive" topic group will thus aim to investigate selectivity, efficiency and sturdiness of passive gears, such as gillnets and longlines (mainly species selectivity), fish pots and large scale fish traps (mainly efficiency and sturdiness). It will document and evaluate current and past work regarding gillnet and longline modifications as well as fish pot and fish trap development. This will include a wide range of fields such as species behaviour, gear design and hydroacoustics. Ongoing and future projects regarding enhanced economical, ecological and social sustainability of passive gears will be discussed and potential synergies identified that will hopefully stimulate new ideas and innovation.

4.2 Overview passive Topic Group 2019

Focus and structure

The conveners of the topic group decided during the preparation of the meeting to focus on one type of gear each year during the three years of the topic group. All ToRs are addressed every year, with a joint recommendation after the third year. During the 2019 meeting, the focus was on pots and traps. Since pots are considered an alternative gear for some fisheries, the conveners also included the topic of implementation and problems that accompany the introduction of new fishing gears. The topic group meeting started with four keynote presentations: a review of pot development, a case study of pots as a mitigation device to reduce bycatch, an overview of passive gears in China, a talk on the implementation of new or modified fishing gears in Japan and a summary of issues with the implementation of new gears identified by the Topic Group "Change" (2015 – 2017).

Participant list

Timothy	Werner	Anderson Cabot Center for Ocean Life, New England Aquarium	twerner@neaq.org
Mohd Fadzliee-bin	Asmat	WWF-Malaysia	mfadzliee@wwf.org.my
Terje	Jørgensen	Institute of Marine Research	terjej@hi.no
Haraldur Arnar	Einarsson	Marine & Freshwater Research Institute	haraldur@mfri.is
Yoshiki	Matsushita	Nagasaki University	yoshiki@nagasaki-u.ac.jp
Teng	Wang	Chinese Academy of Fishery Sciences	twangshanghao@163.com
Liuyi	Huang	Ocean university of China	huangly@ouc.edu.cn
Georg	Haney	Marine and Freshwater Research Institute	georg.haney@hafogvatn.is
Lauren	Fields	NOAA NMFS	lauren.fields@noaa.gov
Zhaohai	Cheng	Fisheries and Marine Institute of Memorial University of Newfoundland	zhaohai.cheng@mi.mun.ca
Ludvig	Krag	DTU Aqua	lak@aqua.dtu.dk
Lotte	Kindt-Larsen	DTU Aqua	lol@aqua.dtu.dk
Peter	Ljungberg	University of Agricultural Sciences, Department of Aquatic Resources	peter.ljungberg@slu.se
Daniel	Stepputtis	Thuenen Institute of Baltic Sea Fisheries	daniel.stepputtis@thuenen.de
Liming	Song	Shanghai Ocean University	lmsong@shou.edu.cn
Xun	Zhang	Chinese academies of fishery sciences	zhangx@ecsf.ac.cn
Isabella	Kratzer	Thuenen Institute of Baltic Sea Fisheries	isabella.kratzer@thuenen.de
Pieke	Molenaar	Wageningen Marine Research	Pieke.molenaar@wur.nl
Kelsey	Richardson	University of Tasmania and the Commonwealth Scientific and Industrial Research Organisation	kelsey.richardson@csiro.au
Matthias	Van Opstal	Institute for Agricultural and Fisheries Research	mattias.vanopstal@ilvo.vlaanderen.be
Eric	Gilman	Hawaii Pacific University	EricLGilman@gmail.com
Raymon	Van Anrooy	FAO	Raymon.VanAnrooy@fao.org
Mollie	Brooks	DTU Aqua	mollieebrooks@gmail.com
Ying	Dai	Dalian University of Foreign Language	286143216@qq.com

4.3 Output passive Topic Group 2019

Keynote presentations

Pot fisheries – a recap (Peter Ljungberg, Sweden)

Abstract

History time line pot fisheries.

Key points

- long history of pot fisheries in some countries
- less documentation in other countries
- Data (data base/ factsheets) should be further collected
- Reviews are needed

Fishing for alternatives - Bait and pot trials in the Upper Gulf of California (Lotte Kindt-Larsen)

Abstract

Fishing for Change- Development alternative fishing gear for saving the Vaquita
Lotte Kindt-Larsen, Mikkel Kehler Villadsen and Sara Königson

The Vaquita porpoise (*Phocoena sinus*) has almost been driven to extinction by incidental bycatches in gillnet fisheries in the Upper Gulf of California. The Mexican government has thus banned the use of gillnets in the entire distribution range of the Vaquita. To find alternative fishing gears for the enrolled gillnet fishers, a project developing vaquita-friendly fish pots was pushed forward by ECOFT (Expert Committee on Fishing Technologies) supported by the Mexican government and in collaboration with WWF Mexico. The aim was to create fish pots, as an alternative fishing gear to gillnets in the no-gillnet zone of the Upper Gulf of California. To ensure the best performance of the pots, an experiment was conducted testing three different baits available to the fishers. Three baits were selected and tested in the area of San Luis Gonzaga, Mexico. Fish attraction were recorded using GoPro cameras. The results showed that in daylight Flat-iron Herring proved to be the most effective bait, whereas the results from the night were inconclusive. In total three different pot types were tested, two floating and one bottom standing. The results showed that the bottom standing pot design had the highest fish catches but the species caught were very area dependent. During the trials the average catch per fishing journey was 25 kg. Total catches, however, can be improved by increasing the numbers of pots used, placing the pots at the best possible fishing grounds and leave the pots in the water with optimal soak times. Thus if fishers are willing and capable of fulfilling these requirements, fish pots can turn out profitable and become a viable alternative to gillnets in the Upper Gulf of California. However, more trials are needed to conclude this.

Key points

- The upper gulf has a high need for new gears with no bycatch of Vaquita
- Flat-iron herring is very suitable as bait
- Bottom-set pots has the highest catch rates
- Fish pots catches can be improved by increasing the number of pots in the water and the choice of area.

Passive gears in China (Xun Zhang)

Key points

- More than 100’000 vessels operating using passive gears
- Large variety of gears: gillnets, lines, pots & traps, swing nets, lift nets
  “swing” or “stow nets” were new to most passive group participants
    - swing net: large (75m by 50m) net set into tidal current with codend to retain catch
    - can swing according to incoming our outgoing tide
- Type of gear dependent on region

The whole presentation is available upon request from the conveners.

Introducing new/modified fishing gear to the real world: Experiences in Japan (Yoshiki Matsushita)

Abstract

In Japan, fishing gear modifications that did not enhance catch amount and the value (not efficiency) was never welcomed by fishers between 1960s-1980s, when the national fish production increased. Gear modifications for bycatch reduction were the only ones observed by the distant water fishers that operated in adjacent waters of foreign countries to avoid diplomatic issues. However, the fishers stopped using the modified gear if the catch efficiency decreased. In 1984, when the fish production almost peaked, all the stakeholders including the fishers, managers and the scientists realized the necessity for development of measures for sustainable fish production, but it was very difficult to reduce the fishing efforts at that time because industries were driven only by economies. Consequently, the national and the local governments started stock enhancement programs to restock the water body by releasing artificial hatched juveniles of commercial species. However, they faced a challenge whereby the released small juveniles were caught by coastal fisheries such as gillnets, pots and trawls. From this, gear modifications were encouraged by the National Federation of Fisheries Co-operative Associations, the national and the local governments in Japan. I believe that this was a start of voluntary acceptance of new/modified fishing gear for something other than “more catch”.

Since then gear modifications have been conducted not only to reduce bycatch, but also to save fuel and labors, suggesting that immediate threats to business sustainability are always motivation to introduction of new/modified fishing gears. In addition, media information on threats to sustainability of fisheries such as ocean warming due to climate change and micro-plastic pollution have also reached out to fishers with receptive minds. In my talk, I will present such examples.

Key points

- Drivers that facilitated implementation:
    - enforced by law or moratorium
    - natural causes (e.g. jellyfish bloom blocked traps)
    - bycatch of choke species
    - “honor” by the minister or emperor
- Already small economic efforts were a hindrance in implementing bycatch reduction devices

Recap of Topic Group "Change" (Steve Eayrs)

Key points

- The paradox of the fishermen: ability of fishers to adapt rapidly to environmental changes (such as weather), but their resistance to adapt new approaches in fishing gear
- The elephant and the rider:
  - a simile describing the overwhelming power over emotion (elephant) over the rationale (rider)
  - need to connect with stakeholders on an emotional level
- Kotter model: 8-step-model to initiate organizational change
- Little to no voluntary uptake in the last decades
- Output of TG was described in a publication: DOI: 10.1093/icesjms/fsy178

4.4 Discussion Groups

Following the keynote speakers, the group was divided into three subgroups, each led by one of the conveners. The conveners rotated every 45 minutes so that all participants had the chance to discuss all three topics.

Group 1 – Literature Review/Database

The group discussion was divided into how to complete the history line of pot fisheries and where future focus perspectives should be. At a general level most participants identified a lack of studies from non-western world countries especially Asia and Africa. Further are project reports, often written in native languages missing in a history timeline. Ways to fill these gaps could be to go through FTFB mailing list, trough that contact a country representative and they may put you in contact with the people within that country to address the question of adequate literature written in native languages. Also, with online publication becoming more common, the use of existing fact sheets could be a way to collect data on pot development from different countries. Another suggestion would be to couple dear development fact sheets to the WGFTFB group.

Regarding future focus areas there were several suggestions. The most important issue to address seem to be how to make pots efficient enough to be a realistic alternative in fisheries as they for many, especially finfish species, have a high price for catch and catch efficiency has to be improved enough to reach economic returns. Other focus areas needed are to conduct further studies of both target, non-target species and how fishermen relate to the implementation of new gear. Another way to evaluate efficiency would be to do meta-analysis of existing finfish fisheries to examine variables that make them profitable. In addition there has to be a holistic approach to the whole gear, not just the pot. At the level of management of pot as gear it is important to evaluate materials that may be used in order to make pots and especially escape panels/vents biodegradable. To address the question of cheap tracking systems for pot fishing to mark pots and reduce ghost fishing is also of importance along with a more general view of how to incorporate passive fishing gear into the blue economy.

Group 2- pot design

The discussions of pot design were separated into to four aspects of pots design. 1) Attraction; 2) Entrance design; 3) Holding the catch and 4) Rope entanglement.

Attraction: Under attraction, it was stated that bait trials are important before setup of new pot trials. Knowledge on prey species of target species can provide information on what could work as attractors but in some cases, baits that is not part of the regular diet, has shown a higher attraction. Ideas on bait could also be collected from longlines fisheries if these exist in the area. Test of a variety of baits, can lead to better understanding of attractors and thus higher catches. The simplest way to collect information on bait attraction is by use of video cameras as this can be done without interference of pot-design. Ideas of testing anise oil, animal meat, sounds of "chewing fish", shadow/hiding areas and light where brought up as especially light potentially could work under high currents where normal bait is too easily dissolved.

Entrance: Under the entrance discussions, focus where mostly on size and materials. Size should always be a compromise, as it should both be an easy entrance but a difficult exit. Ideas on having first a large entrance and then a more narrow one was brought up, as this could work as a kind of funnel. With respect to materials it was believed that transparent and knotless materials would be the best. Ideas of electronic openings were also suggested.

Holding the catch: Holding the catch is both to stop exits and to let new catch come in. By adding funnels to the entrances it was generally believed that these could hinder catch escape. However, these funnels can also hinder catch from getting in, as fish needs to be willing to swim through. It was discussed if hidden chambers could move away fish from the bait so new fish will enter the pot. But it was argued that fish might sense other fish presence even though they are not visible.

Rope entanglement: With respect to rope entanglement this is mainly a problem in areas with occurrence of larger whales. The whales becomes entangled in the lines from the bottom to the surface. Thus, it was recommended to keep the amount of lines from the bottom to the surface to an absolute minimum by having pots set in strings instead of single based. Ideas on having acoustic releasers, dissolvable zink releasers, thin ropes to the surface, ropes in other colors (red) and small "scarecrows" on lines were put forward. A review of what already have been done will be provided to the group.

Group 3 – Implementation

All participants confirmed the experiences presented by S Eayrs, independently of the nationality. Overall, incentives that have been noted to facilitate uptake are primarily financial, either in the form of increased catches or the possibility to receive a sustainability label that increases the market value. On the other hand, the danger of losing a sustainability label in case of continued practices also seemed to be a possible incentive. Uptake also took place as a response to a potential ban or punishment. Differences in catch need be substantial to make any voluntary uptake possible.

Furthermore, participants reported that the identification of influential individuals in a (fishing) community are crucial; individuals can be fishermen, but may also be members of the Church or "older people" in a community.

The participants also identified a lack of suitable communication skills by scientists as a problem to perform outreach tasks. It was also noted that broadcasting needs time and patience. It was concluded that all projects regarding the development of new or alternative gears need to take social scientists as well as adequate PR into account, in order for any modification to have a chance to be applied.

4.5 Outlook for next year

Next year's passive topic group will most likely focus on gillnets, as the joint WGFTFB and WGFAST meeting allows to combine forces regarding the acoustic issues related to gillnet by-catch. Experts dealing with behavior of marine mammals and their sensory abilities will be invited as well as fishermen to give insight into other perspectives regarding uptake of new gears.

5 Topic Group: Evaluating the application of artificial light for bycatch mitigation (Light)

Conveners: Noëlle Yochum (USA) and Junita Karlsen (Denmark)

Note taker: Valentina Melli (Denmark)

5.1 Introduction

A WGFTFB topic group (TG) of experts was formed to evaluate the use of artificial light as a fisheries selectivity tool. This TG met during the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) annual meetings in 2018 (Hirtshals, Denmark) and 2019 (Shanghai, China). The goals of these meetings were to:

i. form a community of researchers applying light for bycatch mitigation;
ii. identify related work that has been and is being done globally;
iii. provide background knowledge and develop tools that can be used to support this community of researchers; and
iv. identify and discuss common challenges when using light as a selectivity tool.

5.2 Background and Objectives

The success of bycatch mitigation in fisheries is linked with understanding how fish interact with fishing gear. A component of fish behavior that is increasingly being evaluated is how artificial light could be used to elicit species specific responses in and around the gear. There are many unresolved questions about how to conduct research to evaluate fish response to artificial lights, how to interpret the results, and how effective the lights are as a fisheries selectivity tool. The focus of this TG was to create a community of researchers using light as a fisheries selectivity tool to address these questions. Through collective review of research being done, we aim to identify variables that play a role in the efficacy of using artificial light for bycatch mitigation (e.g. species, gear type, environmental conditions). We will also discuss common experimental, technological, and analytical challenges when doing this research, and identify gaps in knowledge and other fisheries that might benefit from the application of artificial light. Through the analysis of completed and on-going research, and collective knowledge of the TG experts, we will also highlight important considerations for conducting research on the application of artificial light for bycatch mitigation. We hope that these meetings will also foster an exchange of ideas and support, and stimulate innovation.

5.3 Terms of Reference

This topic group was established to evaluate the use of artificial light for bycatch mitigation, and to develop tools to support these endeavors. The terms of reference (ToRs) were:

1. Describe and summarize completed and ongoing research related to the application of light for bycatch mitigation.
2. Identify patterns with respect to species and fishery/ gear types, noting fish behavior in response to light (attraction, repulsion, guidance), and other variables that play a role in the efficacy of using artificial light for bycatch mitigation (e.g. vision, depth, etc.).
3. Describe best sampling techniques for testing the application of artificial light under varying circumstances, including guidance for dealing with common experimental challenges.
4. Highlight areas of needed research in the field of fish behavior with respect to light, and fisheries that might benefit from the application of artificial light.

5.4 2019 Topic Group Meeting Overview

The topic group met April 11-12, 2019 (Thursday - Friday) for approximately six hours (both days combined). The agenda included introductions, with each person sharing their involvement and interest in research using artificial light (for some, this included video sharing). This was followed by each person filling out a card to indicate experimental, technological, and analytical challenges that they have been confronted with in doing this research. The remaining time was allocated to two keynote presentations (see 'Keynote Presentations', 5.3.2) and four discussion topics (see 'Workshop Discussions', 5.3.3). The topics of the keynote presentations were linked to the six fundamental principles of conducting research using artificial light to affect behaviour that have been identified for this Topic Group (see 'Keynote Presentations', 5.3.2).

2019 Topic Group Participants

There were 25 TG participants over the two days, representing 16 countries (See 'List of Participants', 5.2.1.1). Several participants had not yet conducted research applying artificial lights, but were interested in learning more about the topic. For those who had prior experience, the participants had worked with a range of gear types and species. The former included gillnets, purse seines, pots, jigging, trawls, and FADs. Lights had been used to affect behaviour of fishes (e.g. cod, haddock, salmon), invertebrates (e.g. Norway lobster, shrimp, snow crab, squid), sharks, marine mammals (e.g. dolphins), and seabirds (e.g. penguins). Research included the evaluation of glowing baits for longlines, a 'laser trawl', glow-in-the-dark netting, and light-emitting diode (LED) lights in ruggedized housings. Objectives for applying these light sources was to modify fish behaviour inside the trawl (e.g. attract or lure fish) to increase selectivity (e.g. guiding fish in order to separate catch), to make gear easier to handle, and to reduce seafloor-gear interactions. In addition, scientists were evaluating how camera lights affect fish behaviour and the role of the light color, and why lights affected behaviour differentially in different environments.

List of Participants

NAME	COUNTRY	INSTITUTE	EMAIL
Steve Earys	Australia	Smart fishing Consulting	smartfishing1@hotmail.com
Maarten Soetaert	Belgium	Institute for Agricultural and Fisheries Research	maarten.soetaert1@ilvo.vlaanderen.be
Mattias Van Opstal	Belgium	Institute for Agricultural and Fisheries Research	mattias.vanopstal@ilvo.vlaanderen.be
Shannon Bayse	Canada	Memorial University of New-foundland	Shannon.Bayse@mi.mun.ca
Narcisse Ngando	China	Shanghai Ocean University	narcisseebango@yahoo.fr
Tian Fei Cheng	China	Shanghai Ocean University	279600721@qq.com
Weijie Wang	China	Shanghai Ocean University	weijiwang@shou.edu.cn
Valentina Melli (Note taker)	Denmark	DTU Aqua	vmel@aqua.dtu.dk
Junita Karlsen (Co-chair)	Denmark	DTU Aqua	jka@aqua.dtu.dk
Juan Santos	Germany	Thünen Institute of Baltic Sea Fisheries	juan.santos@thuenen.de
Georg Haney	Iceland	Marine and Freshwater Re-search Institute	georg.haney@hafogvatn.is
Go Takayama	Japan	National Research Institute of Fisheries Engineering	golgo13@affrc.go.jp
Serena Adam	Malaysia	WWF Malaysia	serena.adam@wwf.org.my
Pieke Molenaar	Netherlands	Wageningen Marine Re-search	pieke.molenaar@wur.nl
Carol Scott	New Zealand	Southern Inshore Fisheries Management Company Lim-ited	cscott@southerninshore.co.nz
Åsmund Bjordal	Norway	Institute of Marine Research	aasmund.bjordal@hi.no
Aud Vold	Norway	Institute of Marine Research	aud.vold@hi.no
Maria Tenningen	Norway	Institute of Marine Research	maria.tenningen@hi.no
Ólafur Ingolfsson	Norway	Institute of Marine Research	olafur.arnar.ingolfsson@hi.no
Pedro Sá	Portugal	Euronete Portugal	pedrosa@lankhorsteuronete.com
Taweekiet Amorn-piyakrit	Thailand	Southeast Asian Fisheries De-velopment Center	taweekiet@seafdec.org
Dan Watson	UK	SafetyNet Technologies	dan@sntech.co.uk
Tom Catchpole	UK	Centre of Environment, Fish-eries and Aquatic Sciences	thomas.catchpole@cefas.co.uk
Mike Pol	USA	Massachusetts Division of Marine Fisheries	mike.pol@mass.gov
Noëlle Yochum (Co-chair)	USA	NOAA Alaska Fisheries Sci-ence Center	noelle.yochum@noaa.gov

5.5 2019 Topic Group Accomplishments

The high number of participants in the TG (see '2019 Topic Group Participants', 5.2.1) demonstrate the continued interest in using artificial light for bycatch mitigation and that the establishment of this TG is timely. The first stepping stone for this group was establishing a community in 2018 during the WGFTFB meeting in Hirtshals, Denmark, which led email communication in-between meetings and the broadening of the 'Light' community. During the meeting in Shanghai, the TG provided updates on recently completed and on-going research (Terms of Reference, ToR, 1). In addition, according to the goals of the meeting (see 'Introduction', 5.1), common challenges were identified and discussed in workshop discussion groups (see 'Workshop Discussions', 5.3.3) and through filling out survey cards. Among the resources that are being provided to the community through the TG meetings are keynote speakers (see 'Keynote Presentations', 5.3.2), and a literature library with a reference list (see 'Literature Library', 5.4.1). Discussions from this TG meeting shed light on how lights are being used to affect fisheries bycatch and why results from these studies are varied. It is clear from the TG meeting discussion that, while lights are a tool in the fisheries toolbox, it is not a 'silver bullet'. More evaluation is needed to understand when and why the lights work, and when to stop research evaluating them for a particular fishery or species. The first two years of this TG has shed light on variables that need to be considered when conducting this research, and what are the broader implications for applying lights in fishing gear. The final TG meeting year in 2020 will provide another opportunity for discussion, and will allow time to complete a more comprehencive evaluation of light as a fisheries slectivity tool.

Presentations and Posters in Plenary

There were five contributed papers on artificial light in the plenary. Of these, three were oral presentations and two were posters. The former were presented in the following sessions: 'Light, fish behaviour and fishing', 'Technology and management to reduce bycatch and discards', and 'New technologies for fisheries research and education' (see Section 3 for abstracts):

Title	Presenter (underlined) and co-authors
Mesopelagic fish: responses to artificial light	Åsmund Bjordal, Melanie Underwood, Anne Christine Utne-Palm, Jan Tore Øvredal
Gear innovations to reduce the catch of undersized whiting in fly shooting fisheries	Mattias van Opstal, Maarten Soetaert
Infrared fish observation iFO	Andreas Hermann, Daniel Stepputtis, Jerome Chladek

Two of the presented studies (Bjordal et al., van Opstal and Soetaert) focused on fish responses to artificial light. The study by Bjordal et al. found that, in natural habitat, mesopelagic fish avoided blue, green, and white artificial light. Also, white light forming a dish could herd the fish down, but not up the water column as observed with an acoustic echosounder. The fish did not respond to red or infrared light. The study by van Opstal and Soetaert found that whiting responded to white and multicolour lights used simultaneously in a 'flyshooter'. The research presented by Stepputtis detailed a new camera system that can be used to monitor fish behavior in creels at low ambient light levels using infrared light.

The two posters presented (for abstracts, see ‘Posters’, 3.12) were:

Title	Co-authors
All eyes on you: infrared fish observation	Andreas Hermann, Daniel Stepputtis, Jérôme Chladek
UV illumination to reduce sea turtle bycatch in Mediterranean set net fisheries	A. Petetta, M Virgili, C. Vasapollo, G. Bargione, A. Lucchetti.

The poster presentations described research using infrared and ultraviolet lights. For the former, Hermann et al. detailed a low cost infrared light and camera system that can be used to observe fish at low ambient light levels without influencing fish behavior (as has been observed using white artificial lights with cameras). Testing the system on cod in creels demonstrated that the visual range of the camera system was 1.8 m. The research by Petetta et al. involved the use of ultraviolet lights on gillnets as an alternative to light-sticks. Results from the study suggested that the lights caused reduced interaction with sea turtles with no change in the catch efficiency.

Keynote Presentations

The application of artificial light as a fisheries selectivity tool requires complex research that involves a multidisciplinary approach and a foundation in six “pillars” (see WGFTFB 2018 report for additional details). These include:

Pillar 1: Engineering – Light sources: design, characteristics, and measurements

Pillar 2: Physics/Optics – Characteristics of light, transmission of light in water

Pillar 3: Biology/Physiology – Vision and perception of light

Pillar 4: Behaviour – Response to light stimuli

Pillar 5: Fisheries technology and practices – Target species and gears

Pillar 6: Design, analysis, and interpretation

It is necessary to have some understanding of these disciplines when using artificial light as a stimulus to manipulate the behaviour of marine animals for bycatch mitigation. For this reason, keynote speakers representing different ‘pillars ‘are invited each year to speak during the TG session to provide background knowledge. Pillar 5 “Fisheries technology and practices” is covered each year in plenary by fishing gear technologists of the WGFTFB group. During the first two years of the TG meeting (2018, 2019), all six pillars have been covered at least once. In 2018 pillars 1, 2, 3, and 6 were covered (see WGFTFB 2018 report for additional details). At the 2019 meeting, pillars 1 and 4 were covered by the two keynote presenters.

Keynote 1
Squid behavior in relation to artificial lights observed by behavioral experiments and bio-telemetry surveys (Go Takayama)

Abstract

In Japanese squid jigging fisheries targeting *Todarodes pacificus*, squid attracted by powerful fishing lights are caught by automatic squid jigging machines. Currently, metal halide lamps are mainly used as light sources. In recent years, the experimental use of LED fishing lights has been implemented as an energy saving light source due to rising fuel prices. However, the catch efficiency and cost advantage of LED fishing lights is not fully comparable to conventional fishing lights.

The behavior of squid against fishing lights is paradoxical. The rays of fishing light attract squid from a wide area, but squid don't aggregate in the strongly illuminated sea surface area, they gather in the shadow area formed under the squid jigging boat. To improve efficiency of LED fishing lights, we have tried to clarify the capture process of the squid jigging fishery through behavioral experiments and bio-telemetry surveys.

In tank experiments, responses of squid to various light environments were observed. As a result, it was inferred that the behavior of squid aggregating under fishing lights is caused by two autonomous responses; positive phototaxis and dorsal light reflex. Also, it was reported in a previous study of field observations with echosounder that squid avoid environments where squid received upward light rays. From these results, we inferred the capture process hypothesis as follows. A squid that recognize fishing light approaches the squid jigging boat with positive phototaxis, but in the high irradiance area near the boat where backscattering of light (i.e. upward light) in seawater also occurs strongly, the squid moves toward the deeper layer to avoid such an environment. After reaching under the boat, squid continue staying there by dorsal light reflex.

We also conducted bio-telemetry surveys to verify squid behavior in the fishing ground. In the observation, the squid moved a maximum 4 nautical miles from the release point to the squid jigging boat. In addition, when approaching the fishing light, the swimming depth of the squid dropped as it approached. As described above, the hypotheses have been verified by bio-telemetry surveys.

We got some suggestions from these studies. For example, there is a possibility that powerful fishing lights are useful for attracting squid from a wide area, on the other hand, they may not be optimal for concentrating the squid under the boat. To resolve such contradictions, we are currently researching optimal wavelengths, onboard panel arrangements, and light distribution designs of fishing lights.

* *golgo13@affrc.go.jp*; National Research Institute of Fisheries Engineering, Japan

Key points

- Using a combination of laboratory and field experiments can improve the understanding of animal response mechanisms occurring in a capture process.
- Observed fish behavior may be caused by a mix of response mechanisms rather than just one.
- The orientation of the animal relative to the artificial light source may elicit different response mechanisms.
- There can be individual variability in fish Behavioural response to light.

Discussion/questions

Following this keynote presentation, the TG participants discussed the importance of expecting high individual variability in behavioural responses to artificial lights, especially when planning laboratory experiments. The possibility of using the fish school as the experimental unit instead of individuals was suggested, but Dr. Takayama explained that not all species show schooling behaviour and each individual may be responding independently to the stimulus.

Additional parameters to be considered in these experiments were highlighted by the participants, including: the combination of artificial light and natural light, the back-scattering from the tank walls, and predator-prey reactions deriving from the presence of other species in proximity of the lights. According to Dr. Takayama, the relevance of these parameters needs to be evaluated on the basis of the knowledge about the species of interest and depends on experimental design. For example, the behaviour of the squid species that was studied varies during day- and night-time, with the individuals naturally concentrating in a dense school during daytime. Moreover, the level of back-scattering is difficult to control at sea, but can be regulated when conducting laboratory experiments by choosing the appropriate colour for the tank walls.

Keynote 2
Let it glow, light-emitting technology under the sea (Dan Watson)
Abstract

This presentation will cover various light emitting technologies and their application to fishing gears in the past, present and future. Environmental, cost and scalability considerations will be explored, as well as a range of case studies. Topics will also focus on how to take prototype technologies that demonstrate positive impact to sustainable implementation in industrial and artisanal fleets, the role of regulation in supporting those activities, and design principles for light-emitting technologies.

* *dan@sntech.co.uk*; SafetyNet Technologies, UK

Key points

- Technology needs for each use case may be different, but can be based on mass-customization, rather than starting from scratch each time.
- The economic case for technology needs to scale for each use case to enable sustainable implementation.
- Prototypes can be great for science, but commercial products for operational use will look/feel different.
- Ecological aspects (plastic waste, electronic disposal/maintenance) need to be considered when designing technology used for research.
- "Things are changing rapidly in [the] field [of artificial lights applied to fisheries] and we need to keep up with the technology." (Dan Watson)

Discussion/questions

After the comprehensive presentation of different LED light sources currently available and their potential application to fisheries, the discussion focused on overall lessons learned: can we effectively use artificial lights to affect fish behaviour? From the technological point of view, Watson indicated that the resources are ready. However, variability in the research results implies that more science needs to be done to better understand the behavioural responses of the studied species. The discussion proceeded by highlighting that collaboration with fishermen may be useful to quickly identify potential applications, and that careful interpretation of the feedback provided by the fishermen is essential. The complexity of behavioural responses to lights could lead to misinterpretation of the effect of their application. It was noted, however, that it can be hard to maintain engagement with industry if results are not significant or are variable. This can also lead to difficulty in getting research funding.

Lastly, alternative ways of powering the artificial lights were discussed, in particular the possibility of using power from the vessel. The conclusion was that the energy required to maintain stable flux would be too high to make it a viable option and rechargeable batteries, especially when combined with a single recharging station (less potential failure points), is currently the most cost-efficient option.

Workshop Discussions

During the TG meeting, there were four facilitated discussions pertaining to the use of artificial lights to affect fisheries selectivity. The group discussion addressed the following four questions:

1. How confident are we that artificial light can reliably be used to manipulate fish behaviour?
2. When using artificial lights, what are the unintended issues that we need to be aware of and how do we mitigate those issues?
3. Where are more applications for or research on artificial light to affect fisheries selectivity needed?
4. Technology used in research to evaluate artificial light as a fisheries selectivity tool: what people are using, what is working, what is needed?

A summary of highlights from the discussion follow.

Discussion Topic 1
How confident are we that artificial light can reliably be used to manipulate fish behaviour?

This question arises due to the fact that many of the observed responses when using light for bycatch mitigation differ from the intended response or is variable. One of the take home messages from the 2018 'Light' TG keynote speakers was to "know your animal' (i.e. know their responses and adaptations in their natural environment). The approach in the first part of this discussion was therefore to identify which natural responses might be good candidates to manipulate in a fishing context. This knowledge could be used when deciding what behaviour one is trying to elicit when using artificial lights, and, therefore, what type of lights (e.g. colour) and how to use them (e.g. where placed in the fishing gear).

The following behavioural responses were put forward as good candidates for manipulation and discussed in relation to research completed:

1. Phototaxis
   One of the behavioural responses to light that most completed studies have attempted to elicit is phototaxis, movement in response to light (positive: toward the light source; negative: away from the light source). Examples from TG participants were from laboratory and field trails, including reactions to lighted crab pots and the use of vertical separation experiments in trawl fisheries. The discussion focused on the variability of the results obtained, both between laboratory and field experiments and between field experiments in different fishing areas. The participants highlighted that the confusing results may derive from our lack of understanding of the response/s triggered: are the individuals attracted to the lights? Or to other organisms concentrated around them? Does the type of response vary depending on other environmental parameters (e.g. water current)? Currently we can measure the direction and strength of the reaction, but do not have the understanding for the cause of the reaction.
2. The meaning of phototaxis in the context of active gears was also questioned, as the lights are moving relative to the individuals' position and not necessarily vice versa. In these applications, the response could be better quantified as orientation with respect to the lights. Moreover, in trawl gears, depending on the lights used, the entire trawl section may be illuminated, increasing the complexity in identifying the direction of the response. Thus, application of the lights in the forward part of the trawl may be easier to interpret and have less additional stimuli involved. The importance of choosing the right intensity for the right species and application was highlighted.
3. Optomotor response
   The few examples provided by the TG participants suggested that the optomotor response may be difficult to manipulate for the purposes of increasing selectivity. The discussion related to this behavioural response focused on the potential for artificial light to disrupt the optomotor response, for example by breaking the contrast between netting and background.
4. Anti-predator behaviour
   Additional discussion focused on anti-predator behaviour, including mention of a trawl that uses lasers as an alternative to physical gear to heard fish. This 'laser trawl' attempts to elicit an escape reaction similar to that normally achieved with mechanical stimulation.

The experiments conducted so far have identified some potential in terms of strength of the response. However, the reaction seems very difficult to trigger and it is not clear if it in fact is a reaction to the laser beams.

5. The TG participants also discussed how the escape response might be strongly affected by the position in the gear, as well as by the water current. Indeed, rheotaxis (i.e. orientation with respect to water flow) and other forms of stimuli were suggested as potentially more reliable responses to manipulate species behaviour in fishing gears.
6. Dorsal light reflex
The dorsal light reflex response has been identified in passive fisheries for squid as presented by keynote speaker Dr. Go Takayama. However, there were not any examples of observations or studies of this response in active fisheries.

During the TG meeting in 2018, keynote speakers presented information about how the visual systems of fish and their adaptive plasticity are highly diverse. Based on this concept, further discussion focused on visual system variables that are good to understand when conducting studies with artificial light, including: (1) sensitivity to different wavelengths of light; and (2) how the animal uses cone and rod vision. These variables can inform the light color and intensity used to elicit behaviours in its ambient environment. For example, rod vision is by orders of magnitude more sensitive than cone vision, but is colour blind. Also, it can be useful to know the time required for dark/light adaptation. Having a review about the visual perception of the most common commercial species was identified as a shared necessity among the participants.

The final part of this first TG discussion focused on evaluating behavioural responses to artificial light given that in and around the fishing gear the animal is experiencing multiple stimuli (e.g. other visual stimuli such as the netting, sound, water current, other fishes, vibrations). For example, while catch-comparison analysis can be used to quantify the effect of the application of artificial light, one cannot necessarily tease apart the influence of the light from the other stimuli present during the catch process. Indeed, these competing stimuli were identified as the potential cause of the variability in results across experiments.

The overall conclusion of the discussion was that conducting light studies in trawl gear is challenging given the many unknown variables and difficulty in interpreting behavioural responses. There was a consensus that guidelines on how to conduct these studies would be useful as well as identification of the research that needs to be done in support of ‘Light’ studies.

Discussion Topic 2
When using artificial lights, what are the unintended issues that we need to be aware of and how do we mitigate those issues?

The second discussion focused on unintended issues and challenges related to using artificial lights as a fisheries selectivity tool. One of the key questions being addressed by this TG is how effective lights are at reliably affecting fish behaviour. Given that, it is important to consider, if the lights are successful in affecting catch in the intended way, what barriers exist and what unintended impacts could result from applying the lights in the fishery.

The main points that were raised were focused around managing the use of lights, fishermen behaviour regarding uptake of the lights, unintended impacts to fish, and environmental impacts.

1. Management/ Regulation
   A reoccurring topic from this discussion was on how lights could be regulated or managed if they became broadly used. This includes both how managers could verify that the lights were working as intended (e.g. charged/ functional) if they were mandated, and how the lights could be kept from being used for the wrong reasons (e.g. IUU fishing or using too many if the lights were too efficient). It would also require monitoring to ensure that the lights were not disposed of at sea.
2. Fishermen Behaviour
   One participant mentioned that when fishermen found out that results from trials indicated that the lights did not work as intended, the fishermen did not want to use them or explore their use. This highlighted the need for fishermen buy-in and uptake if the lights are going to be applied in a fishery, and the importance of engaging fishermen in the process. This also means considering the cost of the lights and being thoughtful about the potential for robbery in passive gear. Also, if extra monitoring is required to ensure proper use of the lights, it is important to be aware that the additional cost would likely fall to the fishermen and could influence their potential buy-in.
3. Impacts on Fish and Catch
   An unintended impact when applying lights is that, while the lights could elicit the intended behaviour from the species of interest, the lights could also change the behaviour of other species in and around the fishing gear. This could lead to reducing CPUE of the target catch, or could increase bycatch rates or could change the composition of the bycatch. Moreover, the lights could also cause visual impairment to the animals.
4. Environmental Impacts
   A more in-depth discussion focused on environmental impacts of using lights in high numbers given the potential harm caused by light pollution (especially with high-density, stationary pot fisheries), and the relatively disposable nature of many of the lights that are available (e.g. the short 'life' of LED lights). Concern was expressed over the carcinogenic materials found in LED lights (e.g. lead) and the plastic pollution that could results from lights that are disposed of at sea intentionally or otherwise. Participants expressed the need to get a sense of the scale of the issue, and placed importance on the consideration of responsible material management (e.g. rechargeable batteries) when designing lights to be used for this application. Participants suggesting that there are alternative materials that might be effective, but there are trade-offs in usability. Also suggested was having lights that have a medium to high cost to prevent intentional disposal at sea. There was also the discussion over the danger in using lithium powered lights at sea in regard to the potential for the devices to catch fire and affect human lives.

While there is potential to mitigate bycatch by manipulating animal behaviour using artificial lights, the unintended impacts, challenges, and barriers for implementation need also be considered when determining best practices for increasing selectivity in a fishery. This remains true when artificial lights are used in fisheries in general. Like all strategies applied in fisheries research, all aspects should be considered.

Discussion Topic 3
Where are more applications for or research on artificial light to affect fisheries selectivity needed?

The third TG discussion focused on which variables need to be considered when designing an experiment with artificial lights. This discussion was in the context of how these variables present a challenge in understanding the way artificial lights are affecting fish behaviour in and around fishing gear, and how they could be linked with unreliable and conflicting results under changing conditions. Also discussed was the potential for camera lights, used to monitor fish behaviour, could affect behaviour and lead to biased results. The discussion is summarized below in four broad categories: environmental variables, fish behaviour, light properties, and data analysis and interpretation. Key points of the discussion indicate that more research is needed to understand if, when, and why these variables affect fish behaviour.

1. Environmental Variables
   Environmental variables were discussed only briefly as these were the subject of more in-depth discussion during the first TG meeting in 2018 (see WGFTFB 2018 report for additional details). The variables discussed in Shanghai were ambient light levels, water temperature, depth, water current, weather conditions, water transparency/turbidity, and temporal variables (season, time of day).
2. Fish Behaviour
   As discussed during the first keynote presentation, fish behaviour can be individual, which can lead to variable results. Moreover, there is the potential for the state of the animal to affect its reaction to artificial lights. The state could be affected by hunger level, predator-prey interactions, where the animal is in the gear (e.g. being herded), and prior experience. There is also the potential that the animal is habituated to the lights.
3. Light Properties
   As was the focus in 2018, much discussion focused on light properties and the unknown regarding how behaviour is affected by the intensity, wavelength, diffusion, and strobe rate of lights, in addition to the number of lights. Along these lines, there is the recurring question over the best way to measure light and how the fish interpret light based on their visual system. It is also important to consider the placement of the light in the gear, and its orientation relative to the animal and pieces of the gear that are illuminated (i.e. making the gear more conspicuous). It is possible that the light will be experienced differently by animals based on the properties of the gear around it (e.g. the color of the netting, the vibration of the gear around it, etc.). Also, it is important to consider artificial light relative to ambient light levels.

4. Data Analysis and Interpretation
   The way data are analyzed and interpreted are similarly important to the way they are collected when evaluating fish behaviour. The TG participants discussed the potential for incorrectly interpreting an animal's response to light based on anthropomorphic assumptions or otherwise. Moreover, a factor that contributes to the ability to correctly quantify behaviour is having high quality video and/ or catch data (depending on how the study is designed). For studies using video, it is important to be aware of errors related to duplicate counts or missed observations of fish. Along these lines, participants discussed how time intensive it is to go through video and process acoustic data.

This discussion highlighted variables that influence results from light studies, and explain why results have, at times, been variable or conflicting. As was discussed during the first keynote presentation, it is incorrect to assume that all fish (and at all states of being) will exhibit the same behavioural response to a stimulus. However, by collecting data on variables that could affect that behaviour, it will become easier to determine if and how light affects behaviour and whether that behaviour can be elicited reliably given the average fishing conditions for a given fishery. This discussion also led to a consensus that a standard way to collect data, and express and share results of light experiments is important. Also important is to be aware that other senses could be being stimulated more than response to light. For example, noise of the gear or olfactory cues could overpower phototaxis.

Discussion Topic 4
Technology used in research to evaluate artificial light as a fisheries selectivity tool: what people are using, what is working, what is needed?

This final discussion focused on the technology used when conducting experiments to evaluate fish behavioural responses to artificial lights. This includes the lights themselves, technology to monitor behaviour, and software to analyze data. For the lights, the following features were identified as essential: long battery life, easy attachment to netting, and robustness/ a durable housing. There was some discussion on the availability of lights and the issue of intellectual property rights. There are an increasing number of companies working to manufacture lights given the interest in their application. It was mentioned that, in addition to 'off the shelf' lights that are available, different pre-made components can be purchased (e.g. housings) and combined to create lights that meet the needs of a specific fishing gear/ species. Some examples of this were bike lights in plastic enclosures, and concert lighting in modified housing (for a laboratory study).

Technology that has been used to evaluate animal response to artificial lights include: cameras (live-feed and recording, machine vision), acoustic devices, and light sensors/ spectrometers. There are increasingly more low light cameras being manufactured for lower costs. However, the issue remains that lights that illuminate the camera field of view that can be detected by the animal can still bias research results. Red and infrared lights were used by some participants, but the trade-off with those is a narrow field of view and difficulty with image quality. Knowledge of the visual field of the species of interest is necessary to choose the most appropriate lights for camera illumination.

Alternatives to cameras like acoustic technology also have trade-offs. While light is not required, the technology can be expensive, requires a wide range, and can be difficult to observe behaviour and differentiate species that are morphologically similar. An alternative to using these technological options is using catch comparison, which speaks to overall ability to exclude or include animals, but does not produce information on animal behaviours.

Finally, there was some discussion about technology used to analyze data from light experiments. Animal behaviour software was mentioned as a tool that can be used to quantify behaviours. Also, because it is common to obtain many hours of video observations, which are very time-consuming to manually process, artificial intelligence for video processing has potential to reduce processing time and labor requirements. Unfortunately, the development of such technology has still a relatively low TRL (Technology Readiness Level). While this can increase efficiency, it does require substantial effort to calibrate the software.

This discussion highlighted the increasing availability of technology to support research that evaluates animal behaviour in and around fishing gear. It also highlighted limitations and trade-offs when using the different forms of technology. In general, there are many technological tools that can support effective research on animal behaviour; however, it is important to be aware of the trade-offs in light of the goals of the research.

5.6 Progress toward ToRs and Recommendations

Literature Library

Literature are being collected through literature searches in WebOfScience and through encouraging the TG community to send papers (especially grey literature and ongoing/recent research that are not yet/easily available; addressing ToR 1). The collected literature is uploaded onto the SharePoint site of WGFTFB under the folder 'Working documents' and subfolder 'Light TG' under the meeting folder for 2018. Furthermore, the literature collected by the previous TG has also been uploaded to this site. The literature files are being indexed in a spreadsheet and categorized under at least one of the six pillars (see section 5.3.2). The TG community is notified about recent publications and is encouraged to share publications to the group email distribution.

Examination of Research Using Artificial Light

The TG conveners are developing a database that delineates the important components of research pertaining to the use of artificial light as a selectivity tool. Over the course of the TG (2018-2020), papers shared through the TG community and information shared during the WGFTFB annual meetings is providing information about fisheries, gear types, and species to which light is being applied as a tool for bycatch mitigation (ToR 1). After the final year of the TG, this information will be used to identify patterns (e.g. with respect to species and gear types) and variables that play a role in the efficacy of using artificial light for bycatch mitigation (ToR 2). In addition, discussions regarding experimental, technological, and analytical challenges will be used to provide guidance on best sampling techniques for conducting future research studies (ToR 3). Discussions during the three TG meetings will also be used to identify needed research and fisheries that might benefit from the application of artificial light (ToR 4).

5.7 Plan for 2020

At the 2020 ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) meeting in Bergen, Norway, the 'Light' Topic Group of experts will meet for the final year. The goals of this meeting will be to: (*i*) welcome new community members; (*ii*) identify new research using artificial light for bycatch mitigation that was not presented at previous meetings and new projects, and discuss research results; (*iii*) provide background knowledge in the way of invited keynote speakers related to the "six pillars" representing the different disciplines that can highlight important issues when using artificial light as a stimulus to manipulating the behavior of marine animals; (*iv*) synthesize information related to patterns in results across gear types and/or species, targeted behaviours, and variables that most strongly affect behaviour; (v) evaluate guidelines for conducting research related to evaluating animal response to light; and (vi) complete a more comprehensive evaluation of where we are with the use of light as a selectivity tool and what the next steps should be in research.

6 TOPIC GROUP: Evaluation of trawl groundgear for efficiency, bycatch and impact on the seabed (Groundgear)

6.1 Full report from the Topic group

In Annex 4 is full report from the Topic Group with list of content and Appendix with relevant information. Page 226 to 332.

6.2 Introduction

The WGFTFB topic group convened by Antonello Sala and Pingguo He (with remote support from Roger B. Larsen) met during 8–12 April 2019 in Shanghai, China (Appendix 4). The group continued their work on the knowledge of designs of groundgear and other components dragged along the seabed as discussed during the 2017 WGFTFB meeting in Nelson, New Zealand and 2018 WGFTFB meeting in Hirtshals, Denmark.

The discussion on definitions of ground gear again continued in this meeting. It was decided that if new definitions were being recommended by the topic group, they would need to be agreed upon by the full WGFTFB group. It was decided that standard definitions and parameters should be included when describing fishing gears in technical reports and papers (e.g. defining mesh size measurement used). The following summarizes findings from this meeting:

1. Factsheets on groundgear used around the world have been assembled to provide examples of the diversity and variety of groundgears used for different species and bottom types but the latter information was insufficiently provided
2. Bottom trawls towing over seabed with its groundgear touching the seabed, while semi-pelagic trawls may either have trawl doors or the groundgear touching the bottom, but not both.
3. A variety of groundgears are used in trawls, ranging from combination ropes, chains, rubber cookies, discs, rockhoppers, and bobbins. The sizes of the elements are typically related to the type of seabed
4. A variety of rigging of groundgear is used for different types of trawls, such as single bottom otter trawls, twin trawls, triple trawls, or multiple trawls
5. Research on groundgear is often related to the bottom handling capability of the gear, catch efficiency and the selectivity on bottom-dwelling species
6. More recently, some research has focussed on energy efficiency and seabed friendliness
7. Historically, comparative fishing trials are carried out to compare catch (efficiency and selectivity) and robustness
8. Optical methods are used to document fish reactions to different groundgears, and their escape under the groundgear
9. Flume tank tests and numerical simulations are used to understand drag forces of different groundgears and their effect on trawl geometry. Numerical tools are also used to examine the flow pattern and the force of the groundgear on the sediments

It was agreed that the topic group would continue for one more year with a short session/meeting during the 2020 meeting. The topic group would report this year with conclusions, but no recommendations. During the next year, the topic group will table recommendations for discussion and approval by the topic group and the entire WGFTFB.

6.3 Justification

With uncertainties around the use of groundgear in bottom trawling and its impact on bottom fauna, it is important to review the current status of the design and use of groundgear in various fisheries and to propose new investigations that will contribute to more environmentally-friendly fishing gears. Continuous contact between gear and seabed during bottom trawling is believed to be of importance for efficient harvesting in many ground fish fisheries, but in some bottom trawls, total weight of the trawl may be out of proportions for the purpose. High fuel consumption in trawl fisheries is often associated with heavy groundgear being dragged along the seabed. Recent research and practices in the North Pacific and Northwest Atlantic bottom trawl fisheries indicate that ground-contacting components including groundgear can be modified with no or little impact on the catch of target species. In the Northeast Atlantic, bottom trawling is often performed in areas of important fisheries for king crab and the rapid growing snow crab fishery, with unknown impact on these crab stocks. As crab fisheries increase in intensity, more gears will be damaged and lost due to collisions between trawl and crab-pot fisheries. Alternative and lighter ground gears have been tested, but it is unclear if they are efficient for retaining target species and not increasing the catch of unwanted bycatch compared to conventional configurations. Discussion and summary of current knowledge and possible future development of bottom trawl gear or its alternatives for harvesting traditional groundfish species.

6.4 Revised terms of reference

Through extensive deliberations at the Hirtshals meeting, the topic group members revised the terms of references so that they are more specific and achievable. The revised terms of references are:

- Creating a collection with example-factsheets of selected/commonly used types of bottom-trawl groundgear.
- Discussing and describing methods to reduce bottom contact and fuel use.
- Discussing and providing examples on the effect of trawl groundgear on the efficiency and selectivity for target and bycatch species.
- Making recommendations on future experimental and theoretical work to understand and improve the function of groundgear of bottom trawls.
- Discussing implications (trade-offs and legislation requirements) regarding the design and operation of groundgear with less effect on seabed and greenhouse gas emission contributing to the development of best practices of bottom trawling.

N.B. Go to annex 4 for full report from this Topic Group (pages 227 to 332).

7 TOPIC GROUP: Factsheets on fishing gear selectivity and catch comparison trials (Facts)

A WGFTFB topic group convened by Barry O'Neill (Denmark) and Jordan Feekings (Denmark) was formed during the 2018 WG meeting in Hirtshals, Denmark to develop a series of factsheets on fishing gear selectivity and catch comparison trials. The two convenors were unable to attend the WGFTFB meeting in 2019 and worked remotely in advance of the meeting with the topic group participants to prepare factsheets.

7.1 The Terms of Reference:

1) to review the different types of fishing gear related factsheets that have been produced and explore the possible solutions that would be appropriate to fishing gear selectivity and catch comparison trials

2) to agree on the content and on a common format and to decide what information is required to produce the factsheets. Specific consideration will be given to how these issues will affect (i) the ease with which the factsheets can be formulated and (ii) their accessibility and usefulness.

3) to produce, on an annual basis, factsheets on fishing gear selectivity and catch comparison trials, from a range of fisheries.

4) to identify the best means to disseminate and store the factsheets to ensure that they are easily accessible, both now and in future, by the fishing industry, netmakers and all relevant stakeholders.

7.2 Justification:

Many trials have taken place of novel and modified fishing gears to improve selectivity and to reduce discarding. Very often, however fishers, skippers, netmakers and fisheries managers are unaware of these developments. As a result, potential solutions to problems faced in particular fisheries may go un-noticed or resources may be wasted on trials of gears that have already be shown to be ineffective. One way of disseminating this type of information is through accessible and easy-to interpret factsheets. The EU funded Horizon 2020 project DISCARDLESS has assembled a catalogue of nearly 70 factsheets, each of which describes the results of individual selectivity and catch comparison trials (http://www.discardless.eu/selectivity_manual). A new project, 'Gearing Up', aims to provide a platform to access existing information on gear selectivity experiments. Here we would like to further develop these types of approaches, paying particular attention to disseminating information in an accessible and easy-to interpret format and circulating it as widely as possible to fishers, netmakers and all relevant stakeholders. The ICES – FAO WGFTFB has a global membership and perspective and thus is ideally placed to both gather and disseminate this type of information. It also has the technological expertise to ensure that the factsheets address bycatch and discard issues that are being faced by the fishing industry.

At the meeting in Hirtshals in 2018, the WGFTFB recommended that prior to the 2019 WGFTFB meeting in Shanghai, China:

- A template will be circulated with guidelines on content, design, style and format;
- Members will be encouraged to produce factsheets on fishing gear selectivity and catch comparison trials and on the development of technologies and techniques that address bycatch and discard issues including those that improve discard survival;
- Members will submit their factsheets along with their national reports.

And that during the WGFTFB meeting:

- The topic group meet to review and edit the submitted factsheets;
- Make recommendations on the guidelines, design, style and format of the factsheets;
- Make recommendations on medium to long-term storage of the factsheets.

7.3 Activities in preparation and during the 2019 meeting:

As mentioned above, neither of the two convenors were able to attend the WGFTFB meeting in 2019 and decided to carry out as many of these activities as possible remotely in advance of the meeting. During March an email was sent to the working group members encouraging them to produce factsheets on fishing gear trials and on the development of technologies and techniques that address bycatch and discard issues including those that improve discard survival.

A template factsheet in the form of a one-page powerpoint document was also circulated, providing an outline of the design, style and format of the factsheets as follows:

(i) One side of an A4 page,

(ii) A title over two lines that specifies the gear or trials (on the first line) and what it intends to do (on the second line)

(iii) A double column format with sections entitled Aim, Target species, Gear trials, Results in (in boxes with a blue background)

(iv) two or three figures helping to describe the trials or gear modifications and a graph or table helping explain the results.

(v) a logo of the institute/organisation who carried out or funded the trials and a contact name, email, report or website where further information can be found

As we want the target audience to be as broad as possible, we suggested it would be better to avoid presenting results in terms of selectivity or catch comparison curves, or to use terms such as L50 or selection range, which can be difficult to interpret if you are not familiar with them. A more intuitive and possibly more informative way is to present proportional change caught of the species of interest, or perhaps a measure of the reduction of discards, etc. We also stressed, however, that these are just general guidelines and certainly would not suit every case. Further as the rationale for the factsheets is to raise awareness of what work has been done, it is more important to do this than to be inhibited by any particular format or approach.

Twenty factsheets were prepared. These are mostly on gear selectivity and catch comparison trials but there are also some on laboratory experiments and technological developments. These are included in Annex 5 and will be uploaded with the factsheets that are on the EU project Discardless' website (http://www.discardless.eu/selectivity_manual).

A short presentation was prepared and presented to the WGFTFB by the WG chair and questioned whether the working group wants to continue producing factsheets? Does it consider them useful? Are they a good way of publicising and disseminating our work?

If the working group thinks the factsheets should continue, a further series of questions need to be addressed. Do we have the correct format? Do we expand their scope? (not just gear trials, but laboratory experiments, technological developments, etc) should we have a review/ranking process? Do we translate to other languages? How we address longer term storage issues? Should we incorporate them into national reports? Do we need a rolling term of reference to produce factsheets?

7.4 Recommendations for 2020:

That WG members prepare factsheets in advance of next years meeting.

That the topic group meet during next years meeting to edit and produce factsheets.

That the Working Group decides in plenary whether it wants to continue producing factsheets.

Participants:

Name	Institute	Email
Barry O'Neill (convenor)	DTU Aqua, Denmark	barone@aqua.dtu.dk
Jordan Feekings (converor)	DTU Aqua, Denmark	jpfe@aqua.dtu.dk
Emma MacKenzie	MSS, Scotland	emma.mackenzie@gov.scot
Luis Arregi	AZTI, Basque Country	larregi@azti.es
Mikel Basterretxea	AZTI, Basque Country	mbasterretxea@azti.es
Elsa Cuende	AZTI, Basque Country	ecuende@azti.es
Maria Tenningen	IMR, Norway	maria.tenningen@hi.no
Rikke Frandsen	DTU Aqua, Denmark	rif@aqua.dtu.dk
Valentina Melli	DTU Aqua, Denmark	vmel@aqua.dtu.dk

8 NATIONAL REPORTS

8.1 Introduction

Prior to the annual meeting member nations and participating countries are requested to send in a national report. National reports are structured to give an overview over current and planned activities in the institutes and organizations of the county that are active in research in fishing gear and fish behavior. The reports are presented in summary at the meeting and published thereafter here. They are an important tool to stimulate collaborative research by highlighting research themes and ideas that other countries might also benefit from. Countries are free to choose the contents and extend of the report. As such they provide a snapshot of each country's activity over the previous year but do not necessarily reflect the views and consensus of the FTFB working group.

For the 2019 conference in Shanghai, 17 reports were received. Of those 14 were by member countries and 4 by participating nonmember countries.

In the following section, the national reports are published as submitted.

8.2 Belgium

ILVO – Institute for Agricultural and Fisheries Research
Contact person: Mattias van Opstal, Mattias.VanOpstal@ilvo.vlaanderen.be

Summary

- Combituig: Little initiative from sector, 1 test with spoilers running.
- Selectivity brown shrimp monitoring: 1 year of reference measurements completed
- NIKO II: succesfull tests with 85 mm square mesh escape panel in flyshoot net to get rid of (undersized) whiting without losing squid and large mullets.
- eBRP: Last trials finished: 200 mm eBRP retains all marketable sole while losing significant amounts of undersized sole, benthos and debris.
- Sorting machine Urk: Reference measurements done with old machine. Waiting for upgrade of sorting machine to examine the increase in effectivity.
- Mavitrans: Realization of market recognized auction clock, supporting vessel owners in their fisheries improvement plan.
- VISTools: Achieving automatic data gathering on board of fishing vessels.
- SUMARIS: First seatrips, optimization of housing conditions ray and protocols
- Benthis National: project proposal & approval.

Projects

Combituig ('Technical innovations in beam trawling to reduce bycatch and improve survival.')

Contact person: mattias.vanopstal@ilvo.vlaanderen.be, Els.vanderperren@ilvo.vlaanderen.be

April 2017 – march 2019

The introduction of the landing obligation poses a major challenge for the Belgian fishing sector, since it mainly practices mixed beam trawling. In order to assist the sector in dealing with the landing obligation, ILVO and Rederscentrale intend to reduce the catch of choke species and other bycatch in beam trawling and improve survival in the Combituig project through the development and refinement of technical innovations.

In this project innovations are tested to reduce choke species and other bycatch species in the net. It is also aimed to improve the selectivity of the net through the use of panels, different net materials and mesh sizes and shapes. The project tests what adaptations have an influence on the survival of the catch. The effects of the volume caught, the haul duration, organization on deck are be examined. In the first year of the project, lights, laserbeams, benthic release panels, whirl-spoilers, and larger cod end mesh-sizes were tested in lab conditions and/or during sea trials on commercial and research vessels. Evaluation on commercial vessels is done by means of self-sampling by the crew, followed by an extensive catch analysis by ILVO.

The project aims at intensive communication with and strong participation of the sector. All findings and results will be communicated with and to the rest of the sector through the intensification of the "Innovating Fishing" Knowledge meetings and consultation and planning moments with interested fishermen, shipowners and the Rederscentrale.

Selectivity of pulse trawling on brown shrimp

Contact person baseline measurements 2018: josien.steenbergen@wur.nl & jimmy.vanrijn@wur.nl

Contact person innovation experiments 2019: Maarten.soetaert@ilvo.vlaanderen.be, mattias.vanopstal@ilvo.vlaanderen.be

Duration: 2018 - 2019

Project partners : WMR (NL), ILVO (BE) and Thunen Institut (GE)

This EFMZV project was started with the specific aim to assess the differences in impact of pulse trawling on brown shrimp compared to the traditional beam trawl in N2000 areas. All five pulse trawlers on shrimp (HA31, ST24, TH10, WR40 and WR109) were involved, although the WR109 served as reference vessel since he had too much technical problems with his (new developed) pulse gear.

During the first year of the project, so called '0-measurements' were done, in which the catches of the pulse trawlers were compared to their traditional fishing colleagues. This was done in three ways.

First, there was a continuous data recording in which the skipper determined the total catch volumes based on the height of the catch in the hopper as well as the commercial catches of shrimp. This was done for every haul, including the time and location. The data of the pulsetrawler fishing with 2 pulse trawls was compared with that of a buddy, fishing with 2 traditional trawls.

Next, the pulse trawl was obliged to switch 1 pulse gear for a traditional trawl, allowing for a direct catch comparison several weeks per quarter. During this period, 'selfsampling' was done during several weeks every quarter during which the vessels were fishing with a traditional gear at one side of the vessel and a pulse trawl at the other. During these trips, catch volumes and commercial catches were logged again from both sides (pulse & traditional) and samples of both catches were collected which were sorted and analyzed in the lab. Last, observertrips were carried out in junction with the selfsample trips during which an on board catch comparison was done between the pulse gear and the traditional gear.

This approached guaranteed a continuous monitoring on haul-level combined with a detailed catch comparison with selfsampling or observertrips once every quarter for every vessel. This way, an good spatial and temporal distribution of the data is obtained.

In 2019, the second year of the project, a similar approach will be used to do 'innovation experiments' during which fishermen will be allowed to make adaptations to their net, electrodes or to some extend pulse settings in order to optimize the selectivity of their gear. Therefore, fishermen will keep 1 pulse trawl unchanged (identical configuration as defined within the technical limitations and used for the base line measurements in 2018) while testing their innovation in the other trawl. To compare both gears, selfrecording will be done by the vessel comparing his both catches, and observertrips will be done for an in-depth analysis of the catches once the fishermen have indicated that they have optimized their adaptation.

Net innovation trawlers II ('NIKO II')

Contact beamtrawl plaice & nephrops: Pieke.molenaar@wur.nl

Contact beamtrawl sole & Flyshoot: Maarten.soetaert@ilvo.vlaanderen.be

Duration: Q4 2016 - Q1 2019

This project supports fishermen with specific ideas to improve the selectivity of their gear and reduce bycatch. Workshops or meetings were held at the start of the project to facilitate new ideas and motivate fishermen to take initiative in the practical implementation. Fishermen first optimize their innovation and do a first check of the impact by doing self-sampling which is, in case of success, followed by observertrips. Little progress was made in the sole (*Solea solea*) fishery in 2019. The work on flyshooting focussed on the reduction of whiting discards, a possible choke species. Therefore camerawork was done to get an insight in the target species behaviour with & without an square meshed escape window and with & without additional mechanical or visual stimuli. A catch analysis was also done to assess the proportion of (undersized) whiting and other species escaping through the panel.

Sorting machine for fish @ Fish auction Urk

Contact: heleen.lenoir@ilvo.vlaanderen.be

Duration: 2018-2019

Fish auction Urk has developed an innovative automatic sorting line for flatfish. The advantages of the machine are that sorting is faster and qualitatively better. Because the fish is sorted more quickly, the time that the fish is not cooled reduces which improves the quality of the fish. Two years ago the new sorting machine was taken into use for the sorting of plaice.

The processing speed of the sorting machine is not yet optimal at the moment. The machine should achieve a processing capacity of 60 tons per hour, in practice it now appears to be a maximum of 30 tons per hour. This creates long waiting times at peak times and the intended cost savings and improved efficiency are not achieved. This is caused by the fact that the removal of the ice takes up to much time. As a result, only a limited amount of fish per hour can enter the sorting process. Both the supply and removal end of the sorting line require new technical innovations, with which the requested capacity can be achieved. The cold chain is interrupted during the sorting process. For the quality of the fish, it is extremely important to bring the fish back into the tubs as quickly as possible after being sorted.

Together with a machine factory, new technical solutions are being developed to double the processing capacity. This is carried out under the watchful eye of the producer organization (PO) Urk. PO Urk represents the suppliers (shipowners) and oversees the quality assurance of the sorted fish in this project.

The Institute for Agricultural, Fisheries and Food Research (ILVO) is actively involved in this project as a scientific organization and ensures the scientific foundation of the results. ILVO will carry out various efficiency measurements in this project. This involves both the amount of fish per hour processed by the sorting machine and the quality of the flatfish to be sorted. The time needed for the fish to go through the sorting process and the temperature of the fish through this process are the most important parameters for maintaining fish quality.

eBRP (‘Development path for the Electrified Benthos Release Panel’)

Contact: Maarten.soetaert@ilvo.vlaanderen.be, Heleen.Lenoir@ilvo.vlaanderen.be,

Duration: 2014 – 2018

Benthos release panels (BRPs) are known for their capacity to release large amounts of unwanted benthos and debris. Additionally, they are also more selective hence catching less undersized fish. However, until now, unacceptable commercial losses of sole (*Solea solea* L.) was hampering a successful introduction in commercial beam-trawl fisheries. To eliminate this drawbacks, two approaches were tested. First, the BRP was rigged differently to prevent slack. Second, the minimal electrical stimulus to immobilize Dover sole was determined in the lab with the idea of preventing the fish to dive and escape through the panel. Afterwards, a pulse module was developed to generate a small electric field in the aft end of the net above the BRP and the effect on the selectivity of square meshed with different mesh sizes (200, and 240mm) was determined. Our results indicate the loss of sole is eliminated in a well stretched 150 mm BRP or a well stretched 200 mm electrified 200 mm electrified BRP (eBRP) while releasing in average about half of the benthos and debris caught, which should lead to a better fish quality and discard survival.

Mavitrans (Market recognition for a Belgian fishery in transition)

Contact: lancelot.blondeel@ilvo.vlaanderen.be, ellen.pecceu@ilvo.vlaanderen.be

Duration: 2017-2019

The Belgian fishing fleet, mainly composed of demersal beam trawlers, has faced numerous challenges in the past decade (high fuel prices, additional rules and regulations, outflux of crew…). Consequently, the number of fishing enterprises decreased considerably. Due to the nature of the fishery, fishers could not get MSC certified unless they made drastic adjustments. As a result, all the main stakeholders agreed on the need to assess and monitor the sustainability of the Belgian fishery and to set targets to become a sustainable fishery by 2020.

To meet these challenges, Belgian stakeholders decided to develop a sustainability assessment tool called VALDUVIS which utilises 11 indicators to monitor the social, economic and ecologic progress of the Belgian fleet. A participatory approach involving fishers and their representatives, government officials, NGOs, fish auctions, distributors, processors, retailers and researchers remained a strong focal point throughout the process. The VALDUVIS tool formed the basis for the introduction of a fisheries improvement program and a market recognition that communicates efforts made by fishers to buyers at the auction. The initial entry criteria into the program were set at an approachable level to ensure participation of the entire fishing sector. The aim has been to apply a step-by-step approach with progressively increasing thresholds for participation and to gradually convince and prepare fishers to change their current practices. This would enable the entire fleet to evolve into a more sustainable direction that would benefit everyone in the long-term. The main challenge now is to keep the fishers motivated to continuously improve their sustainability and to stay in the fisheries improvement program. This project is funded by the European Maritime and Fisheries Fund (EMFF).

VISTools : Fishing vessels as automatic data-gathering platforms

Contact: *lancelot.blondeel@ilvo.vlaanderen.be*

Duration: Oct 2018- Dec 2020

A skipper of a fishing vessel has access to a lot of information that helps him to manage his work. Sensors track the location (GPS), monitor the fishing activity (towing force, depth), fuel use and register the catch (electronic scale). These sensors gather valuable data, but none if it is integrated, stored or processed.

By automating data-gathering from conventional onboard sensory equipment, the VISTools-project aims to (1) develop a business intelligence tool for fishers and (2) evaluate the possibility of sharing this information for scientific purposes. With this approach, we hope fishers gain more insight in their daily practices. This could trigger small behavioral changes that increase the efficiency of the vessel and simultaneously reduce the impact on the environment. Additionally, the information could be an opportunity for scientists to better follow the activities of the fleet. This data could open new research possibilities including catch prediction models, avoidance of bycatch and sensitive areas, and real time closures. This high resolution information can also lead to better advice to fisheries management and governmental bodies. This project is funded by the European Maritime and Fisheries Fund (EMFF).

Benthis-nationaal
('National application of the Benthis assessment framework, related to ICES WGFBIT')

Contact: Gert.VanHoey@ilvo.vlaanderen.be, Jochen.Depestele@ilvo.vlaanderen.be

Duration: 2018 – 2020

The European project 'Benthis' (Benthic Ecosystem Fisheries Impact Study, EU-FP7) was recently finalized and has proposed a method to (1) map the extent, distribution and frequency of physical disturbance by bottom fishing and (2) assess the degree of adverse effects on seabed habitats. In June 2017 ICES provided advice on EU request that this method or any of its variants will be utilized to set the standards for assessing fisheries effects on seafloor integrity, and thus in assessments feeding into the Natura2000 process as well as MSFD Descriptor 6.

The method was developed for generic gear groups, like 'demersal otter trawls', 'beam trawls', 'seines' and 'dredges'. The Project 'benthis-nationaal' will fine-tune the generic 'Benthis' model to regional and local conditions by developing a fine-scale gear-footprint model of various types of mobile bottom contacting gears which are relevant for the Belgian fishery. We will also assess how these fisheries impacts can be better evaluated by improving the different indicator approaches and applying them to local conditions in the benthic ecosystems of Belgium. These developments will be financially supported using the European Maritime and Fisheries Fund (EMFF).

SUMARiS Work Package 2: survival rate tests with skates

Contact: noemi.vanbogaert@ilvo.vlaanderen.be

Duration: June 2017 – June 2020

Project partners: Rederscentrale (BE), KEIFCA (UK), FromNord (FR), Nausicaa (FR), IFREMER (FR)

Observers: CEFAS (UK), VisNed (NL), Aquimer (FR)

One of the main aims of the INTERREG – 2 Seas project "SUMARiS" (Sustainable Management of rays and skates) is to quantify vitality, injury and survival rates of four different skate species (thornback ray - *Raja clavata*, spotted ray - *Raja montagui*, undulate ray - *Raja undulata* and blonde ray - *Raja brachyura*) discarded by English Channel and North Sea active and passive gear fisheries. During seatrips on-board of Belgian commercial beam-and ottertrawlers, skates were randomly selected from the catch and evaluated for vitality, reflex responsiveness and extent of injury using the Reflex Action Mortality Predictor (RAMP) method. A selection of these sampled rays was monitored ex situ for a three week monitoring period. During this period, survival and health parameters were monitored, such as weight development, spiracle opening rate per minute, swimming and burying behaviour, etc. So far, a total of 493 individuals belonging to four different species were scored during three Belgian commercial seatrips. Forty percent scored "excellent" (vitality class A), 32% of the individuals as "good/fair" (vitality class B), 24% as "poor" (vitality class C) and 4% were scored "dead" (vitality class D). Immediate (at-vessel) mortality ranged between 0 and 9%, while average delayed mortality (after three weeks) was much higher, namely 50%.

The immediate and delayed mortality percentages which have been calculated are in line with previous survival research which showed that immediate mortality was generally lower than delayed mortality. Hence, our first results show that a sufficiently long monitoring period is necessary to allow the delayed mortality to asymptote. Further analysis of the data will show the effects of different environmental, technical and biological factors on both types of mortality using modelling in R statistical software. The outcomes of this work will deliver important insights for (inter)national decision makers and fishery managers on whether an exemption on the landing obligation should be granted for these skate species.

8.3 Canada

Fisheries and Marine Institute

T90 Codends for Redfish

Contact Person: Paul Winger, Paul.Winger@mi.mun.ca

April 2017 – March 2020

In partnership with colleagues in Iceland and USA, we are currently evaluating the engineering and catching performance of T90 mesh for redfish (*Sebastes* spp.) in eastern Canada. Flume tank observations are being conducted to evaluate water flow, mesh opening, and codend dynamics under different loading scenarios. Sea trials are planned for summer of 2019.

Helical Rope

Contact Person: Gebre Kebede, Gebre.Kebede@mi.mun.ca

Feb 2018 – Feb 2019

In partnership with Hampidjan Iceland and the Marine and Freshwater Research Institute, we are currently evaluating the "science" of self-spreading ropes. Flume tank experiments were recently conducted to compare the hydrodynamic coefficients of self-spreading and conventional ropes made up of twisted and braided PA and PE materials. Follow-up experiments are currently underway to examine whether helical ropes also exhibit reduced vibration.

Shaking Codend

Contact Person: Shannon Bayse, Shanon.Bayse@mi.mun.ca

Feb 2019 – March 2020

This project investigates the potential for shaking codend technology (Kim, 2013, 2015) for potential use in redfish fisheries in eastern Canada. Initial flume tank experiments have been encouraging. Field trials are planned for summer 2019.

LED Lights – Snow Crab Pots

Contact Person: Paul Winger, Paul.Winger@mi.mun.ca

Jan 2016 – Dec 2019

In partnership with the Institute for Marine Research (IMR) and Fisheries and Oceans Canada, this project is investigating the potential benefits of using artificial light in snow crab traps to enhance CPUE. Laboratory experiments were completed to investigate the behaviour of snow crab toward various colours of lights. Subsequent sea trials demonstrated that that CPUE could be enhanced by as much as 40-70% using small low-powered LED lights, depending on the colour and soak time utilized.

Glow in the Dark Netting – Snow Crab Pots

Contact Person: Paul Winger, Paul.Winger@mi.mun.ca

April 2017 – Dec 2019

In partnership with the Institute for Marine Research (IMR) and NOFIMA, we recently evaluated the performance snow crab pots constructed with glow in the dark netting. Preliminary benchtop experiments suggest the glow lasts ~2 hours (visible to the human eye) but >9 hours (visible with low light cameras). Comparative fishing experiments were conducted in 2018 on the south coast of Newfoundland, Canada. Preliminary results suggest CPUE could be enhanced (~55%) during short soak times, while longer soak times exhibited no difference compared to conventional pots.

Merinov - Centre d'Innovation de l'Aquaculture et des Pêches du Québec

Redfish Trawl Development

Contact Person: Damien Grelon, Damien.grelon@merinov.ca
The main objective of this project is to develop a semi-pelagic trawl, followed by a pelagic trawl, for the reopening of the redfish fishery in the Gulf of St-Lawrence, in order to exclude redfish juvenile and bycatch species, with the lowest possible contact of the trawl with the seafloor. Different grid systems and mesh sizes and orientations will be tested in the codend.

Documenting Different Tools to Evaluate the Bottom Contact of Different Redfish Trawls

Contact Person : Marie-Claude Côté-Laurin, marie-claude.cote-laurin@merinov.ca
This project will document different technologies and direct or indirect indicators that could be useful to evaluate the presence/absence and if possible the degree of bottom contact of the three types of trawls that might be authorized in the redfish fishery (bottom, semi-pelagic, pelagic trawls). The different indicators will be tested onboard commercial redfish trawls. The information gathered is aimed to help fishermen in using different tools to follow and control their trawls during fishing activities according to the regulations, and to provide DFO with some estimates of the impacts of the trawls on the bottom and benthic communities in order to improve decision-making.

LED Lights: Snow Crab Pot in Québec North Shore

Contact Person: Thomas St-Cyr Leroux, Thomas.st-cyr-leroux@merinov.ca
A small project was undertaken to test the efficiency of low-powered LED lights (Lindgren-Pitman) in baited traps targeting snow crab. The project was conducted under commercial fishing conditions on the north shore of the Saint-Laurence River with the help of the Office des pêcheurs de crabe des neiges zone 16. The result showed a little augmentation of the CPUE when combining normal bait and white bait light without being statistically significant.

Improving Fishing Yields for Common Crab and Spider Crab Traps

Contact Person: Lise Chevarie, lise.chevarie@merinov.ca
These two relatively recent fisheries in Quebec require some improvements to increase trap performance. For crab, the incidental catch of lobsters in traps, a predatory species, is detrimental to the capture of crab. A selectivity device will be tested at the entrance to the traps. This should allow entry by crabs but not lobsters. In the case of the spider crab, the fishermen use different types of traps that initially served for other species and which perform more or less well. It is therefore a question of experimenting with different forms of traps and trying to maximize their performance and thus obtain a more satisfactory catch rate. Underwater camera observations are now completed and analysis of the video is underway.

Smart Gear: Turbot Gillnet Innovation

Contact Person: Thomas St-Cyr Leroux, Thomas.st-cyr-leroux@merinov.ca

This two-year project aims to reduce by-catch in the commercial monofilament gillnet fishery, including the threat to 12 endangered, endangered and threatened species (and 11 additional species assessed by COSEWIC). It also aims at making modifications to the fishing gear in relation to the requirements of the MSC certifications envisaged for these fisheries and thus to improve the quality of the fish caught for marketing purposes.

Safety Design Criteria Onboard Lobster Boats in Quebec

Contact Person: Francis Coulombe, francis.coulombe@merinov.ca

Since 2012, an important research program concerning lobster boat crew safety was undertaken in the Quebec Gaspe Peninsula and Magdalen Islands fisheries. In cooperation with Laval University ergonomists, we analyzed the risks and determined factors involved in overboard falls; we documented collective and individual prevention solutions that can be adapted to lobster boats; and we identified, with the most promising risk reduction scenarios. In 2015, we developed, tested at-sea, and implemented practical integrated technical solutions for the pot hauler and the supporting fishing lines rack. Both of these are most used by crewmen for easing their work. Attention has been paid to reduce ropes entanglement risks and body efforts when hauling and launching the fishing gear. Results are currently under analysis.

Entanglements of Right Whales – Weak Links for Snow Crabs Fisheries

Contact Person: Jerome Laurent, Jerome.laurent@merinov.ca

This feasibility study aims to measure tensions in the vertical ropes of snow crab traps, in all fishing situations encountered by fishermen in the Gulf of St. Lawrence. The data collected will be used to determine the minimal breaking load of the rope for a use without risk of trap loss. Other mounting configurations of the fishing gear will be tested to try to decrease the tension in the vertical rope. These data will be compared with theoretical tensions that a right whale would impose on the rope in its efforts to become disentangled. In case of compatibility between the data, the next step will be to size and configure a weak link system and carry out sea trials in fishing situations.

Fisheries and Oceans Canada

Monitoring Survey Trawl Performance

Contact Person: Truong Nguyen, Truong.Nguyen@dfo-mpo.gc.ca

We have developed and implemented a new scanmar logger program to show in realtime trawl performance. This feature is important for helping our scientific staff determine if the performance parameters are within specified standards in real time. The new developed program is also able to capture all streaming data from all scanmar sensors and other applicable shipboard instruments.

Toggle Chain Adjustment

Contact Person: Truong Nguyen, Truong.Nguyen@dfo-mpo.gc.ca

We made changes to the way the toggle chains are rigged on the Campelen 1800 survey trawl to make it easy to attach and disconnect the footgear from the trawl for repairs. We used a combination of two rings and quick links rather than the traditional bobbin chain comprised of a piece of chain and two rings wrapped around the fishing line and travel chain on footgear. For consistency, we kept the lengths of both bobbin chain riggings the same, i.e., there is no difference in distance between fishing line and footrope. This rigging change will save a lot of time when changing footgear or nets at sea. We tested this rigging out on the fall survey trip aboard the CCGS A. Needler. We analyzed the trawl sensor data and found no changes in trawl performance (trawl geometry) with this new gear modification compared to the old rigging and are confident that there was no change in catchability of the survey trawl thus preserving time series of catch data. Given this promising result, we plan to apply this modification to the CCGS Teleost trawls for the 2019 fall survey.

Updating Survey Trawl Manual

Contact Person: Truong Nguyen, Truong.Nguyen@dfo-mpo.gc.ca

We are conducting a review for our 2009 survey trawl operation manual as it is considered as a living document and requires periodical updates.

University of Prince Edward Island

Catching Invasive European Green Crab with Fyke Nets

Contact Person: Pedro Quijón, pquijon@upei.ca

The European green crab has successfully invaded the east coast of Canada and is disrupting commercial lobster fisheries. A directed fishery to control the spread the species has been implemented in various regions, however minimizing the bycatch on non-targeted species is important.

We developed and tested a novel barricade to encourage American eel and winter flounder to swim up and over the entrance of the fyke net. Bycatch counts were 4.4 times lower in the experimental net. See recent manuscript in Fish Res. for more information. See recent manuscript: DOI 10.1016/j.fishres.2018.02.018

8.4 Denmark

Real-time observation and decision making in trawls (Smartfish H2020 and TechnoFish)

Contact: Ludvig A. Krag (lak@aqua.dtu.dk), Barry O'Neill (barone@aqua.dtu.dk)

2018 - 2021

In the EU funded SMARTFISH 2020 project DTU are leading 3 work packages on "Real time monitoring and analysis of the biomass entering the fishing gear during trawling" and "Development of Smart Gear Systems that affect fish retention in towed fishing gears" and "Test and demonstration of the developed technologies".

One of the aims is to develop real-time observations (video, time-of-flight laser camera and low frequency sonar) systems to observe species and sizes that is entering the trawl during the entire fishing process. A cable based real-time observation system is developed and is mounted onboard DTUs research vessel and in the nationally funded TechnoFish project on a commercial trawler to accelerate the development. Advanced image analysis and machine learning is used on the video recordings to extract the catch composition (species and sizes) in real time. The work is a collaboration between MARPORT, SINTEF Digital, Marine Scotland and DTU Aqua.

Another aim to provide fishing skippers with the technologies that will allow the modification of the fishing gear during the fishing operation. In collaboration with Marine Scotland Science, Safety Net Technologies and Marport, we are developing LED technology that will allow the light settings to be modified during a tow and a catch control system to control the capture process. This will help to optimize the catching performance of trawl fishing gears and to maximize the quality and economic value of the catch.

FLEXSELECT: counter-herding devices to prevent the catch of fish in the *Nephrops*-directed trawl fishery

Contact: Jordan P. Feekings, jpfe@aqua.dtu.dk, Valentina Melli, vmel@aqua.dtu.dk

2017 - ongoing

The *Nephrops* (*Nephrops norvegicus*) directed mixed trawl fishery in the northeast Atlantic has globally one of the highest bycatch rates and is likely to be affected by the landing obligation introduced by the new EU Common Fisheries Policy. Commercial-sized fish are generally wanted bycatches but, depending on the vessel's quota availability, exhaustion of fish quotas can prevent the fishermen from exploiting the main target species, *Nephrops*. Therefore, fishermen have an increased interest in adopting flexible gear modifications that can adjust the trawl's selectivity at the haul level. In this project, we are developing and testing simple counter-herding devices which aim at reducing the bycatch of fish by scaring them away from the trawl path, without affecting the catches of the target crustacean. We are studying the efficiency of these devices using a paired gear catch comparison methods, and using different materials and configurations to generate the counter-herding response. These devices have so far proved very efficient in reducing fish catches, and as it is an anterior gear modification, it has the advantage of: (i) preventing fish from interacting with the trawl, thus most likely enhancing their survival and fitness, and (ii) not requiring major changes to the trawl geometry and fishing dynamics.

Fast-Track II – Sustainable, cost effective and flexible gear solutions under a landing obligation

Contact person: Jordan Feekings, jpfe@aqua.dtu.dk

2018 - ongoing

The project is a continuation of the Fast-Track project, which has already been running since 2015. The project aims to continue the collaboration with stakeholders (fishers, net makers, producer organisations, managers and scientists) pertaining to the development of ideas and technical solutions originating from the industry. Furthermore, effort is being devoted toward creating regional and international networks that ensure the knowledge about selective devices in specific fisheries is shared, and that there is a broad acceptance of the results obtained. In addition, fisheries and gear-specific workshops will be organized with the participation of international experts who provide knowledge of selective gears from comparable fisheries.

With the reform of the EU Common Fisheries Policy and the introduction of a Landing Obligation the ability of fishers to adjust the selectivity of their gears to suit the quotas which are available to them will be an important factor in determining the revenue and rentability in the fishery. As the combination of gear, fishing practice and quota shares will differ between vessels, changes to the selectivity of the gears will need to be implemented at the vessel level and based on the quotas which are available to the vessel at a given time. For this to be realised, simple and cost effective solutions which can be quickly coupled with existing gears will be in demand.

These solutions will need to be implemented quickly in order for them to solve the issues at hand without losing substantial income. Furthermore, these solutions will need to be scientifically tested to document their effect before being considered for implementation into the legislation.

A description of the project as well as the work being carried out in the project can be found on the project home page: www.fast-track.dk

Seal-safe fishery

Contact: Lotte Kindt-Larsen, lol@aqua.dtu.dk

2017 - ongoing

Aim of the project is to develop innovative fishing gears, which can serve as alternatives to longlines and set nets in areas where well developed seal populations cause damages to the catch of such passive gears. Potential alternatives should therefore be able to be operated from smaller vessels used in the longline and set net fisheries. Additionally to seal-scaring devices, a pontoon trap and a mini Danish seine constitute candidates that are tested within the project, whereby the gear technology group is mainly involved in the development and testing of the mini seine. The experimental testing period of this new fishing gear consists of a phase of adjusting it in order to maximize efficiency and a following catch comparison between mini seine and set net as original gear. Parameters to be looked at here are the handling, the catch efficiency, the catch quality and the resulting final income for the fishermen. Additional ecological advantages of the gear over the set net are the expected less catches of species protected under the EU Habitats Directive (Directive 92/43/EEC) and the bird directive (Council Directive 2009/147/EC) like harbor porpoise (*Phocoena phocoena*) or different sea birds, and the reduced risk of ghost nets in the area.

Discard survival in relation to the landing obligation under the new European Common Fisheries Policy

Contact: Junita D. Karlsen, jka@aqua.dtu.dk

Dec. 2016 – Dec. 2018

One of the main aims of the COPE-project was to create a catalogue of survival rates of commercial flatfish species subject to the landing obligation, based on information provided by the scientific literature and the amount of landings, discards and raised discard ratios in Danish waters. Another main aim was to conduct new assessments of European plaice (*Pleuronectes platessa*) for the Danish seine and trawl fisheries in Skagerrak. For the trawl fishery, these assessments further investigate potential effects of season, target species (i.e. plaice or *Nephrops*) and gear modifications. In addition, the data gathered within these experiments was used to investigate if vitality could be used as proxies for survival rates, which would allow to provide survival estimates for a range of fishing practices within the fleet (e.g. using self-sampling by the fishermen).

Based on the estimated survival rates, the exemptions from the EU landing obligation was given for the Danish seiner fishery and the winter season of the trawl fishery for the fleet using ≥120 mm for ICES division 3a (Skagerrak/Kattegat) and subarea 4 (North Sea).

The response of fishes to artificial light and how to use light stimuli to guide fish for species separation in the trawl fisheries

Contact: Junita D. Karlsen (jka@aqua.dtu.dk)

Successful separation of fish and organisms with hard and spiny outer surfaces can provide differentiated size selection in upper and lower compartments while retaining valuable catch as well as improve the quality of both fish and Nephrops. The project VISION explores ways of increasing the proportion of fish entering the upper compartment without compromising the catch of Nephrops. The responses of important Danish commercial species to different light characteristics are largely unknown. The responses of cod (*Gadus morhua*) to different LED light characteristics such as wavelength, light intensity and light flickering rate are investigated in the laboratory. Emphasize is made on how different light stimuli affects the optomotor response of cod, and how this response is influenced by other simultaneous stimuli relevant for the fishery, such as water current. Also, fish response to different light sources such as LED point lights and luminous ropes are investigated in the laboratory and/or at sea.

Industry-led gear selectivity improvements – strengths and weaknesses under the new European Union Common Fisheries Policy

Contact: Tiago Malta (timat@aqua.dtu.dk)

2015 - ongoing

With the goal of increasing fishermen' sense of ownership of the gears available to the industry the project will scientifically test gear selectivity solutions developed by the industry with the aim of solving the issues faced under the new CFP landing obligation system. The project will also attempt to understand whether gear selectivity data collected by the industry can be used as a fast and cost effective way to obtain efficient and accurate data on species and size selectivity in the gears. With the purpose of ensure the quality of the industry collected data with the minimum impact in the fishermen workload the optimization of the data collection protocol will be conducted. The protocol optimization will be carried out using stochastically simulated data and it will primarily aim to determine the minimum number of fish needing to be sampled during commercial fishing to maintain the necessary data quality. This will be evaluated in terms of provided catch comparison and ratio information and associated uncertainties. Furthermore, by discussing the strengths and weaknesses of industry collected gear selectivity data and how its collection can be streamlined under the new CFP we hope to increase our understanding of a wider range of fishing gears selectivity issues. We expect that new and innovative solutions will be presented by the industry and that the project will be able to provide guidelines for a faster implementation of those solutions in the legislation.

A combined approach to optimise the use of selective devices and new technologies in trawls.

Contact: Marco Nalon (mnal@aqua.dtu.dk)

2018 - ongoing

Under the EU Common Fisheries Policy (CFP, 2013) fishermen need to be able to actively adjust the selectivity of their gears according to quota availability. As the combination of gear, fishing practice and quotas differs between fisheries and vessels, changes to the selectivity of the gear need to be applied quickly and at a vessel level. Within Europe there is extensive documentation on a wide range of gear modifications from a wide variety of fisheries and geographic areas. These modifications were typically tested individually in relation to a legislated alternative. To make use of the extensive documentation already existing, we aim at developing a theoretical meta-analytical approach to define what the best combinations of gear modifications are, depending on specific fishing and quota conditions. The predictions obtained from this analysis will be benchmarked through actual commercial sea trials. Moreover, this approach will incorporate and explore the potential of new technologies emerging in other fields, to improve the economy in the fisheries and reduce their environmental impacts. In particular, new sensors (e.g. acoustic) and polymers will be tested to further improve species and size selectivity.

Improving selectivity and catch efficiency in demersal trawl fisheries using real-time camera monitoring and real-time decision making tool both prior to and during the fishing operation.

Contact: Maria Sokolova (msok@aqua.dtu.dk)

2018 - ongoing

Commercial fishing with trawls compared to similar industries is a field where the uptake of technology has been low. This means that there are currently both economically and biologically costly fishing activities, where part or the entire fishing process is taking place in blind. The technologies that change this are today available and may be transferred from other sectors and adapted to fisheries. Establishing the future fishing gears that aim to ensure the best possible economic and biological sustainability as well as comply with ambitious management goals such as the EU landing obligation (Common Fisheries Policy, CFP), requires the fishermen to control the catch process and actively respond to what they observe. It is therefore a crucial first step to establish a real-time monitoring of the catch process. There is an expectation that future fishing gear will contain significantly more technology as well as solutions that can actively affect the selectivity of gears without necessarily interrupting the capture process.

The PhD project will be focused on developing and establishing decision-making tools primarily in trawl fisheries. The goal of this approach is to make fisheries more targeted and intelligent in its catch process and to ensure the best possible economic and biological sustainability in the trawl fisheries.

DiscardLess (http://www.discardless.eu/)

Contact: Barry O'Neill (barone@aqua.dtu.dk)

The EU funded H2020 project DiscardLess finished this year. It was a very broad ranging project examining ecosystem, economic and policy implications of the implementation of the EUs Landing Obligation, and with the aim of providing the knowledge, tools and technologies to achieve the gradual elimination of discarding. The first focus was on preventing the unwanted catches from ever being caught, and the second was on making best use of the unavoidable unwanted catch.

During the last year, in collaboration with Marine Scotland Science, a meta-analysis of plaice otter trawl codend selectivity data was completed and found that selectivity could be explained in terms of the mesh size, the number of meshes in circumference and the twine diameter. This study is being written up at present.

Sandbanks

Contact: Barry O'Neill (barone@aqua.dtu.dk)

Sandbanks is a European Maritime Fisheries Fund (EMFF) project to investigate the benthic impact of fishing and the fishing pressure of the seine net and sand eel fisheries on the sandbanks of the central North Sea. This year the Fishing Technology group in Hirtshals have been involved primarily with describing the swept area and predicting the physical impact of the Danish anchor seine.

Bycatch mitigation of protected species, hereunder sea birds and harbour porpoises

Contact: Lotte Kindt-Larsen (lol@aqua.dtu.dk)

2018 – ongoing

Harbour porposes (*Phocoena phocoena*) and seabirds are protected according to the habitat- and bird-directive. Thus incidental bycatch of these species should be avoided. However, at this stage there are no solutions available to reduce bycatch of seabirds in gillnets fisheries except from effort reductions or gear change. Thus in order to reduce bycatch of seabirds new technologies, hereunder flashing lights and acoustic signals are tested. With respect to porpoises solutions to avoid bycatch of harbour porpoises are available, however, very little is known on porpoise behavior in relations to these sounds. New trials on both porpoise behavioral responses to pinger sounds and field test of e.g. increased pinger spacing are being conducted.

All technologies are tested in cooperation with commercial gillnet fishers by use of REM (Remote Electronic Monitoring) where bycatches of protected species are also being registered.

8.5 France

IFREMER

Contact person: Pascal Larnaud, pascal.larnaud@ifremer.fr , coordinator of this report

Summary

The fishing technology activities carried out in France in 2018 are distributed in four main topics:

- Improvement of trawl selectivity on commercial vessels in the Celtic Sea, Western Channel, Eastern Channel (respectively REJEMCELEC - OPTISEL - SELUX).
- Discards survival (DREAM);
- Alternative fishing gears: design of fish pots (BAITFISH) based on target fish species' behaviour and ecology; design of "off bottom" doors for bottom trawling (REVERSE)
- Evaluation of *Nephrops norvegicus* abundance in the Bay of Biscay (FU23-24) by counting their burrows using a submarine video camera (LANGOLF-TV).

Projects

"REJEMCELEC" : Decreasing discards in the Western Channel and in the Celtic Sea

Contact persons: Gaël Lavialle, gael.lavialle@cobrenord.com, Producer organization "Cobrenord", contact@cobrenord.com, Pascal Larnaud, pascal.larnaud@ifremer.fr, Marie Morfin, Fabien Morandeau, Julien Simon, Jean-Philippe Vacherot, Ifremer Fishing gear technology and biology laboratory – Lorient.

January 2016 – June 2018

https://archimer.ifremer.fr/doc/00483/59493/

In the context of the new European Common Fisheries Policy and in particular the Landing Obligation, two Producers Organisations, COBRENORD (Northern Brittany) and OPN (Normandy) launched the REJEMCELEC project in partnership with IFREMER and net suppliers. The funding partners are the association « France Filière Pêche » and the Brittany and Normandy Region Councils. The project was set to complementary the CELSELEC project (last year' report). The main goal is to reduce whiting, haddock and pelagic discards for single bottom trawlers fleets targeting whiting, squids, cuttlefish and monkfish within the Western Channel. A specific fleet targeting hake and John Dory in Celtic Sea during summer (around Scilly Island) was also studied in order to reduce their discards of small haddock, hake and boarfish.

After a state of the art review, an analysis of quantitative data and various workshops organized in partnership between fishermen, equipment manufacturers and scientists, five "selectivity case studies" were identified. A variety of selective devices was evaluated with regard to three criteria: reduction of unwanted catches (sizes and species), commercial losses and ergonomy of the device. The most interesting results considering these three criteria were given by the following two devices

The first one is a T90 panel (80 mm) on the top of the baitings and of the extension to avoid the undersized whiting and its first commercial category and to keep cephalopods. The T90 panel was used by a vessel doing the bottom trawl metier in the Western Channel with a 80 mm codend. This device selects the whiting near the last size of the commercial category 40 (27-32 cm) without commercial loss. In addition, a reduction of undersized haddock, horse mackerel and mackerel was observed. Proof of its efficiency, the voluntary ship for this test continues to use this device.

The second is a large 100mm T90 panel on almost all the top of the extension (13m long on the top of the straight part of the trawl) for fleets targeting hake and John Dory in Celtic Sea during summer with a 100 mm codend. This device was tested as an alternative to the mandatory 120 mm square mesh panel (only 3m long in comparison). The enlargement by four of the selective surface and the adjustment of the mesh to the targeted sizes of hake and haddock, allowed to decrease significantly the catches of small fishes (< 30 cm for haddock; < 36 cm for hake) and to increase the catches of good-sized individuals (> 35 cm for haddock; > 47 cm for hake). In addition, a slight decrease of the boarfish catches was observed. This approach would on one hand allow to save more young breeders, and on the other hand to take advantage of their growth by having a better capacity to capture them once bigger.

OPTISEL

Contact persons: Quiterie Sourget, sourget.aglia@orange.fr, AGLIA (Association du Grand Littoral Atlantique), Pascal Larnaud, pascal.larnaud@ifremer.fr, Sonia Méhault, sonia.mehault@ifremer.fr, Ifremer Fishing gear technology and biology laboratory – Lorient

January 2018 – December 2019

In the continuity of the REDRESSE project, the partnership between AGLIA ((Association du Grand Littoral Atlantique), Ifremer and the fishermen continues through the OPTISEL project that still aims to improve the selectivity in the fisheries of the Bay of Biscay in order to decrease the discards. It is funded by the European Maritime and Fisheries Fund (EMFF) and by the « France Filière Pêche » association.

3 lines of work have been defined :
1. *Nephrops* grids,
2. Monkfish grids,
3. Swordfish longlines.

The work on *Nephrops* grids in the REDRESSE and GRILLETINE projects showed satisfactory results on ergonomics (no problem for handling) and selectivity (significant reductions in *Nephrops* discards from -20% to -40% and small commercial losses).
However, after a few weeks of rough use at sea, the grids tested showed some weaknesses (cracks, etc.) and commercial losses increased.
The objective of the OPTISEL project is to optimize the grid and make it more reliable by :

- Improving the effectiveness of the grid and limit commercial losses.
- Designing a rugged grid while working on materials, articulation between different parts, mounting, etc.
- Testing the device over the long term and on different vessels.

Different types of grids have been tested and a polyurethane grid in 6 articulated pieces has produced the best results, both from the point of view of the mechanical resistance and the escapements of small Nephrops. It will be tested on a large scale in the Bay of Biscay in 2019 on about ten ships.

The flexible monkfish grid tested as part of the CELSELEC project in West Brittany is also being tested in the Bay of Biscay.

SELUX : Improvement of selectivity in artisanal trawlers fishery in the Channel and South of North Sea via the use of lighting devices

Contact persons: Manon Joguet, m.joguet@fromnord.fr, Loeiza Lancelot, l.lancelot@fromnord.fr, Producers organization "FROM Nord", Franck Coppin, Franck.Coppin@ifremer.fr, Ifremer Fisheries Ressources Laboratory – Boulogne sur Mer, Pascal Larnaud, pascal.larnaud@ifremer.fr, Julien Simon, Jean-Philippe Vacherot, Ifremer Fishing gear technology and biology laboratory – Lorient.

January 2019 – January 2021

This project is coordinated by the Producer Organisation FROM Nord in partnership with Ifremer and the companies SafetyNet and Le Drezen.

The objective of the SELUX project is to test the association of well-known selective devices (square mesh or T90 panels or cylinders) with lighting equipment in order to improve their selectivity for the different target species, in particular for whiting.

The devices are made of fluorescent twine (Brezglow, Le Drezen company), or waterproof LED (SafetyNet Pisces system), organized into different configurations. In order to prepare for future offshore observations, the devices were filmed and observed in complete darkness in Lorient flume tank, with sensitive video cameras, without additional light.

Preliminary sea trials will take place in April and May 2019 on professional fishing vessels in the Eastern Channel – South of North Sea, with video observation of fish behaviour in contact with the devices and with small meshes covers. The best devices will be tested by catch comparison method in autumn 2019 and spring 2020.

DREAM Evaluation of the fate of discard

Contact persons:
Dorothée Kopp dorothee.kopp@ifremer.fr, Sonia Méhault, sonia.mehault@ifremer.fr, Ifremer Fishing gear technology and biology laboratory – Lorient,

January 2019 –December 2021

The landing obligation introduced in the reform of the European Common Fisheries Policy requires all catches of species under quota to be landed. However, exemptions may be granted for species for which "scientific evidence demonstrates high survival rates". The aim of the DREAM project is to study discard survival from a broad point of view. The survival of common sole targeted by commercial trawler in the Bay of Biscay will be assessed using acoustic telemetry.

Non-commercial invertebrate's survival will also be tested in captivity as well as discard consumption by seabirds. This project is carried out by IFREMER, in collaboration with PELAGIS, MNHN and the COREPEM.

BAITFISH: Behaviour, performAnce, Impacts of poTs FISH

Contact person: Sonia Méhault, sonia.mehault@ifremer.fr, Dorothée Kopp, Fabien Morandeau, Ifremer Fishing gear technology and biology laboratory – Lorient

January 2018 – December 2020

The goal of the BAITFISH project is to design fish pots addressing three requirements: (1) optimality in targeting commercial fish species, (2) low impacts on ecosystem functioning (3) being usable by fisherman on a regular basis. For that purpose, an ecological approach will be used first to describe fish species ecological needs. During summer 2018, several baits were tested to attract black seabream. Preliminary results showed that cockles, worms and shrimps are efficient at attracting this species. Seabream's behaviour towards the bait will now be analyzed using ethograms. Then this knowledge will serve to design pots and use them under optimal fishing conditions. Once operational, the gears will be transferred to fishermen for testing and their potential impacts will be assessed.

REVERSE : "off bottom" doors for bottom trawling

Contact persons: Benoît Vincent, benoit.vincent@ifremer.fr, Ifremer Fishing gear technology and biology laboratory – Lorient.

January 2017 – December 2019

REVERSE project is funded by the European Maritime and Fisheries Fund (EMFF) and by the « France Filière Pêche » association. It aims at adapting bottom trawling with off bottom door. The project has started with a theoretical part to design doors with higher efficiency using CFD tools and flume tank trials. A six-component force balance was used in Lorient flume tank to validate CFD results. First tests at sea revealed no particular problem. Tests will continue until the end of 2019 with volunteer skippers. Project partners are the door maker Morgère and the French Fishermen National Committee.

LANGOLF-TV

Contact person : Jean-Philippe Vacherot, jean.philippe.vacherot@ifremer.fr, Ifremer Fishing gear technology and biology laboratory – Lorient

Started in 2014, the annual survey Langolf-TV aims at estimating the abundance of *Nephrops norvegicus* in the Bay of Biscay (FU23-24) by counting their burrows using a submarine video camera set up on a sled towed at reduced speed.

It replaced the Langolf trawling survey operated aboard the R/V Gwen-Drez until 2013.

This fourteen days survey has been carried out since 2014 aboard a ship of the Irish P&O (R/V Celtic Voyager or R/V Prince Madog in 2015), and will take place again in May 2019 (2nd to 15th).

Six scientists work 24h/24h in 4h long shifts to get 10 minutes video footages on the sea floor for more than 200 stations distributed across the area of the 'Grande Vasière" (215 stations in 2019). These stations were located from a point fixed randomly in the Bay of Biscay by creating a meshing of 4.7 nautical miles around it (figure 8.5.1.).

These videos, saved on DVDs (the use of a high-definition camera is planned for next year) are analyzed by two accredited observers who then compare the results of their countings of *Nephrops* burrows to find a consensus in their observations. All the readings are done on board during the survey.

After processing, the results of this survey are used in the Bay of Biscay Nephrops stock assessment carried out in the ICES working group WGNEPS.

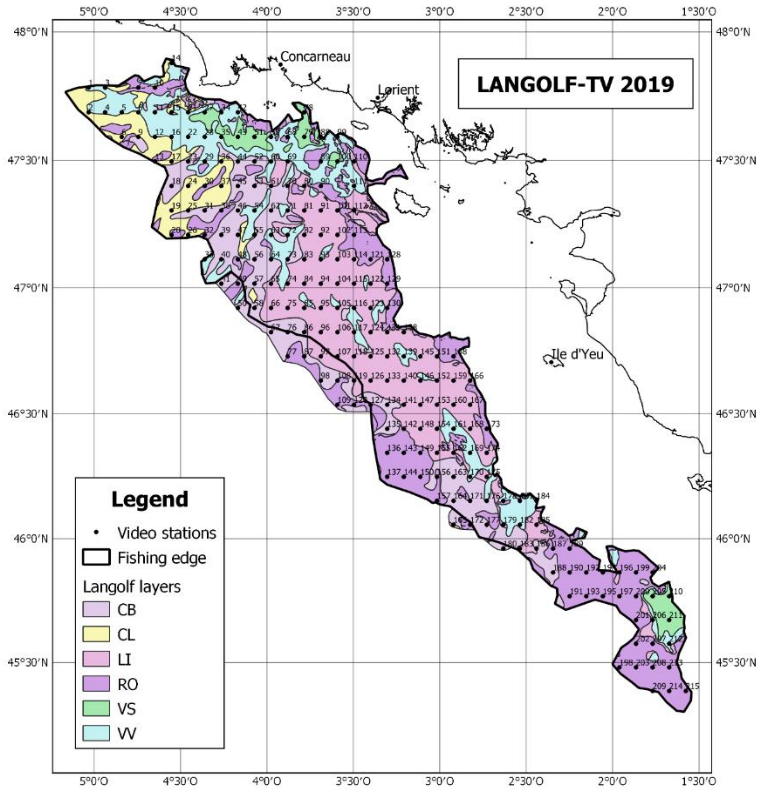

Figure 8.5.1: Video and beam trawl stations – Langolf-TV 2019

8.6 Germany

Thuenen Institute of Baltic Sea Fisheries

Contact person: Daniel Stepputtis, daniel.stepputtis@thuenen.de

Summary

In Germany, research related to fishing gear was mainly conducted by the Thuenen Institute of Baltic Sea Fisheries (see report from university of Rostock below). The focus of the research in 2018 and beginning of 2019 was

- Understanding and improving of trawl selectivity, incl.
  - Grid technologies for beam trawl shrimp fishery (SO753 cruise, 09/2018)
  - Catch separation in the North Sea brown shrimp fishery (SO753 cruise, 09/2018)
  - Development of dual-species selectivity for Baltic Sea (CLU331 cruise, 12/2018)

- Alternative technologies to mitigate the ecological impact of fishing activities, incl.
  - Reduction of plastic waste (Dolly Ropes) from the brown shrimp fishery through gear modifications (SO758 cruise, 01/2019)

- Reduction of unwanted bycatches of marine mammals and birds in gill nets, incl.
    - modification of gillnets
    - improvement and test of alternative fishing gears

Additionally, the fishing- and survey technology working group of the Thuenen Institute currently working on different technical devices which aim to support fishery in general and fishery technological research in particular. Examples are

- Open Scientific Measurement Board (OpenSMB), a scientific Open Source data acquisition system to be used in fisheries sciences
- Infrared Fish Observation iFO, an Open Source camera system for 24/7 video surveillance

Projects

Innovative grid designs for brown shrimp size selection

Contact person: Juan Santos, juan.santos@thuenen.de
09/2018. Experimental catch data collected onboard FRV "Solea" (cruise SO753) continuing investigations initiated in 09/2017 (cruise SO739) in collaboration with Wageningen Research Institute (Netherlands)

The brown shrimp (*Crangon crangon*) beam-trawl fishery is one of the most important North-Sea fisheries, supporting an international fleet of more than 500 vessels with yearly revenues of up to 100 million Euro. Surprisingly, the fishery remains largely unregulated in part due to the short life cycle of the targeted shrimp, which hamper the establishment of usable biological reference points to support management actions on the exploited stock. However, the question regarding the sustainability of the exploitation patterns in the fishery emerged during the last years. To ask such question, the Thuenen Institute, in collaboration with Hamburg University and the Industry, investigated the size selectivity of the commercial codends and more than thirty alternative codend designs experimentally during the project CRANNET. The experimental information obtained regarding codend selectivity was used for theoretical analysis of the population dynamics of brown shrimp, based on bio-economical assessment of the fishery under different environmental and fishing scenarios. This study suggested that size selection patterns sharper than available codend selectivities might be of great benefit in terms of economical revenues for the fishermen and the sustainability of the fishery (stock size, population structure, recruitment). Consequently, investigations are being conducted regarding grid technologies as potential technical solutions to achieve sharper selectivity patterns and therefore meet the theoretical advice. Investigations started in 2017 with a joint German/Dutch cruise on FRV "Solea", used to test several innovative grid systems proposed by Dutch fishermen (09/2017, Cruise SO739). The information and experiences collected during this first experiment were used to further develop grid technologies to be tested in 2018 onboard FRV "Solea" (09/2018, Cruise SO753). Three grid-designs, varying in construction material (plastic, fiberglass and steel), bar design (polygonal, drop-shape-like, round) and bar thickness were tested in experimental fishing onboard research vessel.

The selectivity parameters and contact probabilities for the different grids were obtained using covers. As intended, the L50 estimated for the three grids were close to the minimum marketable shrimp length (50 mm), while the Selection Ranges (SR) ranged from 5.0 mm to 7.9 mm, far below the expected SR obtained by codends providing similar L50. Contact probabilities ranged from 55% to 69% indicating further investigations are still required in order to make the observed grid selectivities available for larger percentages of shrimps entering the gear.

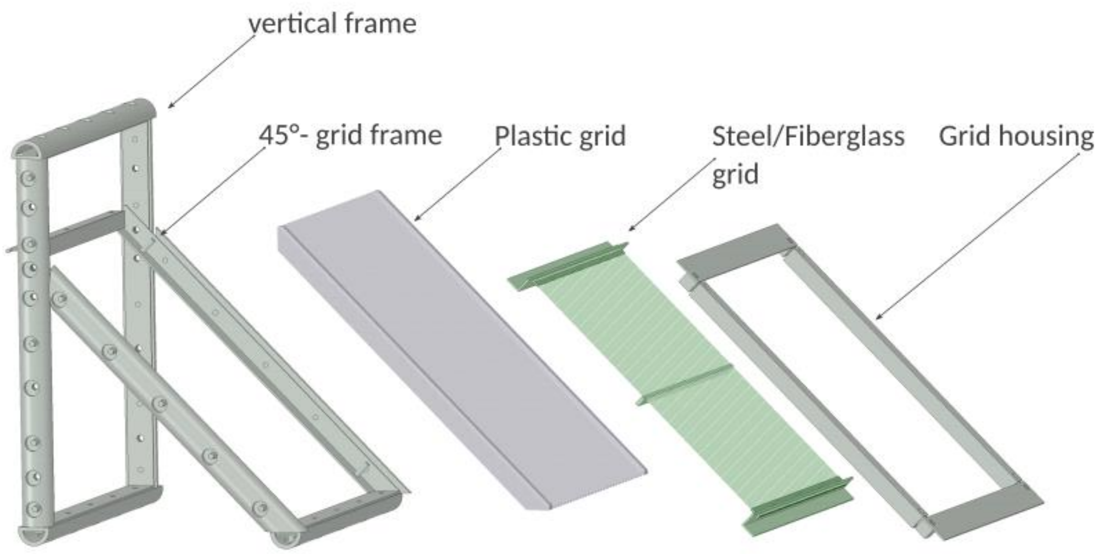

Figure 8.6.1: An innovative concept device (developed to allow the modular test of different grid designs) based on steel housing and removable grids made of plastic, steel and fiberglass was tested during the sea trials.

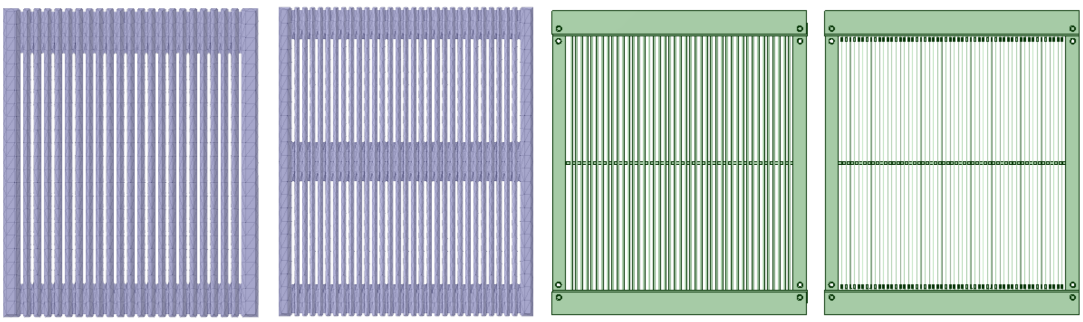

Figure 8.6.2: Grid-designs tested (Front view). From left to right: Plastic-grid 1(Dutch design, Type 1); Plastic-grid 2(Dutch design, Type 2); Fiberglas-dropshaped-grid; Steel-grid (2mm bar width)

Investigations on the vertical zonation of brown shrimp in the aft of trawl gears

Contact person: Daniel Stepputtis, daniel.stepputtis@thuenen.de
09/2018. Experimental catch data collected onboard FRV "Solea" (cruise SO753)

Information regarding behavioral patterns of fish or invertebrates entering a trawl gear is very valuable to develop and optimize bycatch reduction devices. To the best of our knowledge, no study has investigated so far behavioral aspects of brown shrimp in their path across the trawl body towards the codend. Linked to the grid technologies research described in the previous entry, the FRV "Solea" cruise SO753 was also used to quantify for first time the vertical zonation of brown shrimp in the aft of the trawl. In order to collect quantitative catch data of brown shrimp at different heights, the experimental design involved a significant alteration of the trawl. The standard codend was replaced by an extension piece mounting a quad-split frame at its rear end. Each of the four compartments established by the frame was covered by net bags to collect the shrimps entering the aft of the trawl at a given height. Three different experimental designs (D) were considered in the experiment to assess the effect of sieve nets (the most used Bycatch Reduction Device in the fishery) and guiding panels on brown shrimp zonation. In terms of average catch weight, half of brown shrimp catches were found in the lowest zone (cover 1, covering the lowest 25% of the cross section), with a (nearly) linear decrease in percentage with increasing height (D1). Adding the sieve net increased the percentage of the average catch weight in cover 1 to almost three-quarters (D2). Adding a guiding panel after the sieve net slightly increased the percentage of catches in cover 1 (+5%) relative to the previous design (D3). Length-based analysis pending.

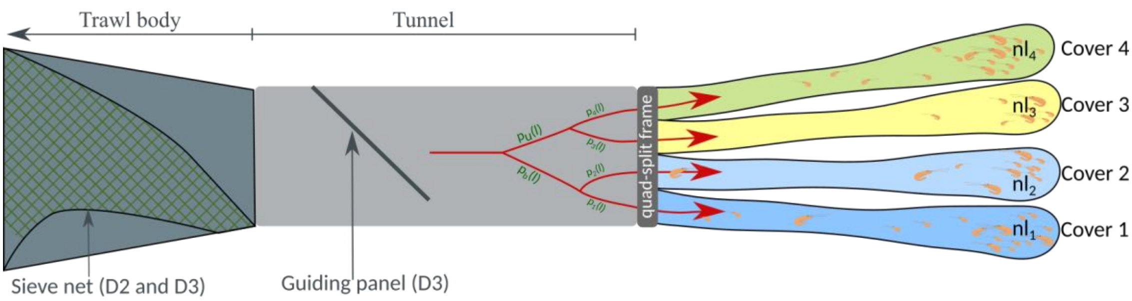

Figure 8.6.3: Experimental gear used to quantify vertical zonation of brown shrimp – schematic view

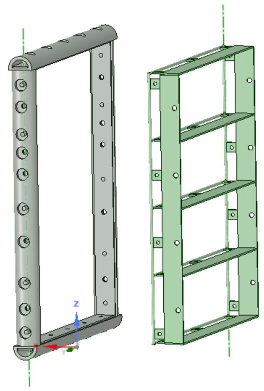

Figure 8.6.4: Experimental gear used to quantify vertical zonation of brown shrimp – technical drawing of the quad-split frame. The outer frame (left) is identical to the one used for the grid experiments (see previous topic)

Dual-species selectivity in Baltic Sea trawl fishery with SORTEX: second development stage using selective codends.

Contact person: Bernd Mieske, bernd.mieske@thuenen.de; Juan Santos, juan.santos@thuenen.de

12/2018. Experimental catch data collected onboard FRV "clupea" (cruise CL331)

BACOMA and T90 codends have been applied since 2005 in the Baltic Sea to shape the exploitation patterns of cod. While being highly selective for the target species, both codends provide poor size selectivity properties for flatfish co-habiting the fishing grounds exploited by the Baltic bottom trawl fishery. Consequently, the high bycatch rates of flatfish often observed in the fishery could be potentially mitigated by addressing this mismatch in selectivity. A strategy to increase the overall selectivity of Baltic trawls could be to split flatfish and roundfish into separated codends during the catch process, enabling technical strategies to establish size selection patterns optimized for the different groups of species. SORTEX is an experimental SORTing EXtension developed to achieve such catch separation, by utilizing observed differences in species swimming behaviour in the aft of the trawl. Previous studies using blind codends experimentally quantified the sorting efficiency of different SORTEX designs, resulting in separation rates at least of 80% for cod, as well as for flatfish-species. Based on such promising separation rates, the FRV "Clupea" research cruise CL331 (December 2018) was used to further develop the intended dual-species size selectivity concept. Based on a twin-trawl experimental design, we compared the catches from a reference trawl with those from the twin trawl mounting SORTEX (test trawl). The reference trawl used a T90 codend with 122.5 mm measured Stretched Mesh Opening (SMO), while the test trawl mounted two codends: the same T90 codend as used for the reference trawl connected to the upper compartment of SORTEX (cod codend), and a T0-134 mm measured SMO codend connected to the lower compartment (flatfish codend). Data analysis pendant to be shared next year.

DropS – Reduction of plastic waste from beam trawl fishery through gear modifications

Contact person: Bernd Mieske, bernd.mieske@thuenen.de ; Daniel Stepputtis, daniel.stepputtis@thuenen.de

project duration: 01/2018-12/2020

To protect the bottom side of beam trawls (targeting sole or brown shrimp), the trawl is often equipped with abrasion protection. Various materials can be attached to the meshes of the gear in order to prevent abrasion of the material on the seabed - especially of the codends.

One of the most common materials used as scuff protection in North Sea beam trawl fisheries are the so-called „dolly ropes". These are Polyethylene ropes (PE ropes), which are cut to size by the fishermen and woven into the net material. During fishing, the dolly ropes fray very easily and parts of it break off. According to the Dutch project DollyRopeFree (www.dollyropefree.com), 10 to 25% of the material is torn off within the first two weeks of usage. After this time, the remaining cords become tangled or entangled, reduce their flexibility and cause sand and gravel to clog. As a result, the remaining dolly ropes are replaced. Whereas the DollyRopeFree-project mainly focused on alternative materials, the German project DRopS aims to develop and test trawl gear modifications that reduce or prevent the contact of the gear with the seabed, thus making the use of dolly ropes as abrasion protection superfluous. Initially the project focuses on the shrimp fishery in the North Sea.

During the project, four different approaches are investigated

1. Change of cutting of the gear: The cutting of the beam trawl may provide opportunities to further lift the codend off the ground. So far, side net panels (wedges) are installed between upper and lower net panel, which are aligned towards the seabed. In this project side panels will be tested, which are oriented upward, so that the distance between the seabed and the gear, in particular the codend, increases (Figure 8.6.5). The catch comparison on the cruise SO758 (FRV "Solea", 01/2019) showed that with the ascending trawl 2% more brown shrimp were caught than with the conventional trawl.

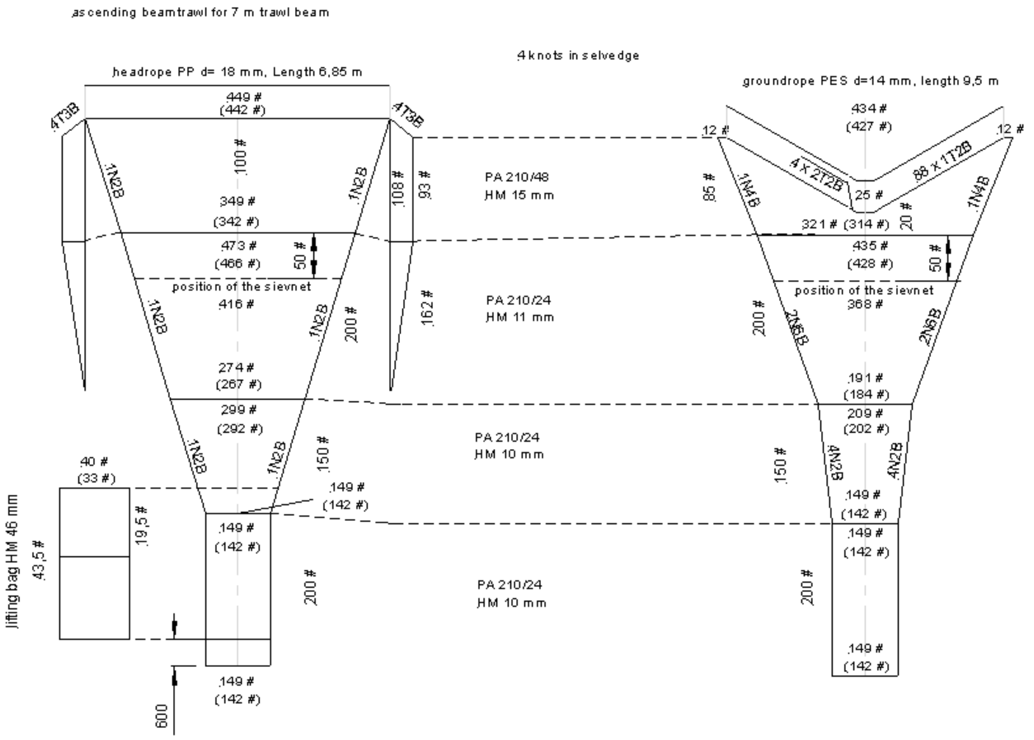

Figure 8.6.5: cutting plan of the tested ascending beam trawl-net

2. Achieving a constant cylindrical shape of the codend, and thus avoiding ballooning of T0-codends when the catch accumulate. Two strategies were tested:

a) Use of ring reinforcements (strengthening ropes) and thus preventing increased diameter of the codend when the accumulates.
b) Testing of hydrostatic and hydrodynamic floating devices, such as kites.
c) Orientation of the meshes: It is known (e.g. form previous experiment in the CRANNET project) that the orientation of the mesh material has a significant influence on the shape of the codend during the catch process. Meshes in T90 but above all meshes in T45 orientation reduce the perimeter increase of the codend as the catch size increases in the codend.

3. Testing of hydrostatic and hydrodynamic floating devices: To keep the codend clear of the sea bottom, several setups using hydroastatic (e.g. buoys) and hydrodynamic devices (kites) were tested to identify optimal configuration.

4. Reduction of the catch of heavy material: The codend is also pulled down by catching heavy organisms (e.g., clams and sea urchins) or heavy material (e.g., stones and sand). Accordingly, one approach is to reduce the amount of these heavy materials - especially as they are unwanted bycatch. Several options are possible, such as:

a) Benthos Release Panel (BRP) (sea test to be conducted in 2019)
b) Changes of the ground rope (Figure 8.6.6). During the research cruise SO758 (FRV "Solea"; 01/2019, a modified beam trawl with straight roller gear was tested in comparison to a conventional trawl (with U-shaped groundrope). The catch performance of the new straight footrope trawl was almost identical compared to the conventional trawl.

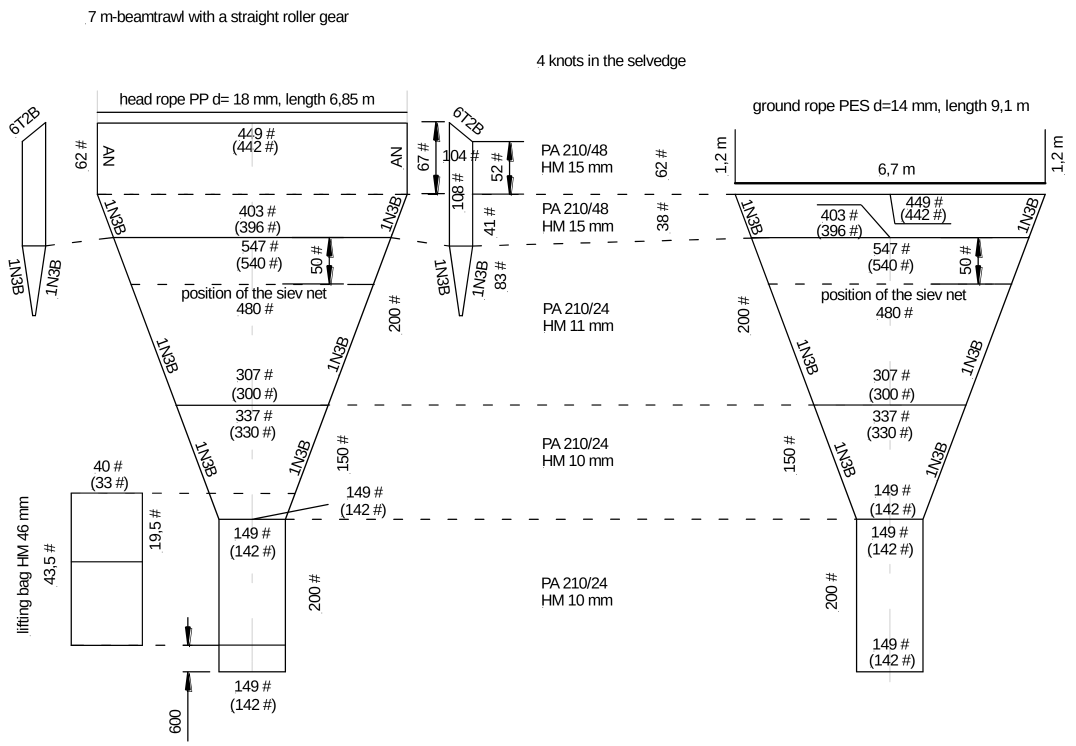

Figure 8.6.6: cutting plan of the tested beamtrawl with the straight roller gear

STELLA Development of alternative management approaches and fishing techniques to minimize conflicts between conservation objectives and gillnet fisheries

Contact person: project leader: Uwe Krumme, uwe.krumme@thuenen.de; gear technology: Daniel Stepputtis, daniel.stepputtis@thuenen.de

project duration: 01/2017 – 12/2019

link: https://www.thuenen.de/en/of/projects/fisheries-environment-baltic-sea/gill-net-fisheries-development-of-alternative-management-approaches-stella/

Gillnets are one of the most common fishing methods worldwide. Along the German Baltic Sea coastline, local gillnet fisheries provide a source of income for a number of families, form a part of the cultural heritage and play a major role in the touristic attraction of the coastal region. Fishing takes place within and outside of the special protected areas, which make up around 44% of the German EEZ in the Baltic Sea. Large flocks of migratory birds pass through every season and rest within these areas, furthermore there is a small population of harbor porpoise in the Western Baltic. While gillnet fishing is a highly size selective fishing method, unwanted bycatch includes higher trophic species like harbor porpoises and seabirds. Data on the extent of the problem is rare, since gillnet fishing is usually carried out on small vessels (often less than 12m in length) and fishermen are only obligated to deliver a monthly catch report on these vessels without any indication of bycatches.

In STELLA we combine a total of four working packages to tackle the bycatch problem from all angles and find a solution that is effective, sustainable and will find acceptance among fishermen. The project comprises the following: 1) estimating fishing effort of the local gillnet fisheries and identifying behavior patterns of different fisherman groups. 2) development of gillnet modifications to minimize bycatch of marine mammals and seabirds 3) development of alternative fishing gears 4) analyze motives of fishermen and identify incentives that may lead to enhanced acceptance of mitigation methods.

STELLA - Work package 2: Gillnet modification to reduce bycatch of marine mammals and seabirds

Contact person: Isabella Kratzer, Isabella.kratzer@thuenen.de (in close cooperation with DTU Aqua, DK)

Previous attempts to reduce bycatch of porpoises include trials to raise the acoustic reflectivity of gillnets. Most of these studies use a trial-and-error approach and lack to address the problem in a systematic way. Furthermore, it is hypothesized that porpoises are able to detect gillnets or parts of them, but fail to recognize them as an obstacle, possibly due to masking of the netting by the highly visible floatline. The ideal object to be hung in the net should be very small, have a reflectivity similar to the floatline and be hung at distances small enough that the porpoise perceives the net and objects as an impenetrable pattern. In a systematic study, we simulated the acoustic reflectivity of a variety of objects in different shapes, sizes and bulk characteristics (e.g. Young's Modulus, density) and experimentally verified the simulations in a water tank. First simulation results indicate that commercially available acrylic glass spheres of less than 10mm diameter exhibit promising characteristics with up to -42dB target strength at 130kHz (the frequency used by harbor porpoise).

Echograms taken with the sonar of FRV "Clupea" revealed that the net with spheres is highly visible at 120kHz compared to a standard gillnet (Figure 8.6.8). At 38 kHz both modified and standard gillnet were not visible.

Figure 8.6.7: Gillnet with Acrylic-pearl (diameter: 8mm)

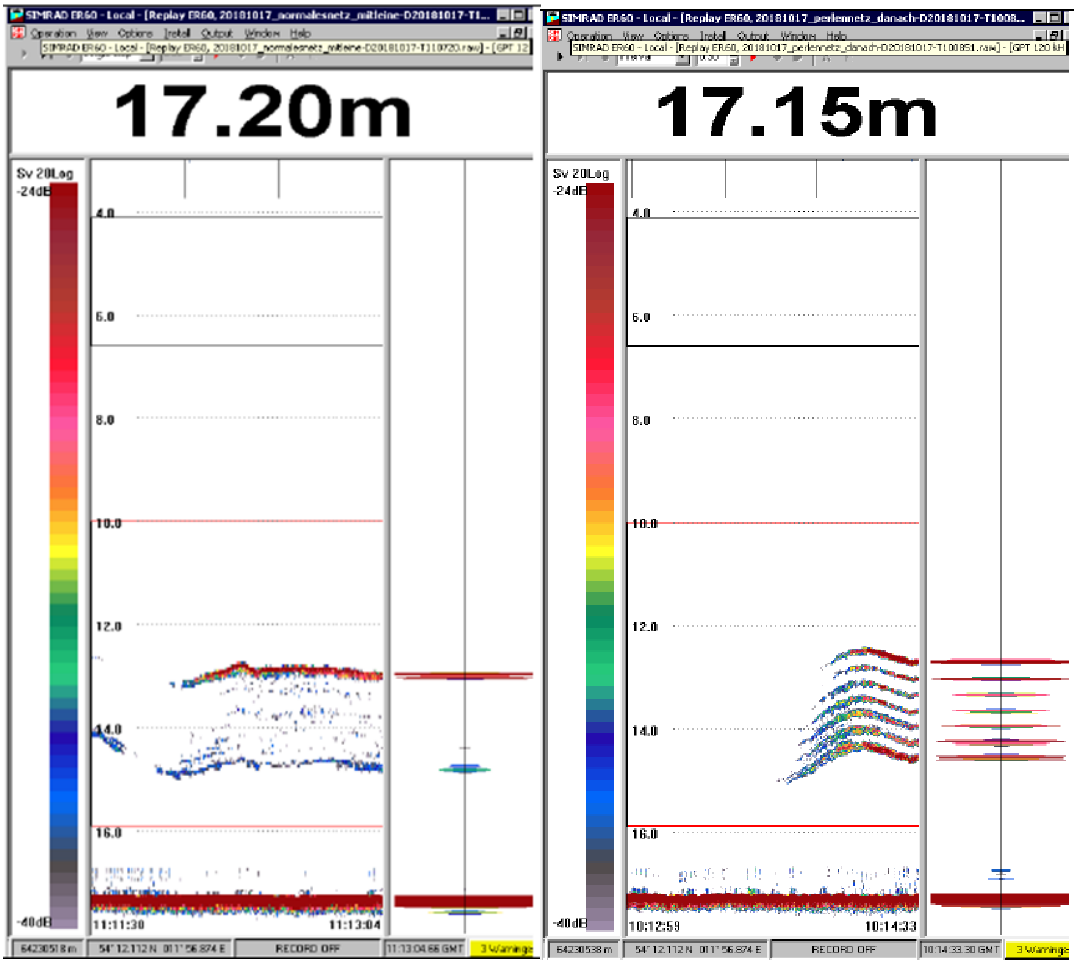

Figure 8.6.8: Echograms taken with the sonar (SIMRAD EK60, 120kHz) of FRV "Clupea": Left: standard gillnet without pearls; Right: modified gillnet with pearls

A field experiment carried out in Fyns Hoved (Denmark) between end of July 2018 and beginning of September 2018 was supposed to determine the reaction of porpoises to the modified net. Due to weather conditions, as well as unusual behavior of the observed animals, the experiment needs to be repeated in summer 2019. Furthermore, the "pearl nets" will be tested in the commercial turbot fishery in the Black Sea starting in June 2019.

Remark to international colleagues:

- We have modelled the acoustic properties of different objects for a broad range of frequencies to cover also echolocation frequencies of other marine mammals (paper in preparation). Therefore, we will be able to recommend objects visible to other marine mammals, as well.
- We are still looking for other fisheries with high bycatch of echo-locating marine mammals to test the "pearl net"-concept"

STELLA - Work package 3: development and test of alternative fishing gears

Contact person: Jérôme Chladek, jerome.chladek@thuenen.de

This work package deals with different topics:

1. Fish pot entrance experiment: Several studies have shown that entrance type and funnels are a central factor for fish pot catchability. A detailed understanding of the different entrance types (e.g. funnel type) and characteristic (e.g. funnel length, netting material or net colour) is however still lacking, in part due to the inherent difficulty of testing entrance types/ entrance characteristics in the field. Also, field experiments usually only allow to measure the final fish number in the pot at hauling, long term recording of entry and exit rates per individual fish is (to date) not possible. Thus, in this study we will identify the influences of different entrance parameter on entry- and exit rates into and out of a cod pot with exchangeable entrances ("experimental pot"). The experiment will be carried out in a net pen with individually marked cod and flatfish. The fish will be observed using video camera (daylight & IR sensible for nighttime observation, see chapter on IR-camera) and RFID (radio-frequency identification).
   In an iterative approach, two different designs will be simultaneously compared, differing in only one parameter. First , the influence of different entrance parameters will be tested (e.g. funnel present yes/no, funnel length, funnel cross section (round/square), inclination angle, knotless yarn/nodded yarn).
   The aim is to identify a description of an optimal cod pot entrance for the (German) Baltic Sea cod pot fishery. The experiments started in 2018, but were delayed due to technical problems. The technical problems are solved and the experiment is currently running (March 2019-May 2019).
2. Optimal bait identification for cod pots: The choice of the appropriate bait is a another crucial factor for any kind of bait plume mediated fishery (longlining, angling, potting).While many different bait test were undertaken for cod pot-fishery in general, rather few were performed for the Western Baltic cod stock. Also, different bait studies have occasionally had conflicting results. Understanding of bait effect for cod pot-fishery is thus still low and an efficient and reproducible test is currently lacking. Thus, in this study, reaction of cods in a tank to different kinds of bait will be observed to a) identify the optimal bait for cod pot fishery in the German Baltic and b) investigate if this controlled approach works as a bait quick-n-clean test by outperforming in time and quality usually very time and resource-consuming field test in pot fishing. We hope that this controlled approach will allow suppressing the non-controllable variables (temperature, cod presence/ absence, cod hunger level, current…) usually encountered in fisheries field tests. In the first trial phase, we will test different kind of olfactory baits, in a later stage we will also want to explore visual and acoustic baits
3. Pontoon trap trial in Germany: Pontoon traps are frequently used in the Baltic (mainly Finland and Sweden). This type of trap has some advantages over traditional poundnets: a) relative easy operation during regular catch inspections, b) protection of catch against seals, c) avoidance of seal bycatches (when seal exclusion devices are used). In 2018, a pontoon trap was tested by a German fisherman in the Greifswald Bay (Southern Baltic Sea,). Aim of this initial trial was to test the usability along the shallow areas of the German Baltic coast. It was shown that the original design of the pontoon trap is not ideal for local conditions (mainly: trap too high for shallow areas and hence too much exposed to waves). Consequently, modifications to the original design will be implemented in 2019.

Figure 8.6.9: Pontoon trap in German waters (water depth at position of pontoon trap is approx. 3m)

Open Scientific Measurement Board (OpenSMB)

Contact person: Andreas Hermann, andreas.hermann@thuenen.de ; Daniel Stepputtis, daniel.stepputtis@thuenen.de ; Marcellus Roediger, marcellus.roediger@thuenen.de
link: http://opensmb.net/

Taken into account the way of data acquisition, fishery scientists seems to be very conservative and often stick to a simple length measurement board, paper and pen (the analogue way) - resulting in quite inefficient data sampling procedures (e.g. every single datum passes through, at least, 3 people/work steps). Although, several digital data acquisition tool/electronic measuring boards for use in fishery science were developed over the last years, these are not widely used. We have figured out some major issues: a) lack of adaptability to own needs and future requirements (mostly proprietary solutions), b) restriction to one computer-platform and c) lack of modularity (use of standard hardware). In a nutshell: a system is needed, which is more "future safe".

Sustainable Ocean research (including fishing gear research), requires sustainable data acquisition technology. Open Source –solutions are obvious key elements to achieve this ambitious goal. Ideally, these solutions can

- Make intensive use of user expertise and requirements.
- Extent the life-time of such tools due to independence of manufacturer-product cycles and sufficient documentation for further development, reproduction and repair.
- Make efficient use of resources (available in the different institutions), when working on a joint solution, rather than spending money and effort in institution-specific solutions.

Under this premises, the 'open scientific measurement board' (openSMB) was developed, a scientific Open Source data acquisition system to be used in fisheries sciences (e.g. in Lab, at sea, at commercial vessels). The system includes a highly flexible, modular and future-proof software and hardware, which is easily adaptable to future needs in fisheries science (or even in other scientific fields, such as agriculture). Key design criteria are platform independency, use of standard industrial components, standard formats (e.g. JSON) and interfaces for data and scalable hardware. Due to the integrated SBC (single board computer) the openSMB is far more than a simple fish length measurement device with 1 mm resolution. Moreover, it can act like a complete data acquisition system, managing user defined and complex sampling schemes, interact with other devices (e.g. scales, callipers, internal and external databases, other openSMB, external display devices). The device's interface can be accessed remotely via Wi-Fi or Ethernet using the fully documented API in JSON-format.

Infrared Fish Observation iFO

Contact person: Andreas Hermann, andreas.hermann@thuenen.de ; Daniel Stepputtis, daniel.stepputtis@thuenen.de

A sustainable ocean monitoring strategy needs sustainable technology and measurement devices because that is its primary fundament. What we derived from our long experience is: to achieve this ambitious goal, the most promising way is to follow an open source approach. On the one hand there are plenty of good solutions published under an open source license that can be reused and adapted to our scientific needs and on the other hand it might be useful for others to participate in the improvements.

The use of infrared video surveillance at night is very common for onshore applications and therefore hardware became efficient and cheap. Nevertheless, the observation in a dark environment is also a frequent task in fishery science. In many cases the use of visible light is inacceptable to avoid bias of fish behaviour. Available acoustic cameras reach a high resolution at a medium range, but those are complex and expensive systems. Like humans, various fish species cannot see infrared light. So far underwater infrared video observation is not very common. One major obstacle is the relative high attenuation compared to visible light. But with the increasing effectivity of LED technology, even very cheap CMOS cameras can cover acceptable ranges suited for many application scenarios. Our task was to observe the behaviour of cod at the entrance of different fish traps. After first tests with IR-cameras, we developed our own infrared camera and light system from standard components. It delivers underwater videos in darkness at a distance up to 1.8m. We use a consumer single computer board (Raspberry Pi) and standard industry parts.

A system consists of one camera and two lights, whereas parts are below 250€ including 100m depth rated housing. It uses open source software tools running on a Linux platform. The system offers a webserver, a comfortable scheduler, a motion detection unit and can store internally more than one week continuous video data.

Additionally, we added an LTE router with internal NAS (FritzBox 7890) to be used with up to four camera systems and an external hard disk. This allows storing video data for several weeks and gains full access via VPN and LTE to the whole system. It gives remotely live videos, access to the camera's webserver for adjustment and setup, for instant download of data and to the camera's operating system for maintenance.

University of Rostock, Chair of Ocean Engineering

Contact person: Karsten Breddermann, karsten.breddermann@uni-rostock.de

Summary

The focus of the research in 2018 and beginning of 2019 was on understanding the hydrodynamics of sorting grids used for North Sea brown shrimp fishery and how sieve nets and guiding panels affect the flow in front of the sorting grids.

Projects

Hydrodynamics of size sorting grids used in a crustacean fishery

Contact person: Tiago Alexandre Matias da Veiga Malta, timat@aqua.dtu.dk and Karsten Breddermann, karsten.breddermann@uni-rostock.de

In cooperation with DTU Aqua, Hirtshals, the hydrodynamics of a grid with a bar spacing of 6 mm was experimentally investigated in a wind tunnel with the aim to identify which parameters affect the hydrodynamics. By observing the similarity criteria according to Reynolds it is ensured that the measurement results are applicable to the grid in water. Four grids with different bar shapes were tested at different angles and wind velocities.

Flow simulation in and around a North Sea brown shrimp beam trawl

Contact person: Karsten Breddermann, karsten.breddermann@uni-rostock.de

Shrimp beam trawls to fish brown shrimp (*Crangon crangon*) are made from small mesh size netting. To reduce unwanted by-catch and debris, sieve nets of large mesh size are used in the trawls which guide unwanted objects out of the trawls. In order to improve the size selectivity on brown shrimp, investigation is being done into the application of sorting grids. Furthermore, it is expected that guiding panels of small mesh size, which are rigged in front of the sorting grid, maximize contact probability between catch and grid and hence improve the sorting capability of the grid. However, sieve net and guiding panel obstruct the flow, slowing the flow in the trawl down, possibly resulting in a reduced sorting capability of the grid. Therefore, to investigate the effect of the sieve net and the guiding panel on the fluid flow in front of the sorting grid, the flow through and around a shrimp beam trawl was simulated using "Reynolds averaged Navier-Stokes" (RANS) methods. The dimensions of a trawl with a sorting grid section were provided by the Thünen Institute of Baltic Sea Fisheries. The width of the beam trawl is 7 m and the total length is approximately 20 m.

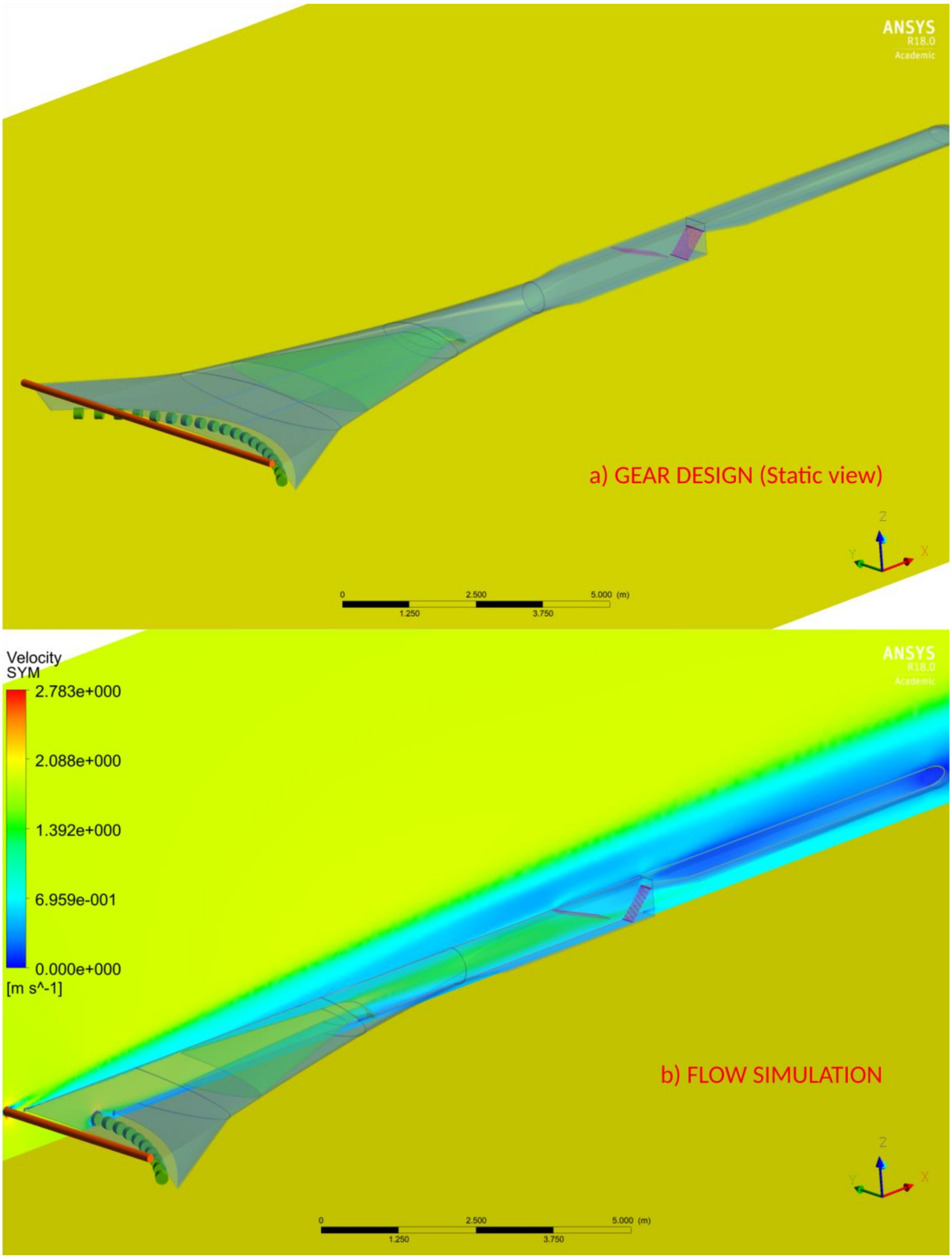

Figure 8.6.10: Gear design used in the simulation in static view (top) and under dynamic flow simulation (bottom)

8.7 Iceland

Marine and Freshwater Research Institute (MFRI)

Contact person: Haraldur A. Einarsson, haraldur.arnar.einarsson@hafogvatn.is

Summary

Projects have been carried out mostly as outlined in 2018. No significant new projects have been added over the past year. We provide updates and an outlook for the coming months an years.

Ongoing Projects

New harvest technologies for lumpfish

Contact person: Georg Haney, georg.haney@hafogvatn.is

2018 – 2019

Lumpfish *(C. lumpus)* is targeted by a fleet of small boats around Iceland for its roe. This seasonal fishery has been significant over decades as the only fisheries outside the transferrable quota system, especially benefitting fishermen in smaller remote communities. Gillnets are set in shallow coastal waters with a maximum soak time of 4 days. Bycatch of birds and marine mammals is significant.

The aim is a method feasible for the fleet of small vessels currently engaged in the lumpfish fisheries that eliminates bycatch of marine mammals and seabirds. Currently the focus is to determine if certain behaviors of lumpfish can be exploited to change where in the water column they are targeted by a potential new gear. 2019 will be used for exploratory trials to inform further grant application with the aim of expanding the project in 2020.

The project will be undertaken in close cooperation with the association of small vessel owners and lumpfish fishermen.

The project will also be closely aligned with other projects at the MFRI dealing with bycatch and discards. Notably there has been an effort to evaluate market ready technology to eliminate bycatch of small cetaceans from the Icelandic gillnet fishery. Both the Banana Pinger and the PAL porpoise have been tested with mixed results that failed to replicate the success of those devices claimed in other regions. Tests with modified PAL pingers will be repeated in 2019 as they showed a level of interaction with the harbor porpoise in Icelandic waters.

Fishscanning

Contact person: Haraldur A. Einarsson, haraldur.arnar.einarsson@hafogvatn.is

2018 – 2021

This project started in 2018 in cooperation with sensor specialist StarOddi and gear manufacturer Hampiðjan. The objective of the project is to develop a lightweight and user-friendly device that provides real-time information on the catch composition. Optical technology will be used to scan the fish before it enters the codend and the data immediately processed. The information is then relayed to the ship by DynIce cable (or by transducer). This promises a major improvement in the analysis of catches in trawls. Today only the catch sensor gives a rough indication of catch levels.

This technology is very likely to have a significant impact on the commercial fishing fleet. The Fishscanner gives fishermen real-time information about catch composition both for species and average sizes. This in turn will help to maximize the value of catches through better organization and utilization of the fishing effort.

The project is still in the design stage and limited progress has been made in 2018.

OptiGear

Contact person: Haraldur A. Einarsson, haraldur.arnar.einarsson@hafogvatn.is

2017 – 2019

The aim of OptiGear is to develop and implement a software to collect and analyze information and data from a vessel during towing. Various parameters will be collected in real-time into a database, such as information on tow speed and trawl positioning and winch characteristics, oil consumption, gear and catch. By analyzing the data, parameters and variables that have an impact on the fishing effort can be identified. Differences in crew and gear can be made visible and adjustments and training applied to improve the efficiency of the fishing effort. The project is a collaboration between the companies Trackwell and Naust Marine. MFRI, the University of Iceland and Loðnuvinnslan will consult and participate in sea trials.

The project will end this year, but discussions are ongoing for a possible extension. Over the past years data has been collected from many vessels during many fishing trips. The analysis of the data has not yet been concluded.

Optitog

Contact person: Einar Hreinsson, einar.hreinsson@hafogvatn.is

2004 – 2019

Optitog, also known as the laser project, is a long running project and collaboration between the MFRI and the Innovation Center Iceland. It aims to use visual stimulation to herd fish instead of bottom contacting gear. The prototype in testing is in scale almost like a possible commercial gear and consists of a towed frame with mounted lasers and an adjustable wing to fly the frame at a precise height over the sea bed.

Sea trials have continued in 2018 to evaluate the effect of the prototype gear on various commercial species. So far Haddock (*Melanogrammus aeglefinus*) and Northern Prawn (*Pandalus Borealis*) have shown herding behavior in relation to the laser array. In 2018 tank test were carried out at ILVO in Belgium to see if this behavior is also seen in other shrimp species. The Common shrimp (*Crangon crangon*) showed little reaction to laser light and light avoidance at best.

Currently grant applications are pending to continue the project. A major focus will be on determining catch rates and economic feasibility in the Northern prawn fishery.

Fishing gear as contributor to the problem of marine plastics

Contact person: Georg Haney, georg.haney@hafogvatn.is

2018 – 2019

After establishing a classification scheme and implementing a registration protocol the MFRi started in 2019 to register all marine debris found during its surveys. There are three main classes: fishing gear, marine industry and waste. Within the fishing gear class gear waste can be registered by gear type or part of the gear such as trawl-net, longline or floatation.

The data will be continuously collected over the coming years and the distribution of waste in the Icelandic EEZ monitored and analyzed.

Reports

Bycatch in Icelandic offshore shrimp fishery

Authors: Haraldur Arnar Einarsson, Georg Haney, Ingibjörg G. Jónsdóttir and Einar Hjörleifsson

This report examines bycatch of the main commercial species in the offshore shrimp fishery (*Pandalus borealis*) in Icelandic waters. This fishery has gone through three distinct regulatory periods, which show clear differences in bycatch composition. Before 1995, bycatch landings from shrimp fisheries were common. The mandated introduction of the Nordmøre grid in 1995 prevented catching those bycatches as the gear then did not select all larger fish. Only after the voluntary use of a 135mm mesh collection bag over the grid escape was allowed, did bycatch landings resume. The allowance made for using the collection bag is the result of a trial undertaken in 2005, which showed that the number of commercial fishes under the minimum reference length (MRL) did not increase while using the collection bag; therefore, the gear did not heavily impact juveniles of commercial species. The effect on unwanted non-commercial species passing through the grid was also minimal.

Access to report: https://www.hafogvatn.is/is/midlun/utgafa/haf-og-vatnarannsoknir/bycatch-in-icelandic-offshore-shrimp-fishery-hv-2018-45

8.8 Ireland

Bord Iascaigh Mhara (BIM), Ireland's Seafood Development Agency

Contact person: daragh.browne@bim.ie

Summary

Ireland continued to carry out studies related to the landing obligation and avoidance of unwanted catches in 2018.

With a value of €53 million in 2017, *Nephrops norvegicus* is the most commercially important demersal fisheries species landed by Irish vessels. In 2018, unwanted catches of very small whiting (*Merlangius merlangus*), measuring less than 20cm (total length), posed a major challenge under the landing obligation for vessels targeting *Nephrops* in the Irish Sea (ICES Division 7a). BIM conducted three studies which provided important information on this issue. BIM also published a paper in the journal Fisheries Research which demonstrated the benefits of a novel double codend trawl with inclined separator panels in mixed *Nephrops* fisheries.

Vessels targeting mixed demersal fish species also face major challenges under the landing obligation. BIM carried out two important pieces of work in mixed demersal fisheries: an Industry raised fishing line workshop at the flume tank in St John's, Newfoundland; and a study which aimed to assess post capture survival of plaice to support an application for a survivability exemption.

Further BIM work related to the landing obligation included: the production of one page summaries of technical solutions to reduce unwanted catches; and the commisioning of a study to identify potential uses for unwanted catches.

Projects

Assessment of Dyneema floating sweeps and fish scaring ropes in the Irish Sea *Nephrops* fishery

Contact person: Daragh Browne, daragh.browne@bim.ie

February 2018

https://tinyurl.com/Dyneema-sweeps

This study involved assessing Dyneema/floating bridles and fish scaring ropes ahead of twin *Nephrops* trawls as a potential fish bycatch reduction measure. Neither modification directly reduced whiting catches. The floating bridles increased *Nephrops* catches which could assist in postponing choking on whiting in *Nephrops* trawls.

Assessment of an increase in codend mesh size and reduced codend circumference in an Irish *Nephrops* fishery

Contact person: Daragh Browne, daragh.browne@bim.ie

May 2018

https://tinyurl.com/Mesh-size-circumference

This study was conducted on foot of an European Commission proposal to raise the minimum codend mesh size in the Irish Sea *Nephrops* fishery and a North Western Waters Advisory Council (NWWAC) request to assess the implications. Increasing codend mesh size from 80 to 90 mm achieved major reductions in catches of small whiting but also substantially reduced catches of *Nephrops.* Reducing the circumference of 80 mm codends from 120 to 80 meshes round improved selectivity for *Nephrops* but had a limited effect on catches of small whiting.

Assessment of a SELTRA sorting box with 90 mm codend mesh size in the Irish Sea Nephrops fishery

Contact person: Daragh Browne, daragh.browne@bim.ie

October 2018

https://tinyurl.com/bim-90mmSELTRA

This study followed on from the prior study and assessed the effects of a SELTRA sorting box with 90 mm mesh (SELTRA 90) on whiting and *Nephrops* catches. The SELTRA 90 reduced catches of very small whiting by 77% but also reduced market sized *Nephrops* by 19%. The weather was exceptionally calm during the trial (Beaufort force 0 – 2) so the 19% reduction was likely a best-case figure, i.e. larger losses would likely occur during rougher weather.

A game of two halves: Bycatch reduction in *Nephrops* mixed fisheries

Contact person: Ronán Cosgrove, ronan.cosgrove@bim.ie

October 2018

http://tinyurl.com/Game-of-Two-Halves

BIM published a paper in the journal Fisheries Research which demonstrates the benefits of a novel double codend trawl with inclined separator panels in mixed *Nephrops* fisheries. The gear significantly reduced below minimum conservation reference size catches of whiting (27 cm) and haddock (30 cm) while generally maintaining market sized *Nephrops* and fish catches. Highly effective species separation facilitates alternative selectivity measures depending on landing obligation requirements. Additional benefits such as improved catch quality and reduced catch sorting times were outlined.

Irish Fishing Industry Flume Tank Workshop, Newfoundland

Contact person: Matthew McHugh, matthew.mchugh@bim.ie

December 2018

http://tinyurl.com/Flume-Tank

Vessels targeting mixed demersal fish species also face major challenges under the landing obligation due to low quotas of species such as cod and flatfish species. Raising the fishing line from the ground gear provides an option for vessels to reduce unwanted catches of cod, flatfish and skates and rays while boosting landings of whiting and haddock.

Previous BIM trials of this gear were encouraging but post-trial testing revealed some issues with gear performance in rough weather and strong tides so further testing was conducted at a BIM-Industry flume tank workshop in Newfoundland in collaboration with the Centre for Sustainable Aquatic Resources. Major improvements were made to the trawl configuration with detailed information on trawl performance parameters such as spread, opening, tension, and drag collected for future testing in Irish waters.

Plaice survivability

Contact person: Martin Oliver, martin.oiliver@bim.ie

November 2018

http://tinyurl.com/Plaice-Survivability

Plaice pose a key challenge under the landing obligation due to low quotas and traditionally high discard rates in areas such as the Celtic Sea. BIM conducted a study which aimed to assess post capture survival of plaice to support an application for a survivability exemption. No significant difference in survival occurred after five days onshore monitoring of trawl caught plaice when 43% of the test fish were still alive. Results compare well with other plaice survivability studies in north western waters which have been used for exemptions in ICES Divisions 7d,e,f, and g. The BIM study will be used to provide further information in support of the those exemptions and to apply for new exemptions in 7a,b,c, h-k.

Reducing unwanted catches: one-page summaries of technical solutions developed by BIM and the Irish fishing industry

Contact person: Matthew McHugh, matthew.mchugh@bim.ie

August 2018

http://tinyurl.com/Technical-Solutions-Fish

BIM produced a new guide on technical solutions which improve fisheries sustainability and help vessels address EU landing obligation requirements. The guide consists of a collection of one-page summaries or snapshots of successful studies conducted by BIM and the Irish fishing Industry over the last four years and provides key information on reducing unwanted catches in commercially important Nephrops and mixed demersal fisheries. Many of the summaries were originally produced in collaboration with the EU DiscardLess project but have been fine tuned to hone in on key issues affecting the Irish Fishing Industry.

A study to identify potential uses for unwanted catches landed into Ireland under the Landing Obligation

Contact person: Dominic Rihan, dominic.rihan@bim.ie

May 2018

https://tinyurl.com/bim-unwanted-catches

This BIM commissioned report assesses the likely volumes of unwanted catches which may be landed into Ireland under the Landing Obligation (LO). It also identifies potential uses for those catches and analyses these options for their potential to deliver an economic return to fishermen.

8.9 Netherlands

Wageningen Marine Research

Contact person: Pieke Molenaar, pieke.molenaar@wur.nl

Summary

Since last meeting several Dutch gear technology and survival projects of Wageningen Marine Research are in their final phase and the reports will be available soon. Meanwhile new projects are starting focusing mainly on reducing unwanted bycatch in the brown shrimp and demersal flatfish fishery. As electric pulse fishing is banned from 2012 by the European parliament several studies on the effects of both sole pulse and shrimp pulse fishing are still on going and results are expected by the end of 2019. Innovative automated monitoring systems for rays in commercial fisheries are developed and in the pelagic fishery projects focus on species separation by improving the fish classification from the acoustic broadband echo sounder.

Discard survival flatfish and rays

Contact person: Pieke Molenaar, pieke.molenaar@wur.nl; Edward Schram, edward.schram@wur.nl

August 2016 – May 2019

Discards survival probability in conventional commercial 80 mm pulse fisheries was assessed for undersized plaice (Pleuronectus platessa n=558), sole (Solea solea n=274), turbot (Scophthalmus maximus n=111), brill (Scophthalmus rhombus n=90), thornback ray (Raya clavata n=99) and spotted ray (Raya montagui n=23). Besides conventional discard survival assesment, measures to promote discard survival were assessed under commercial fishing conditions. Measures tested were a water filled hopper (8 sea trips), short hauls (90 instead of 120 min, 4 sea trips) and a knotless cod-end (1 sea trip) for undersized plaice.

In total nine sea trips were performed on three commercial pulse-trawlers with three trips per trawler. Reflex impairment and damages were assessed for all test fish and summarized in a vitality index score indicating fish condition. The total monitoring period ranged from 15 to 18 days among test-fish depending on the day of collection at sea. Control fish, fish of the same species and in good condition collected in advance at sea, were deployed during all sea trips. Discards survival probabilities were estimated from counts of surviving fish at the end of the monitoring period. Work in progress includes an assessment of the effects of the conditions at sea and characteristics of the fisheries (abiotic variables) on survival probabilities and development of a model that predicts survival probabilities based on reflex impairment and damage scores. Reports, fact sheets and infographics are available here: http://www.wur.eu/fishsurvival

Pulse trawl impact assessment

Contact person: Adriaan Rijnsdorp, adriaan.rijnsdorp@wur.nl

January 2016 – December 2019

In the North Sea an experimental fishery is currently taken place using electrical stimulation to catch sole. The vessels operate under a temporary derogation from the EU. Previous research indicated that pulse fishing may improve the selectivity reduce the ecological impacts (van Marlen et al. (2014). However, there is widespread concern among stakeholders about possible detrimental effects. In order to provide the scientific basis for an assessment of the contribution of pulse fishing to a more sustainable fishery, a 4-year research project started in 2016.

The overall aim of this project is to assess the long-term impact of the commercial application of pulse trawls in the North Sea flatfish fishery. In order to fulfil the overall aim, predictive models of the effect of electric pulses on organisms and on different ecosystem components will be developed and applied. The results will be integrated to assess the consequences of a transition in the flatfish fishery from using tickler chain beam trawls to pulse trawls on the bycatch of undersized fish (discards) and the adverse impact on the North Sea ecosystem.

The research project comprises of four interrelated work packages using a variety of complementary approaches, that will ultimately to an integration in a 5th work package (Figure 8.9.1).

WP1 will carry out laboratory experiments and develop predictive models. Models will be developed of (i) the electrical fields generated by pulse trawls under different environmental conditions and (ii) the electrical fields inside marine organisms. Laboratory experiments will be conducted on the effect of electrical pulses on the behaviour of a selection of marine organisms. To cope with the diversity in species that will be exposed to pulse trawl fishing in the North Sea, species will be classified according to their building plan that determines their sensitivity to electrical stimulus. Fish samples of the various groups will be collected on board of commercial pulse trawlers and analysed for injuries. Collected data will be compared to modelling results to optimize and fine tune the boundary conditions and to estimate confidence intervals for model simulations.

WP2 will carry out field and laboratory experiments on the effect of electric pulses on the functioning of benthic ecosystems, and develop predictive models how ecosystem functioning is affected by pulse trawling. Field samples of the sea bed will be taken from stations before and after pulse trawling.

The species composition and functional characteristics will be determined, and the samples will be exposed to electrical stimulation or mechanical disturbance to measure the effect on geochemical fluxes.

WP3 will develop the tools to integrate the results of WP1 and WP2 in a spatially explicit predictive model of the distribution of fishing activities of pulse trawl fishers and its consequences for the catch, bycatch, and species that are not retained but come into contact with the electric field as well as the impact benthic ecosystem.

In WP4 the results obtained in WP1 – WP3 will be synthesised in an Impact Assessment that will quantify the consequences of a transition of the flatfish fleet from tickler chain beam trawls to pulse trawls. Consequences will be assessed in terms of the bycatch and the impact on the benthic ecosystem (fish and benthic invertebrates). In order to be able to respond to the topics raised in the stakeholder interactions the integration will be organised in a flexible manner to investigate the effects of pulse trawling on the marine ecosystem. The project comprise of four work packages (figure 8.9.1) dealing with the effects of electrical stimulation on marine organisms, both fish and invertebrate species; the effect on the functioning of the benthic ecosystem; the scaling up of the local effects to the effects at the scale of the fisheries and management area; final impact assessment of the transition of the fishery using mechanical stimulation (tickler chain beam trawls) to electrical stimulation (pulse trawls).

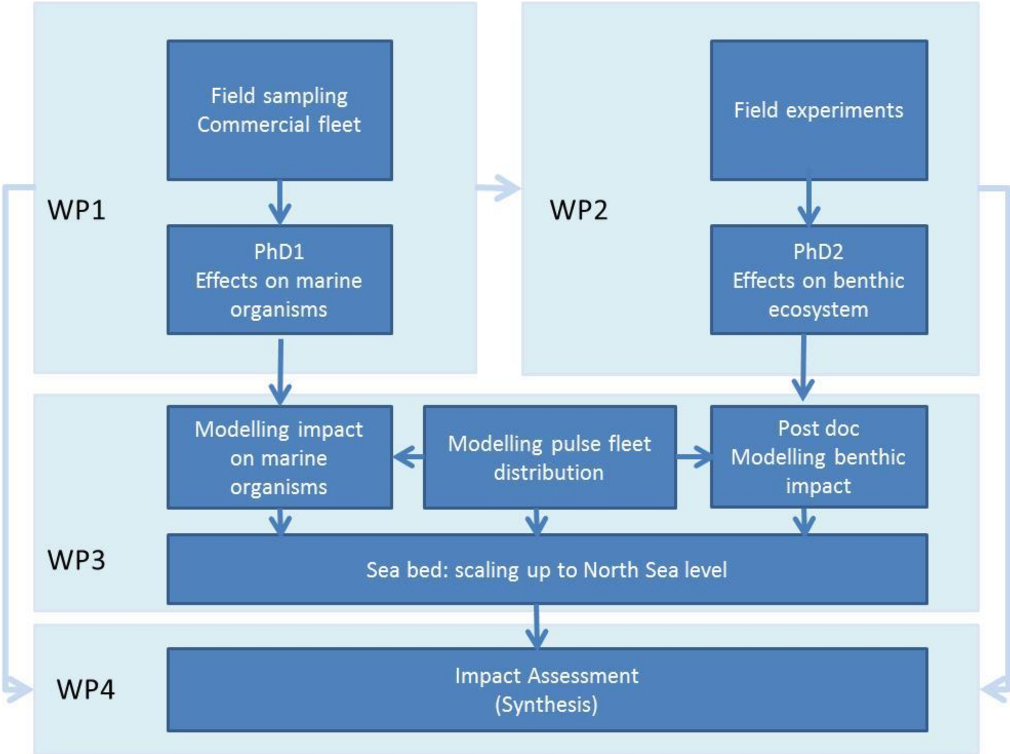

Figure 8.9.1.Relationship and flow of information between the work packages

SEPCRAN

Contact person: Pieke Molenaar, pieke.molenaar@wur.nl ; Jimmy van Rijn, jimmy.vanrijn@wur.nl;

August 2018 – April 2019

Project partners: Thuenen Institute (GE), WMR (NL)

This project is a continuation of the Dutch/German collaboration on SEPCRAN sorting grids in 2017 aiming on reducing bycatch of small shrimp in the North Sea brown shrimp fishery (*Crangon crangon*). Scientist from WMR and the Thuenen Institute tested three rigid grids on board of the RV Solea. The experimental grids were made of different materials (fiberglass, plastic and steel) and with differences in bar thickness. In addition to vertical zonation of shrimp catch in a shrimp trawl and the effect of a sieve net and guiding panel were studied.

Optimization selectivity electrified beam trawls by modifying electric pulse settings

Contact person: Pieke Molenaar, pieke.molenaar@wur.nl ; Jimmy van Rijn, jimmy.vanrijn@wur.nl;

Duration: 2018 - 2019

In the electrified beam trawl (pulse) fishery size selectivity of the target species sole (*Solea solea*) and plaice (*Pleuronectes platessa*) could be improved by modifying the electric pulse characteristics. Changing the pulse duration, frequency and voltage of a pulse module could provoke a different reaction in size classes of the target species and thus the selectivity of the fishing gear. In a large salt water basin a commercial pulse electrode setup was towed along sole and plaice of different size classes at towing speeds comparable to pulse fishing practices at sea. One setting was experimentally modified while the other variables remained on their commercial setting. In those controlled experiments the effect of changing the pulse frequency, duration and voltage were tested on sole and plaice. Their response during and after the exposure was captured on video and analyzed.

Selectivity of pulse trawling on brown shrimp

Contact baseline measurements 2018: josien.steenbergen@wur.nl & jimmy.vanrijn@wur.nl
Contact innovation experiments 2019: Maarten.soetaert@ilvo.vlaanderen.be, mattias.van-opstal@ilvo.vlaanderen.be

Duration: 2018 - 2019

Project partners : WMR (NL), ILVO (BE) and Thuenen Institute (GE)

This EFMZV project was started with the specific aim to assess the differences in impact of pulse trawling on brown shrimp compared to the traditional beam trawl in N2000 areas. All five pulse trawlers on shrimp (HA31, ST24, TH10, WR40 and WR109) were involved, although the WR109 served as reference vessel since he had too much technical problems with his (new developed) pulse gear.

During the first year of the project, so called '0-measurements' were done, in which the catches of the pulse trawlers were compared to their traditional fishing colleagues. This was done in three ways. First, there was a continuous data recording in which the skipper determined the total catch volumes based on the height of the catch in the hopper as well as the commercial catches of shrimp. This was done for every haul, including the time and location. The data of the pulsetrawler fishing with 2 pulse trawls was compared with that of a buddy, fishing with 2 traditional trawls.

Next, the pulse trawl was obliged to switch 1 pulse gear for a traditional trawl, allowing for a direct catch comparison several weeks per quarter. During this period, 'selfsampling' was done during several weeks every quarter during which the vessels were fishing with a traditional gear at one side of the vessel and a pulse trawl at the other. During these trips, catch volumes and commercial catches were logged again from both sides (pulse & traditional) and samples of both catches were collected which were sorted and analyzed in the lab. Last, observer trips were carried out in junction with the selfsample trips during which an on board catch comparison was done between the pulse gear and the traditional gear.

This approached guaranteed a continuous monitoring on haul-level combined with a detailed catch comparison with selfsampling or observer trips once every quarter for every vessel. This way, an good spatial and temporal distribution of the data is obtained.

In 2019, the second year of the project, a similar approach will be used to do 'innovation experiments' during which fishermen will be allowed to make adaptations to their net, electrodes or to some extend pulse settings in order to optimize the selectivity of their gear. Therefore, fishermen will keep 1 pulse trawl unchanged (identical configuration as defined within the technical limitations and used for the base line measurements in 2018) while testing their innovation in the other trawl. To compare both gears, selfrecording will be done by the vessel comparing his both catches, and observer trips will be done for an in-depth analysis of the catches once the fishermen have indicated that they have optimized their adaptation.

Practical trials with cutaway brown shrimp otter trawls

Contact person: Pieke Molenaar, pieke.molenaar@wur.nl

Duration: April 2019 – January 2020

With the restoration of the free flowing connection between the large European river Rhine and the North Sea there are enhanced opportunities for migratory fish species. This project aims compare the catch performance of three designs of a brown shrimp otter trawl with a conventional brown shrimp beam trawl in the proximity of the river entrance. Two of the otter trawl designs will have a recessed head rope that may enable migratory fish to escape from the trawl. The commercial trials are planned for the summer for 2019.

Industry-science collaboration for developing selective devices in the brown shrimp fishery

Contact person: Pieke Molenaar, pieke.molenaar@wur.nl

Duration: March 2019 – March 2021

The Dutch brown shrimp fishery in collaboration with Wageningen Marine Research is aiming to improve selectivity by reducing unwanted bycatch of small shrimp, small flat fish and round fish in the Waddensea. For each species a special solution will be tested including innovative sorting grids, escape panels alternatives for the sieve net. All trials will be performed on commercial vessels under their conventional fishing practices. First trials are expected in May 2019.

Reducing fishing mortality of unwanted bycatch in the Dutch demersal fisheries

Contact persons: Pieke Molenaar, pieke.molenaar@wur.nl, Edward Schram, edward.schram@wur.nl

Duration: March 2019 – March 2021

In a research collaboration between the Dutch fishing industry and Wageningen Marine Research technical innovations are developed and tested for reducing fishing mortality of unwanted bycatch. Reducing fishing mortality could be achieved by either a selective trawl/device or by improving the survival chances of unwanted bycatch after capture. A fisheries innovation model is used for structural stepwise development and testing of the proposed innovations. Initial testing and data collection will be performed by the fishers, subsequently detailed data is collected by scientific observers. The project aims to improve discard survival or reduce bycatch of undersized plaice in the pulse and beam trawl fishery for sole (BT2), reduce bycatches of undersized whiting in Scottish seining (flyshoot TR2) and further develop the SepNep concept and Swedish grid to reduce catches of undersized Nephrops and plaice in the Nephrops fishery.

KB Towards a better understanding of Fishers' Behaviour

Contact person: Marloes Kraan, marloes.kraan@wur.nl

January 2016 – December 2019

Since 2016 we are working on our 'Towards a better understanding of Fishers' Behaviour project (funded by Knowledge base funds of WMR and WEcR). The project aims at developing a new transdisciplinary theoretical framework on fishers' behaviour and will develop new ways of collecting and analysing data of fishers' behaviour. The rational for the project is that successful fisheries management requires a thorough understanding of "fishers' behaviour", the collective set of decisions made every day on board of fishing vessels. Sudden and drastic changes in fisheries management, as e.g. in the case of the current implementation of the European landing obligation, poses the challenge whether our current knowledge of fishers' behaviour is sufficient to forecast changes in fisheries. There is consensus that it is unclear how fishers will respond to new rules and regulations.

We have taken up doing a replication study of the research done by Boonstra and Hentati-Sundberg (2016) Classifying fishers' behaviour. An invitation to fishing styles. In 2018 we have done the quantitative analysis and then started interviewing fishermen (qualitative part). We made a subselection – focusing on the Dutch demersal cutter fleet, as the Dutch fishery is much more diverse than the Swedish (central in Boonstra paper). This year we will analyse the qualitative data and write a joint analysis describing the fishing styles in the Dutch demersal cutter fleet. We have also planned on writing a methological paper on doing this replication study. In the meantime we are discussing the application of fishing styles for science and policy.

Trawl innovation in demersal fisheries 2

Contact person: Pieke Molenaar, pieke.molenaar@wur.nl , Maarten Soetaert Maarten.soetaert@ilvo.vlaanderen.be

January 2016 – March 2019

Project partners : WMR (NL), ILVO (BE)

This follow-up project was initiated by the Dutch cooperation "De Nederlandse Vissersbond" to enhance gear selectivity and release as many undersized fish as possible in four Dutch fisheries as a reaction to the EU Landing Obligation on discards.

In 2018 innovative gear designs were tested in the following fisheries: sole pulse trawl, Nephrops quad-rig, and fly-shoot. Following the design phase a number of gear configurations were tied out on various commercial trawlers. Initial tests will be done using self-sampling protocols and underwater recordings, in some cases followed up by a detailed catch comparison with Wageningen Marine Research or ILVO scientists onboard. The trials included dyneema rope separation panels, double fish herding brush footropes, high preasue air bubble thicklers and the electic benthos release panel in the sole fishery. In the Nephrops fishery the selective SepNep trawl was optimized and a modified swedish grid was tested in the dutch fishing grounds. In the fly-shoot fishery a extended square mesh escape panel was tested.

INNORAYS - Innovative monitoring for rays

Contact person: Edwin van Helmond, edwin.vanhelmond@wur.nl

March 2018 – December 2019

With the potential to enhance data collection programs, Electronic Monitoring (EM) also has the ability to improve data collection for gear technology trials. In particular, species with a lower abundance in the catch or specific fisheries would benefit from a system like EM, the wider coverage of the fleet enabling data collection, which are notably difficult to cover with a traditional observer program, e.g. accidental bycatch of (rare) species, long-distance or small-scale fisheries. However, still a considerable amount of time is needed to manually review video data. To improve this process there is potential for improving species identification and automated recording in REM by making use of computer vision technology. Wageningen Marine Research finalized the first steps in the development of automated monitoring for different rays species in the Dutch North Sea fisheries. An algorithm is developed to recognize and recorded 3 different rays species. The second project phase will start in the second half of 2019.

Ecosystem acoustics

Contact person: Benoit Berges, benoit.berges@wur.nl; Serdar Sakinan, serdar.sakinan@wur.nl

January 2019 – December 2019

The project investigates the school forming behavior of Atlantic herring based on the data collected with multi beam fisheries echo sounder (Simrad ME70) during the North Sea herring survey. 3D shape of the detected fish schools are constructed and characterized based on this data. The project, while aiming to improve species identification during scientific surveys based on such behavioral characteristics, is also expected to inform commercial fisheries for more selective fishing.

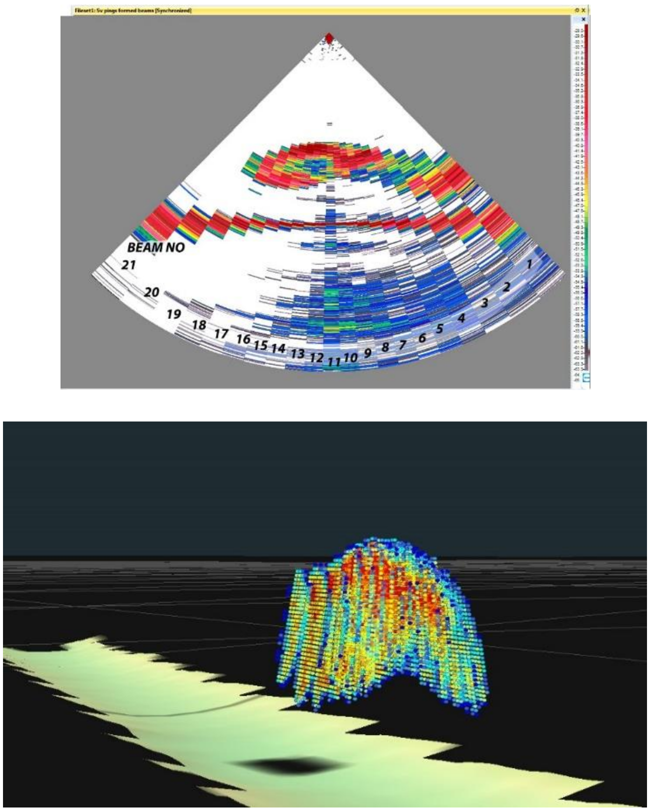

Figure 8.9.2. Impressions of the GoPro net camera system and camera snapshots associated with acoustic records.

Real time fish classification from acoustic broadband echo sounder

Contact person: Benoit Berges, benoit.berges@wur.nl;

January 2016 – December 2019

Newest generation echo sounders utilise broadband technology that can transmit a continuous frequency band in one ping. This technology allows for considerable improvement in range resolution while enabling detailed characterisation of the backscattering spectra. This is important in distinguishing between different species which can help decision making during fishing operations to improve selectivity. A diverse range of information has been collected during the project so far including data for herring, mackerel and horse mackerel from different areas in the North Atlantic and the North Sea at different depths and different seasons, different time of the day and from different vessels. Data contain interesting information on schooling behaviour of aggregated fish as well as dispersal of the individual fish during the night time.

8.10 Norway

Institute of Marine Research

Contact person: Svein Løkkeborg, sveinl@hi.no

Projects
CRISP (Center for Research-based Innovation in Sustainable fishing and Processing technology)

Contact person: Aud Vold, aud.vold@hi.no

June 2019 – June 2010

http://crisp.imr.no/

For nearly 8 years CRISP has developed smart technologies for more responsible trawl and purse seine fishing. The CRISP consortium consists of innovative industry companies and research institutes working together to increase value creation through developing "green" technologies and fishing methods. It has responded to several global challenges faced by the fishing industry. The philosophy of CRISP has been to develop technologies and tools that enables fishermen to take informed decisions on how to harvest the ocean in an eco-friendly manner and at the same time improve catch quality and value.

This has been done in several ways: by developing instruments for pre- and early-catch identification of fish species, size and school volume and for monitoring the fishing gear during capture; by development of environmentally friendly and selective fishing gears, as well as developing gentle capture and handling methods which improve catch quality and income. The pre-catch identification systems developed enables fishermen to avoid catching non-target species or sizes. Monitoring systems that visually and automatically identifies the catch inside the gear (e.g. the

Deep Vision technology) may be linked to active selection devices and thereby reduce bycatch and discarding. Gear modifications and new handling methods may substantially affect fish welfare and thereby also the potential survival of released catch and improved quality of landed fish.

Deep vision

Contact person: Shale Rosen shale.rosen@hi.no, Håvard Vågstøl havard@deepvision.no www.deepvision.no/deep-vision/deep-vision

The Deep Vision in-trawl camera system is now in use as a survey tool for the Institute of Marine Research. Images can be read directly into the LSSS software system when analyzing acoustic data, providing an overlay of the trawl's path and images for verification of the species observed acoustically. A convolutional neural network has been trained to automatically identify three species (Altlantic mackerel, Atlantic herring and blue whiting) from Deep Vision images, results published in ICES Journal of Marine Science (https://doi.org/10.1093/icesjms/fsy147).

Work is ongoing to optimize the techniques and expand to additional species. Scantrol Deep Vision continues to work on automating length measurements from the stereo images and design and testing of a mechanical sorting device to be paried with Deep Vision in a trawl

Catch control in the commercial fishery for blue whiting

Contact person: Shale Rosen, shale.rosen@hi.no, Ólafur Ingolfsson olafur.arnar.ingolfsson@hi.no, Terje Jörgensen, terje.joergensen@hi.no

The commercial pelagic trawl fishery for blue whiting (*Micromesistius poutassou)* in the northeast Atlantic Ocean west of Ireland is challenged by difficulty controlling catch quantities, with catches sometimes exceeding 1000 tons in a single haul. This leads to problems of safety and on occasion burst codends. Even with smaller catch quantities, the dynamics of the trawl during heaving are complex, with the ascending trawl sometimes pulling the vessel backwards. A feasibility study carried out in March 2018 outfitted a blue whiting trawl with a number of depth sensors and cameras to record trawl geometry and ascent during heaving. Ascent of the codend was generally constant (mean 0.3 – 0.4 m/s) from the fishing depth to 100 - 200 m depth, at which time the rate of ascent increased dramatically to on average 1.4 - 2.2 m/s, max 4 m/s. Video observation confirmed that the codend breaks the surface with significant force, creating a large wave visible at 800 m distance from the vessel. Workshops with industry and managers have led to a multi-year follow-up project which will investigate best practices for heaving the codend, controlling the amount of fish captured, and reducing danger to the crew and vessel at key moments during fishing operations. A report from the feasibility study is available at https://www.hi.no/hi/nettrapporter/fangstkontroll-i-kolmuletral--forstudie-2 (in Norwegian with English summary).

Catch control in purse seine fisheries

Contact person: Maria Tenningen, maria.tenningen@hi.no and Mike Breen, Michael.breen@hi.no

May 2017 – May 2021

https://www.sintef.no/fangstkontroll

This is a four-year project funded by the Norwegian Seafood Research Fund and a co-operation between Sintef, IMR and Nofima. The aim of the project is to improve catch control in purse-seine fisheries by developing instruments and methods that provide fishers with better decision-making tools during the capture process. These tools include visualization of the gear and the catch, development of acoustic and optic catch identification technologies and indicators of catch condition. As part of this and other projects, IMR has now developed a catch monitoring platform (CMP) that can be used to monitor and characterise the catch (i.e. species composition, individual size and behaviour), as well as describe environmental conditions in the net (i.e. temperature and dissolved oxygen concentrations). The CMP currently contains a ctd, 360° camera and a GoPro camera and is being further developed in 2019 to inculde a stereo camera and live data transfer. Acoustic catch monitoring methods are being developed in cooperation with Simrad (Kongsberg maritime AS) and deploying monitoring instruments in the seine are currently being tested.

The project also aims to develop indicators of fish stress and vitality in commercial purse seine fishing, to maximise quality, if the catch is retained, or survival, if the catch is to be released. Controlled experiments at HI's laboratory facilities in Austevoll are being conducted to determine how capture stressors affect mackerel.

Semi-pelagic trawling

Contact person: Ólafur Arnar Ingólfsson, olafuri@imr.no and Terje Jørgensen, terjej@hi.no

Comparative fishing trials with a Campelen 1800 trawl (the standard survey trawl at the IMR) fished with bottom and semi-pelagic rigging (trawl and part of the sweeps on the bottom, doors off) was carried out in November 2018 on board the RV «G. O. Sars». Sweep angles and the length of the sweeps in contact with the bottom the same for the bottom and semi-pelagic hauls. This was obtained by using a sweep length of 100 m when bottom trawling and 160 m when trawling semi-pelagically. In addition, a 12 m long constraining rope was used on the warps 200 m in front of the doors. The length of the sweeps that had bottom contact was verified by the use of chain and tape. Simrad sensors were used to monitor door height as well as pitch and roll. The targeted door height above sea bottom during semi-pelagic trawling was 10 m.

Catch rates of commercial sized fish was generally low during the experiment, particularly for haddock. Analysis of the catch data showed reduced catches of both cod and haddock for the semipelagic compared to standard demersal rigging. For cod the catch loss was 35-40% with no significant relation to fish size. For haddock, the relative catch loss was estimated at approximately 60%. Also for haddock, the effect of fish size on catch loss was insignificant.

As the sweep angles and length of the sweeps that had bottom contact were identical for the bottom and semipelagic rigging, the horizontal sweep-distance at the point of foremost bottom contact was the same with the doors on (= door spread) and off bottom. The present study thus suggests that the herding stimuli generated by trawl doors at (or possibly close to) the bottom are essential for the catch efficiency during bottom trawling.

Trawl modification for improving size selection in the shrimp fisheries

Contact person: Ólafur Arnar Ingólfsson, olafuri@imr.no and Terje Jørgensen, terjej@hi.no

Discards of small northern shrimp (*Pandalus borealis*) are a problem in the Skagerrak trawl fisheries. To reduce catches of small shrimp, we studied the effect of trawl belly length on size selectivity in November 2017 and June 2018. Two fishing experiments were performed on board 15 and 27 m long commercial shrimp trawlers, comparing the selectivity of the vessels' standard trawls to that of otherwise identical trawls with 37% shorter bellies in twin-trawl experimental setups. The trawls had bottom panels of 40 mm and codends of 35 mm nominal mesh sizes. The trawls fished shrimps above 19 mm carapace length equally, while catch rates of shrimp below 15.5-16 mm carapace length in the shorter trawl were more than halved. The results were consistent across experiments. In short, modifying trawl length is a simple design modification that reduces catches of small shrimp.

Using artificial light in fish pots

Contact person: Svein Løkkeborg, sveinl@hi.no; Anne Christine Utne Palm, annecu@hi.no; Odd-Børre Humborstad, odd-boerre.humborstad@hi.no

This project aims at finding a method to attract krill to cod pots, where the krill will act as a motivating bait for cod to enter the pot. A fishing trial was carried out in 2016 comparing pots with white and green light and squid bait with pots baited with squid bait only. White light was tested at two different intensities (low 3 mW/m^2 and high 15.000 mW/m^2), while green was only tested at low intensity (0.3 mW/m^2). High intensity white light gave the best result with catches up to 200 kg of cod in one pot. In 2017 and 2018 the same fishing trials were repeated, but this time we tested white and green light of intermediate intensity (500 mW/m^2) comparing them with the white high intensity (15.000 mW/m^2) to see if we could get high catches rates also with lower intensity/energy use. Surprisingly we found that intermediate of both green and white light gave higher catches than the high intensity white light.

Using artificial light in snow crab (*Chionoecetes opilio*) pots

Contact person: Khanh Nguyen, khanh.nguyen@mi.mun.ca, Odd-Børre Humborstad, oddb@hi.no, Svein Løkkeborg, sveinl@hi.no, Paul Winger, Paul.Winger@mi.mun.ca

In 2017 and 2018, experiments were conducted in the Barents Sea with the aim of investigating the effects of adding led lights to crab pots to increase the catch rates. Results showed that pots with purple lights harvested a 12% higher catch per unit effort (CPUE; number of crab per pot) of legal-sized crab than control pots, while pots with white light did not catch significantly more crab. Although purple LEDs increased snow crab capture, the economic benefits of using underwater lights in pots remains unclear given the high capital investment required. In 2019 we aim to further investigate efficiency measures, measures to prevent bycatch of undersized specimens and to introduce measures to prevent ghost fishing in the Barents Sea. These include (but not limited to) testing of a number of new pot designs, escape openings and biodegradable panels in the pots.

Current resistant two-chambers pots

Contact persons: Odd-Børre Humborstad, odd-boerre.humborstad@hi.no; Anne Christine Utne Palm, annecu@hi.no; Svein Løkkeborg, sveinl@hi.no

Catch rates of the two-chamber pot is negatively affected by increasing water current, and video observations have revealed that the pots do not perform well at high current speeds as they get deformed or collapse. In June 2018 the two-chamber pot was modified to resist strong currents by adding an extra rope to the middle frame, lead weights to the bottom frame and floats to the top frame. The effect of this new rigging was recently tested in a comparative fishing trials, where we got higher catches in the current-resistant pots as compared to standard pots at high current speeds. In 2019 fishermen in Northern Norway will test the modified two-chamber pots versus standard pots and compare catches with gillnet and longline catches from same region. In the same experiments' new trials with artificial light in the pots will also be conducted.

Alternative longline baits

Contact person: Svein Løkkeborg, sveinl@hi.no

The most common bait types (mackerel, herring, squid, saury) used by the Norwegian longline fleet are also used for human consumption. Bait prices have increased over the last years due to increased demand for marine food resources, and bait costs comprise a significant proportion of the total costs for the longline vessels. An initiative has therefore been taken by the industry to develop an alternative longline bait that is not based on resources used for human consumption. This collaborative project involves three commercial companies and two research institutes (Institute of Marine Research and Nofima Marin). Two of the companies have developed baits with different scent and flavour that have been tested in behavioural studies and fishing trials for cod. Some of the bait types tested showed promising results. New fishing trials will be carried out during fall 2018.

SINTEF Ocean

Projects

Effect of three different codend designs on the size selectivity of juvenile cod in shrimp trawl fishery

Contact person: Bent Herrmann, Bent.Herrmann@sintef.no; Roger B. Larsen, Roger.Larsen@uit.no ; Jesse Brinkhof, Jesse.Brinkhof@uit.no

Shrimp trawlers use often a Nordmöre sorting grid ahead of a small-mesh codend to avoid by-catch of fish juvenile while shrimps are efficiently caught. However, small fish can pass through the grid to enter the codend and risk being retained. The risk for retention for fish of different sizes depends the size selection in the Nordmöre grid and the size selection in the subsequent codend, which makes the process complex and often results in a bell-shaped size selection curve. In the Barents Sea shrimp fishery, cod is one of the species causing concern because of its great commercial value. We studied the size selection of juvenile cod when the trawl was equipped with the compulsory gear in the fishery: a 19 mm Nordmöre grid followed by a 35 mm diamond mesh codend. As expected, the size selection curve showed a bell-shaped signature with a certain size range of juveniles having high retention risk, while the risk for smaller and bigger cod decreased. The retention risk was highest for cod between 12 and 20 cm in length. We also tested two alternative designs in the aft of the gear: a codend with 35 mm square mesh panels and a square mesh sorting cone section. None of these designs affected the size selection in the trawl significantly.

Effect of gear soak time on size selection in the snow crab pot fishery

Contact person: Bent Herrmann, Bent.Herrmann@sintef.no; Eduardo Grimaldo, Eduardo.Grimaldo@sintef.no

In the commercial pot fishery for snow crab (*Chionocetes opilio*), size selection by the pots is important for reducing catch sorting and unintended mortality. In addition to mesh size and shape, selection in the pots relies on every crab contacting the netting meshes, which makes the process complex because the odour of the bait tends to keep all sizes of crab in the pots. Thus, soak time may affect the extent of the use of the selective potential of the pots. This study was designed to assess the influence of soak time on size selectivity, and the methodology was applied to snow crab data collected in the Barents Sea. The results showed that a minimum soak time is required to reach the full size-selective potential of the pots. Specifically, a fraction of the small crabs inside a pot will not attempt to escape through the pot meshes when the pots are soaked for short periods of time (under nine days). Further, with short soak time, some of the crabs inside a pot will not make selectivity contact with the netting. Therefore, some crabs will not utilize the escape options through the pot meshes. This finding confirms the need for using a selection model that explicitly accounts for such a process when assessing snow crab size selection. Lastly, this study outlines how the concept of selectivity contact can formally be applied to model the effect of soak time on the size selectivity of the snow crab pot fishery.

External damage to trawl-caught northeast arctic cod (*Gadus morhua*): Effect of codend design

Contact person: Guro Moen Tveit, Guro.Tveit@sintef.no ; Bent Herrmann, Bent.Herrmann@sintef.no; *Jesse Brinkhof*, Jesse.Brinkhof@uit.no

The purpose of this study was to investigate the extent of external damage (gear marks, pressure injuries, ecchymosis and skin abrasion) present on trawl-caught cod (*Gadus morhua*) and to examine whether the extent of damage could be reduced by introducing changes in the gear. We tested whether changing the 2-panel knotted codend used by the Norwegian trawler fleet operating in the Barents Sea today to a 2-panel knotless codend or a 4-panel knotless codend could decrease the extent of external damage to the fish in the catch. We evaluated 720 fish over 12 hauls carried out with a twin trawl setup and found that the probability for cod to be without any external damage was 9.4% (4.7%–15.8%) with the codend used in the fishery today. Thus, most fish in these catches are likely to have slight or moderate damage. Gear marks were the most frequent type of damage, with only 11.5% (6.0%–18.9%) of the cod being free of this type of injury. When gear marks were not considered in the analysis, 68.4% (58.8%–78.3%) of the fish was estimated to be flawless. Replacing the knotted netting in the codend increased the probability of obtaining fish without gear marks to 15.5% (6.2%–28.0%). However, the confidence intervals were wide, and this effect was not statistically significant. For the other three damage types, the estimated effects of changing the design of the codend were small and not statistically significant. Changing from a 2- to 4-panel codend was estimated to reduce the probability for gear marks by a further 1.7% (−13.4%–16.8%). However, this increase was not significant. Overall, the two codend design changes tested in this study did not significantly decrease the external damage present on trawl-caught cod.

Quantification of bell-shaped size selectivity in shrimp trawl fisheries using square mesh panels and a sorting cone after a Nordmöre grid

Contact person: Bent Herrmann, Bent.Herrmann@sintef.no; Roger B. Larsen, Roger.Larsen@uit.no ; Jesse Brinkhof, Jesse.Brinkhof@uit.no

Shrimp trawlers in the Barents Sea use a Nordmöre sorting grid ahead of a small-mesh codend to avoid bycatch while catching shrimps efficiently. However, small fish can still pass through the grid to enter the codend, which increases their risk of being retained. In this study, we quantified the selectivity of a standard Nordmöre grid used together with one of two different codend designs, namely a diamond mesh codend with square mesh panels and a codend with a square mesh sorting cone section, for deep-water shrimp (*Pandalus borealis*), redfish (Sebastes spp.), and American plaice (*Hippoglossoides platessoides*). For the first time, the selective properties of these two alternative designs were estimated and compared to those of a Nordmöre grid used together with a 35-mm diamond mesh codend, which is the compulsory gear used in the fishery today. With this traditional codend, the size selectivity of both bycatch species showed the expected characteristic bell-shaped size selection pattern, with low retention probability of very small fish and bigger fish but with high retention probability of certain sizes of juveniles. Using the square mesh sorting cone significantly reduced the maximum retention risk of redfish. The maximum retention with the diamond mesh codend with square mesh panels was estimated to be 14% lower than that of the traditional codend, but the difference was not statistically significant. The two alternative codend designs did not result in any significant reduction in bycatch of American plaice.

SMARTFISH H2020

Contact person: Bent Herrmann, Bent.Herrmann@sintef.no; Rachel Tiller, Rachel.Tiller@sintef.no;

Sintef Ocean is coordinating an EU H2020 project SMARTFISH with 18 partners in total. SMARTFISH runs for four years and started 2018. The objective of SMARTFISH is to develop, test and promote a suite of high-tech systems for the EU fishing sector, to optimize resource efficiency, to improve automatic data collection for fish stock assessment, to provide evidence of compliance with fishery regulations and to reduce ecological impact. SMARTFISH exploits technological developments in machine vision, camera technology, data processing, machine learning, artificial intelligence, big data analysis, smartphones/tablets, LED technology, acoustics and ROV technology to build systems for monitoring, analyzing and improving processes for all facets of the fishing sector, from extraction, to assessment, to monitoring and control. The SMARTFISH systems will:

- Assist fishermen in making informed decisions during pre-catch, catching, and post-catch phases of the extraction process. This improves catch efficiencies and compositions in fisheries across the EU, leading to improved economic efficiency while reducing unintended fish mortality, unnecessary fishing pressure and ecosystem damage.
- Provide new data for stock assessment from commercial fishing and improve the quality and quantity of data that comes from traditional assessment surveys. This provides more accurate assessment of currently assessed stocks and allow the assessment of data-poor stocks.
- Permit the automatic collection of catch data to ensure compliance with fisheries management regulations.

The SMARTFISH systems are tested and demonstrated in several EU fisheries. This contributes to promoting the uptake of the systems by extraction sector and fisheries agencies. An interdisciplinary consortium with technology developers and instrument suppliers, fishing companies, research and fisheries management institutes and universities will realize SMARTFISH.

Catch control in purse seine fisheries

Contact person: Joakim Haugen, Joakim.haugen@sintef.no

SINTEF Ocean's activity in this project in 2018 pertained to further developments of the data acquisition system "Ratatosk" for instruments on board fishing vessels. This system now offers support for logging new signal types, such as doppler current profiler and basic school information from sonar. A portable wireless mesh network extends the data collection so that smart sensor data on deck can be collected and shared in real time. We developed a simple hardware device to measure purse winch speed and connected it with Ratatosk using the mesh network. Effort has also been made to enable data-sharing with third-party scientific behavior analysis software in real time.

Effect of pot design on the catch efficiency of snow crab (*chionoecetes opilio*) in the Barents Sea fishery

Contact person: Bent Herrmann, Bent.Herrmann@sintef.no; Eduardo Grimaldo, Eduardo.Grimaldo@sintef.no

The snow crab (*Chioneocetes opilio*) fishery in the Barents Sea is carried out by large offshore vessels, as the fishing grounds are located far from shore and the gear must be transported back and forth over long distances. Therefore, fishermen use stackable conical pots that allow large numbers of pots to be carried on deck for each trip. One of the drawbacks of using stackable pots is that the entrance is at the vertex of the conical pot, which fishermen claim does not provide the desired fishing efficiency. Thus, the goal of this study was to determine whether a different pot design would improve the catch efficiency of snow crabs. We investigated the efficiency of a new type of pot called the moon pot, which provides increased bait odour intensity as snow crabs make their way towards the entrance of the pot. This alteration was expected to increase catch efficiency compared to that of the conical pots used by the fleet today. However, experimental fishing results showed that the modified pots had significantly lower catch efficiency than the standard conical pots, as only ~65% of the number of crabs caught by the conical pots were caught in the moon pots. The main reason for this reduced catch efficiency likely was the initial steepness of the moon pot, which may have made it difficult for crabs to reach the pot entrance. These results demonstrated that pot design can dramatically affect catch efficiency of snow crabs.

A comparative study of mechanical properties of biodegradable PBSAT and PA gillnets in Norwegian coastal waters

Contact person: Biao Su, biao.su@sintef.no; Heidi Moe Føre, heidi.moe.fore@sintef.no; Eduardo Grimaldo, eduardo.grimaldo@sintef.no

This is comparative study of mechanical properties of biodegradable PBSAT (polybutylene succinate co-adipate-co-terephthalate) and conventional polyamide (PA) gillnets used in Norwegian fisheries. Field tests were performed to simulate abandoned, lost, or otherwise discarded fishing gear. Changes in mechanical properties of PBSAT and PA nets in two Norwegian coastal environments were studied. Samples of biodegradable PBSAT gillnets and PA gillnets were placed inside modified lobster pots at four different locations: two outside the island Hitra in the middle of Norway and two outside Tromsø in the north of Norway. For each pot, seawater temperature was logged each hour, and net samples were retrieved for analyses at 3 to 9 months intervals. Tensile strength testing was performed to determine and compare mechanical properties of biodegradable and PA monofilaments and gillnets. Comparative analyses were conducted, aimed at investigating the different behaviors of biodegradable material and conventional PA material, and the possible influence of seawater temperature on the degradation process of biodegradable PBSAT gillnets. Reduced tensile strength and elongation at break, and a slight increase in stiffness was observed for both PA and PBSAT monofilaments after the field trial at Hitra, indicating degradation of both polymer materials. After 25 months immersion in seawater, the PBSAT gillnets exhibited a significant reduction of tensile strength due to seawater exposure (35%), and the tensile strength of PBSAT gillnets was then 26% lower than the average strength of the PA net samples.

Comparison of fishing efficiency between biodegradable gillnets and conventional nylon gillnets

Contact person: Eduardo Grimaldo, eduardo.grimaldo@sintef.no; Bent Herrmann, bent.herrmann@sintef.no;

Gillnets made of a new biodegradable resin (polybutylene succinate co-adipate-co-terephthalate (PBSAT) were tested under commercial fishing conditions to compare their fishing performance with that of conventional nylon (PA) nets. The relative catch efficiency between the two gillnet types was evaluated over the entire winter fishing season for cod (*Gadus morhua*) in northern Norway. The nylon gillnets caught 21% more fish (in numbers) than the biodegradable gillnets throughout the fishing season and generally showed better catch rates for most length classes, except for sizes between 82 and 90 cm. The difference in elasticity and breaking strength could explain the major difference in the size structure of fish caught by each type of gillnets, especially for larger fish. The number of times that the gillnets were deployed affected the relative catch efficiency of the gillnets with the biodegradable continuously loosing efficiency compared to the nylon. Although less catch efficient than nylon gillnets, biodegradable gillnets still show great potential for reduction of ghost fishing and plastic pollution at sea caused by this fishery.

Experimental fishery and utilization of mesopelagic fish species and krill

Contact person: Eduardo Grimaldo, eduardo.grimaldo@sintef.no; Leif Grimsmo, leif.grimsmo@sintef.no

Extensive mesopelagic acoustic scattering layers (SLs) were found over the North-East Atlantic NEAFC RA1 Reykjanes Ridge area in 2016, 2017 and 2018. The sampling catches from the SLs showed high variation in species composition and the densities of species at different seasons and locations. Catch rates reached up to 12000 kg per hour, being mesopelagic fish and krill the most dominant species in the catches. *Maurolicus muelleri* (Gmelin, 1789) and *Benthosema glaciale* (Reinhardt, 1837), generally found in different SLs, were the most abundant fish species. Clean catches of *Maurolicus muelleri*, mostly taken in the superficial scattering layer (SSL), had a high content of triglycerides; while, *Benthosema glaciale*, most abundant in the deep scattering layer (DSL), contained wax esters. On board processing and analyzes of mesopelagic fish showed a lipid content of 17.9% - 49.7% of dry weight, an omega-3 content of 24.5% of total lipid and an EPA + DHA content of 22% of total lipid, while the protein content was 13.5% -16.5% of wet weight. The lipid class composition contained well beneath the upper limit for the potentially limiting wax esters. Catch samples were also analyzed for unwanted substances such as dioxins, PCBs, PAH, pesticides, and heavy metals, showing values far lower than limiting values.

Other international research collaborations

Contact person: Bent Herrmann, Bent.Herrmann@sintef.no;
Sintef Ocean have in 2018 and beginning of 2019 been involved in several international research collaborations which have resulted in several joint scientific publications including:

Lomeli, M.J.M, Wakefield, W., Herrmann, B., 2018. Illuminating the Headrope of a Selective Flatfish Trawl: Effect on Catches of Groundfishes including Pacific Halibut. Marine and Coastal Fisheries, vol. 10:118-131. https://doi.org/10.1002/mcf2.10003.

Eighani, M., Paighambari, S., Herrmann, B., Feekings, J., 2018. Effect of bait type and size on catch efficiency of narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the Persian Gulf handline fisheries. Fisheries Research 199: 32-35.

Brčić, J., Herrmann, B., Mašanović, M., Baranović, M., Šifner, S., Škeljo, F., 2018. Size selection of Nephrops norvegicus (L.) in commercial creel fishery in the Mediterranean Sea. Fisheries Research, Vol., Pages 25-32.

Jure Brčić, Bent Herrmann, Marina Mašanović, Svjetlana Krstulović Šifner, Frane Škeljo, 2018. CREELSELECT- A method for determining the optimal creel mesh: case study on Norway lobster (*Nephrops norvegicus*) fishery in the Mediterranean Sea. Fish. Res., vol. 204:433-440.

Chryssi Mytilineou, Bent Herrmann, Danai Mantopoulou-Palouka, Antonello Sala, Persefoni Megalofonou, 2018. Modelling gear and fishers size-selection for escapees, discards and landings: a case study in Mediterranean trawl fisheries. ICES Journal of Marine Science, vol 75, 1693–1709.

V. Melli, L.A. Krag, B. Herrmann, J.D. Karlsen, 2018. Investigating fish behavioural responses to LED lights in trawls and potential applications for bycatch reduction in the Nephrops-directed fishery. ICES Journal of Marine Science, vol. 75, 1682–1692. https://doi.org/10.1093/icesjms/fsy048.

Herrmann, B., Eighani, M., Paighambari, S.Y., Feekings, J., 2018. Effect of hook and bait size on catch efficiency in the Persian Gulf recreational fisheries. Marine and Coastal Fisheries, vol. 10, 314-324. https://doi.org/10.1002/mcf2.10031.

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Tiago Veiga-Malta, Jordan Feekings, Bent Herrmann, Ludvig A. Krag, 2018. When is enough, enough? Quantifying trade-offs between information quality and sampling effort for fishing gear selectivity data. Plos One. https://doi.org/10.1371/journal.pone.0199655.

Lomeli, M.J.M., Groth, S.D., Blume, M.T.O, Herrmann, B., Wakefield, W., 2018. Effects on the Bycatch of Eulachon and Juvenile Groundfishes by Altering the Level of Artificial Illumination Along an Ocean Shrimp Trawl Fishing Line. ICES Journal of Marine Science, vol. 75, 2224–2234.

Santos, J., Herrmann, B., Daniel Stepputtis, D., Günther, C., Limmer, B., Mieske, B., Schultz, S., Neudecker, T., Temming, A., Hufnagl, M., Bethke, E., Kraus, G., 2018. Predictive framework for codend size selection of brown shrimp (*Crangon crangon*) in the North Sea beam-trawl fishery. Plos One. https://doi.org/10.1371/journal.pone.0200464.

Tokaç, A., Herrmann, B., Gökçe, G., Krag, L.A., Nezhad, D.S., 2018. The influence of mesh size and shape on the size selection of European hake (*Merluccius merluccius*) in demersal trawl codends: An investigation based on fish morphology and simulation of mesh geometry. Scientia Marina, vol 82, 147-157.

Krag, L.A., Krafft, B.A., Engås, A., Herrmann, B., 2018. Collecting size-selectivity data for Antarctic krill (*Euphausia superba*) with a trawl independent towing rig. Plos One. https://doi.org/10.1371/journal.pone.0202027.

Santos, J., Herrmann, B., Mieske, B., Krag, L.A., Schüz, A., Stepputtis, D., 2018. The efficiency of sieve panels for bycatch separation in Nephrops trawls. Fisheries Management and Ecology, vol. 25, 464-473.

Brčić, J, Herrmann, B., Sala, A., 2018. Predictive models for codend size selectivity for four commercially important species in the Mediterranean bottom trawl fishery in spring and summer: effects of codend type and catch size. Plos One. https://doi.org/10.1371/journal.pone.0206044

Kalogirou, S., Pihl, L., Maravelias, C.D., Herrmann, B., Smith, C.J., Papadopoulou, N., Notti, E., Sala, A., 2019. Shrimp trap selectivity in a Mediterranean small-scale-fishery. Fisheries Research, Vol. 211, 131-140.

Melli, V., Krag, L.A., Herrmann, B., Karlsen, J.D., 2019. Can active behaviour stimulators improve fish separation from Nephrops (*Nephrops norvegicus*) in a horizontally divided trawl codend? Fisheries Research, Vol. 211, 282-290.

Karlsen, J.D., Krag, L.A., Herrmann, B., Lund, H., 2018. Using vertical distribution to separate fish from crustaceans in a mixed species trawl fishery. Canadian Journal of Fisheries and Aquatic Sciences (online DEC 2018).

Lomeli, M.J.M., Wakefield, W.W, Herrmann, B., 2019. Evaluating off-bottom sweeps of a U.S. West Coast groundfish bottom trawl: Effects on catch efficiency and seafloor interactions. Fisheries Research, Vol, 213, 204-211.

The Arctic University of Norway UIT, Faculty of Biosciences, Fisheries and Economics – Norwegian College of Fishery Science

Summary

During 2018 we participated in several projects on bottom trawling for ground fish as well as shrimp, new types of gillnets for the Northeast Atlantic cod fisheries in cooperation with SINTEF Ocean and IMR (CRISP), amongst others.

Projects

Effect of three different codend designs on the size selectivity of juvenile cod in shrimp trawl fishery

Contact person: Bent Herrmann, Bent.Herrmann@sintef.no; Roger B. Larsen, Roger.Larsen@uit.no ; Manu Sistiaga manu.sistiaga@sintef.no; Jesse Brinkhof, Jesse.Brinkhof@uit.no

Shrimp trawlers use often a Nordmöre sorting grid ahead of a small-mesh codend to avoid by-catch of fish juvenile while shrimps are efficiently caught. However, small fish can pass through the grid to enter the codend and risk being retained. The risk for retention for fish of different sizes depends the size selection in the Nordmöre grid and the size selection in the subsequent codend, which makes the process complex and often results in a bell-shaped size selection curve. In the Barents Sea shrimp fishery, cod is one of the species causing concern because of its great commercial value. We studied the size selection of juvenile cod when the trawl was equipped with the compulsory gear in the fishery: a 19 mm Nordmöre grid followed by a 35 mm diamond mesh codend. As expected, the size selection curve showed a bell-shaped signature with a certain size range of juveniles having high retention risk, while the risk for smaller and bigger cod decreased. The retention risk was highest for cod between 12 and 20 cm in length. We also tested two alternative designs in the aft of the gear: a codend with 35 mm square mesh panels and a square mesh sorting cone section. None of these designs affected the size selection in the trawl significantly.

External damage to trawl-caught northeast arctic cod (*Gadus morhua*): Effect of codend design

Contact person: Guro Moen Tveit, Guro.Tveit@sintef.no ; Manu Sistiaga manu.sistiaga@sintef.no; Bent Herrmann, Bent.Herrmann@sintef.no; Jesse Brinkhof, Jesse.Brinkhof@uit.no

The purpose of this study was to investigate the extent of external damage (gear marks, pressure injuries, ecchymosis and skin abrasion) present on trawl-caught cod (*Gadus morhua*) and to examine whether the extent of damage could be reduced by introducing changes in the gear. We tested whether changing the 2-panel knotted codend used by the Norwegian trawler fleet operating in the Barents Sea today to a 2-panel knotless codend or a 4-panel knotless codend could decrease the extent of external damage to the fish in the catch.

We evaluated 720 fish over 12 hauls carried out with a twin trawl setup and found that the probability for cod to be without any external damage was 9.4% (4.7%–15.8%) with the codend used in the fishery today. Thus, most fish in these catches are likely to have slight or moderate damage. Gear marks were the most frequent type of damage, with only 11.5% (6.0%–18.9%) of the cod being free of this type of injury. When gear marks were not considered in the analysis, 68.4% (58.8%–78.3%) of the fish was estimated to be flawless. Replacing the knotted netting in the codend increased the probability of obtaining fish without gear marks to 15.5% (6.2%–28.0%). However, the confidence intervals were wide, and this effect was not statistically significant. For the other three damage types, the estimated effects of changing the design of the codend were small and not statistically significant. Changing from a 2- to 4-panel codend was estimated to reduce the probability for gear marks by a further 1.7% (−13.4%–16.8%). However, this increase was not significant. Overall, the two codend design changes tested in this study did not significantly decrease the external damage present on trawl-caught cod.

Quantification of bell-shaped size selectivity in shrimp trawl fisheries using square mesh panels and a sorting cone after a Nordmöre grid

Contact person: Bent Herrmann, Bent.Herrmann@sintef.no; Roger B. Larsen, Roger.Larsen@uit.no; Manu Sistiaga manu.sistiaga@sintef.no; Jesse Brinkhof, Jesse.Brinkhof@uit.no

Shrimp trawlers in the Barents Sea use a Nordmöre sorting grid ahead of a small-mesh codend to avoid bycatch while catching shrimps efficiently. However, small fish can still pass through the grid to enter the codend, which increases their risk of being retained. In this study, we quantified the selectivity of a standard Nordmöre grid used together with one of two different codend designs, namely a diamond mesh codend with square mesh panels and a codend with a square mesh sorting cone section, for deep-water shrimp (*Pandalus borealis*), redfish (Sebastes spp.), and American plaice (*Hippoglossoides platessoides*). For the first time, the selective properties of these two alternative designs were estimated and compared to those of a Nordmöre grid used together with a 35-mm diamond mesh codend, which is the compulsory gear used in the fishery today. With this traditional codend, the size selectivity of both bycatch species showed the expected characteristic bell-shaped size selection pattern, with low retention probability of very small fish and bigger fish but with high retention probability of certain sizes of juveniles. Using the square mesh sorting cone significantly reduced the maximum retention risk of redfish. The maximum retention with the diamond mesh codend with square mesh panels was estimated to be 14% lower than that of the traditional codend, but the difference was not statistically significant. The two alternative codend designs did not result in any significant reduction in bycatch of American plaice.

Comparison of fishing efficiency between biodegradable gillnets and conventional nylon gillnets

Contact person: Eduardo Grimaldo, eduardo.grimaldo@sintef.no; Bent Herrmann, bent.herrmann@sintef.no; Roger B. Larsen roger.larsen@uit.no

Gillnets made of a new biodegradable resin (polybutylene succinate co-adipate-co-terephthalate (PBSAT) were tested under commercial fishing conditions to compare their fishing performance with that of conventional nylon (PA) nets. The relative catch efficiency between the two gillnet types was evaluated over the entire winter fishing season for cod (*Gadus morhua*) in northern Norway. The nylon gillnets caught 21% more fish (in numbers) than the biodegradable gillnets throughout the fishing season and generally showed better catch rates for most length classes, except for sizes between 82 and 90 cm. The difference in elasticity and breaking strength could explain the major difference in the size structure of fish caught by each type of gillnets, especially for larger fish. The number of times that the gillnets were deployed affected the relative catch efficiency of the gillnets with the biodegradable continuously loosing efficiency compared to the nylon. Although less catch efficient than nylon gillnets, biodegradable gillnets still show great potential for reduction of ghost fishing and plastic pollution at sea caused by this fishery.

Sequential codend improves quality of trawlcaught cod

Contact persons: *Jesse Brinkhof*, Jesse.Brinkhof@uit.no; *Bent Herrmann*, Bent.Herrmann@sintef.no; *Roger B. Larsen*, Roger.Larsen@uit.no

Trawl-caught fish are frequently associated with deteriorated catch quality. This study presents a new dual sequential codend concept with the aim of improving the quality of trawl-caught fish by minimizing the frequency and severity of catch damage. During towing, the fish are retained in an anterior codend segment with the legislated mesh size. A quality improving codend segment, is attached to the aft part of the first codend segment. Its entrance is closed during the towing phase and opened at a predefined depth during haul-back. Comparing the quality of cod (*Gadus morhua* L.) retained in the sequential codend with cod caught in a conventional codend, demonstrated a significant improvement in the catch quality, i.e. reduction in catch damages. Cod caught in a conventional codend had only a 3.6% probability of being without visually detectable catch damage. The probability for catching cod without catch damage was five times higher when using the dual sequential codend. Furthermore, cod caught in the sequential codend had a significantly reduced probability of incurring specific catch damage, such as gear marks, poor exsanguination, ecchymosis, and skin abrasions.

Effect of a quality-improving codend on size selectivity and catch patterns of cod in bottom trawl fishery

Contact persons: *Jesse Brinkhof*, Jesse.Brinkhof@uit.no; *Bent Herrmann*, Bent.Herrmann@sintef.no; *Roger B. Larsen*, Roger.Larsen@uit.no

A new codend concept developed and tested exhibited significantly improved quality of caught cod (*Gadus morhua*) compared to that of the conventional codend used in the Barents Sea bottom trawl fishery. However, the design of the new quality-improving codend raised concerns about its size selectivity and the possibility that higher retention probability could negatively impact the catch pattern by increasing the proportion of undersized cod. Therefore, the goal of this study was to quantify and compare the size selectivity and catch pattern for cod when deploying respectively the conventional and new quality-improving codend in the Barents Sea bottom trawl fishery. The new quality-improving codend had significantly lower relative size selectivity than the conventional codend, but no significant difference in the catch patterns was detected in the trawl. Further, estimation of the total size selectivity in the trawl revealed that the increased retention of small cod when using the quality-improving codend was minor. Hence, despite the reduced selectivity, the quality-improving codend can be used with low risk of retaining small cod.

Combined sorting grid and codend selectivity of cod and haddock in the Barents Sea bottom trawl fishery

Contact persons: *Jesse Brinkhof*, Jesse.Brinkhof@uit.no; *Bent Herrmann*, Bent.Herrmann@sintef.no; *Roger B. Larsen*, Roger.Larsen@uit.no

Previous study documents that large proportions of cod and haddock below the minimum landing size are not released through the Flexigrid, and thus enter the codend. However, the probability of codend escapement of these juveniles has not yet been documented and the total size selection for the Flexigrid combined with codend is therefore unknown. Therefore, this study aimed to answer the following research objectives:

- How much does the Flexigrid section contributes to the overall selectivity?
- To what extend does codend selectivity contributes to the overall selectivity?
- Is there any difference in the size selectivity of the Flexigrid provided in this study compared to the results from previous existing studies?

The results demonstrated that most of the cod and haddock is released through the grid, and that few undersidzed fish entered the codend. The results also demonstrated that large amount of fish aboe the minimum landing size manage to escape, resulting in a low catching efficiency.

Effect of different codend designs on the size selectivity of juvenile fish and shrimp in shrimp trawl fishery

Contact person: Bent Herrmann, Bent.Herrmann@sintef.no; Roger B. Larsen, Roger.Larsen@uit.no ; Manu Sistiaga manu.sistiaga@sintef.no; *Jesse Brinkhof*, Jesse.Brinkhof@uit.no

Shrimp trawlers use often a Nordmöre sorting grid ahead of a small-mesh codend to avoid bycatch of fish juvenile while shrimps are efficiently caught. However, small fish can pass through the grid to enter the codend and risk being retained. The risk for retention for fish of different sizes depends the size selection in the Nordmöre grid and the size selection in the subsequent codend, which makes the process complex and often results in a bell-shaped size selection curve. During the study two different codends were tested; i) a coden with 30 % shorther lastridges, and ii) a coden with T90 meshes. The results were compared to a regular codend. Also two alternative bar spaces were tested in the Nordmøre grid, 17 mm and 21 mm, and compared to the regual bar spacing of 19 mm.

Different codend design reduce the bycatch of juvenile fish and shrimp in the Barents Sea shrimp trawl fishery.

Contact person: Roger B. Larsen, Roger.Larsen@uit.no; Nadine Jacques, nadine.jacques@uit.no; Bent Herrmann, Bent.Herrmann@sintef.no; Hermann Pettersen hermann.pettersen@uit.no.

In September 2018 four members from The Arctic University of Norway, the Institute of Marine Research and the Norwegian Directorate of Fisheries took part in a research cruise on board the Arctic Viking trawler Vessel. Trials took place in the north east of Svalbard - south of Kvitøya, and lasted 10 days. The aim of the experimental design was to analyse selectivity of bycatch species as well as target shrimp catch when the trawl was configured with 30% lastridge ropes combined with 35 mm meshes compared to the standard codend configured with 40 mm meshes. This resulted in 3 different trawl setups which were tested throughout 31 successful tows. From each tow, all individuals of greenland halibut, redfish, cod and haddock were length measured as well as a 1 kg subsample of shrimp taken and measured. Total weight from each of these was also recorded. The gathering of results to build conclusions from these trials is still ongoing.

Is haddock more vulnerable than cod to contact with trawl gear?

Contact person: Manu Sistiaga *manu.sistiaga@sintef.no*; Bent Herrmann, *Bent.Herrmann@sintef.no;* Jesse Brinkhof, *Jesse.Brinkhof@uit.no* Roger B. Larsen, *Roger.Larsen@uit.no* ;

Despite belonging to the gadoid family and being harvested with the same types of trawl gear, cod and haddock are quite different species. They not only behave differently in the trawl, where haddock is a much more active species than cod, but also, haddock has been reported to be more vulnerable to gear damage than cod.

Previous studies evaluated the level of external damages on cod captured with the compulsory grid and codend setup used in the Barents Sea gadoid fishery, whereas another study evaluated the level of external damage on cod and haddock caused by a diamond mesh codend. However, to our knowledge, no study has evaluated the level of external damages on haddock caught with a grid and codend gear setup. Further, no study has estimated the potential differences on observed external damages between cod and haddock captured with this gear in the Barents Sea cod and haddock fishery. The aim of the present study was to evaluate the level of external damages on cod and haddock captured with the compulsory gear in the Barents Sea, and to identify potential differences in the damage levels induced to these two species.

Specifically, we aimed at answering the following research questions:

- is the level of external damages on cod observed in the present study comparable to those observed in earlier studies?
- what is the level of external damages observed on haddock caught using the compulsory grid and codend gear setup used in the Barents Sea gadoid fishery?
- is the level of external damages observed on cod and haddock captured with a grid and codend setup similar? If not, which damage types do they differ on?

The results showed that for cod, gear damages, skin abrasion and exsanguination were the most frequent types of external damages. In general, most haddock evaluated in the study showed some kind of damage type and the probability to obtain completely flawless fish was estimated to be 0.00% (0.00%–0.00%). The comparison between haddock and cod clearly show the probability to observe damages on haddock is much higher than the probability to observe damages on cod.

Effect of a new gentle codend design on catch damages and size selectivity of cod and haddock in the Northeast Arctic bottom trawl fishery

Contact person: Manu Sistiaga manu.sistiaga@sintef.no; Bent Herrmann, Bent.Herrmann@sintef.no; Jesse Brinkhof, Jesse.Brinkhof@uit.no Roger B. Larsen, Roger.Larsen@uit.no

Trawl-caught fish are frequently associated with deteriorated catch quality. Moreover, fishers report issues with the size selective sorting grids clogging under high fishing densities, which also results in reduced size selectivity. Therefore, we tested a trawl without the compulsory size selective sorting grid and a new codend concept. The codend concept was tested with the aim of improving catch quality and size selectivity. The codend constisted of two segments; the anterior segment was built of 155 mm mesh size with 30 % shrunk lastridges. The posterior codend segment consited of 6 mm mesh size with a outer streghtning codend. The idea was that the small mesh size in the posterior codend would cause a «bucket effect» causing the fish to stop in the anterior segment where the size selective process would occur. Thereafter the fish that did not escape through the meshes would fall back in to posterior quality improving codend. The results demonstrated significant improved quality for both cod and haddock. The results for size selectivity remain to be analyzed.

Other national and international research collaborations

UiT The Arctic University of Norway have in 2018 and beginning of 2019 been involved in several international research collaborations which have resulted in several joint scientific publications including:

Brinkhof, Jesse; Herrmann, Bent; Larsen, Roger B.; Veiga-Malta, Tiago. Effect of a quality-improving codend on size selectivity and catch patterns of cod in bottom trawl fishery. Canadian Journal of Fisheries and Aquatic Sciences 2019.

Grimaldo, Eduardo; Herrmann, Bent; Su, Biao; Føre, Heidi Moe; Vollstad, Jørgen; Olsen, Leonore; Larsen, Roger B.; Tatone, Ivan. Comparison of fishing efficiency between biodegradable PBSAT gillnets and conventional nylon (PA) gillnets. Fisheries Research 2019 ;Volum 213. s. 67-74.

Blanchet, Marie-Anne; Acquarone, Mario; Biuw, Martin; Larsen, Roger B.; Nordøy, Erling Sverre; Folkow, Lars. A life after Research? First Release of Harp Seals (Phoca groenlandica) after Temporary Captivity for Scientific Purposes. Aquatic Mammals 2018.

Blanchet, Marie-Anne; Acquarone, Mario; Biuw, Martin; Larsen, Roger B.; Nordøy, Erling Sverre; Folkow, Lars. A life after research? First release of harp seals (Phoca groenlandica) after temporary captivity for scientific purposes. Aquatic Mammals 2018; Volum 44.(4) s. 343-356.

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8.11 Portugal

CCMAR/IPMA Centre of Marine Sciences/ Portuguese Institute for the Ocean and the Atmosphere
Increase selectivity in the crustacean trawl fishery using artificial lights. Project: MINOUW

Contact: Paulo Fonseca (pfonseca@ipma.pt)

CCMAR in collaboration with IPMA, tested blue LED lights in the crustacean trawl fishery to promote bycatch escape. The lights, flashing at 10Hz, were installed on the trawl gear headline with the purpose of triggering an avoidance reaction of blue whiting, a semi-pelagic fish with active swimming behaviour. However, very early in the experiments it was clear that the lights were causing a substantial and unacceptable reduction in the catch of the target species, the red shrimp, *Aristeus antennatus*. The use of artificial light to optimise the selectivity of fishing gears requires previous investment in laboratory testing to understand both target and bycatch species behaviour towards light during the catch process.

Testing modified bivalve dredges. Project: MINOUW

Contact: Miguel Gaspar (mbgaspar@ipma.pt)

Modified bivalve dredges equipped with sorting grids were tested to reduce bycatch, discards and debris captured In the Algarve, Portugal. Although bycatch and discards were reduced by 77%, biomass of the target species *Spisula solida* and *Chamelea gallina* were reduced by 45 %, which is seen as an unacceptable loss by the fishers. A design modification to the dredge has been proposed to reduce losses of the target catch.

CCMAR, Centre of Marine Sciences
Effects of reallocating fishing effort from trawling to creels in a Norway lobster (*Nephrops norvegicus*) fishery. Project: MINOUW

Contact: Margarida Castro (mcastro@ualg.pt)

The consequences of reallocating fishing effort from trawling to creels in an area off the West coast of Portugal on the operation of the trawl fleet, as well as on the population dynamics and the global catch value for the Norway lobster (Nephrops norvegicus) are evaluated. The results suggest that only small portions of the area of interest are used by the trawl fleet, opening the possibility for a trawl ban without major disruption of the trawling activity. The proposed ban is consistent with the ecosystem approach to fisheries management and the Common Fisheries Policy (CFP) where the transition towards more responsible fishing practices is encouraged.

Creel experimental fishing for Norway lobster. Project: MINOUW

Contact: Margarida Castro (mcastro@ualg.pt)

Norway lobster fishing was explored with creels, in order to evaluate the feasibility of using this gear as an alternative to bottom trawling targeting the same species. The viability of creel fishing was confirmed given the quality of the product obtained (large and high vitality lobsters). By-catch is insignificant when compared to trawling and in most cases has commercial value, posing no waste problem. However, great variability in yields was observed, suggesting that the activity and behaviour of the Norway lobster may also display great variability. In-situ image recording was obtained with the objective of monitoring the behaviour of Nephrops towards the trap and possible interactions with other species.

Testing semi-floating shrimp traps for the striped soldier shrimp, *Plesionika edwardsii* off the Algarve coast (southern Portugal). Project: MINOUW

Contact: Margarida Castro (mcastro@ualg.pt)

An experimental survey was carried out aiming at the evaluation of the catchability of the striped soldier shrimp, *Plesionika edwardsii*, using semi-floating shrimp traps off the Algarve coast. Preliminary results suggest that this fishery could contribute to the diversification of fixed gears of low environmental impact targeting deep-water crustaceans, in agreement with the objectives of both the Marine Strategy Framework Directive and the reformed Common Fisheries Policy. However, potential spatial conflicts with trawling, the unknown size of the resource and a necessary precautionary approach may limit the number of licences that can be granted.

Modified slipping method to reduce sardine mortality. Project: MINOUW

Contact: Jorge Gonçalves (jgoncal@ualg.pt)

A modified slipping method was tested in a sardine seine net, using weights to sink a portion of the float line and allow unwanted catch to swim freely out of the net. Survival, physiological stress and physical damage were compared between a standard slipping operation (fish rolled over the float line at the surface) and the operation with the modified seine between a test group and a fish control group of non-slipped and non-crowded sardines.

Testing a guarding net in trammel net fisheries. Project: MINOUW

Contact: Jorge Gonçalves (jgoncal@ualg.pt)

A strip of stiff "guarding net" meshes affixed to the bottom of a trammel net was tested in nets used to target cuttlefish *(Sepia officinalis*) to reduce the catch of non-target benthic species. Unusually low catches of cuttlefish when trials were carried out forced to direct fishing effort to target sole species *Pegusa lascaris*; *Solea senegalensis* and *Microchirus azevia* that were subject to 35% reduction in weight, while reduction in unwanted catch attained similar values.

8.12 Scotland

Marine Scotland Science

Contact person: Emma Mackenzie, emma.mackenzie@gov.scot

Summary

Fish behavior in relation to artificial lights in both sea and laboratory trials

Projects

H2020 – SMARTFISH: Investigating the use of light to promote the selectivity of towed gears – Laboratory Trials

Contact person: Emma Mackenzie, emma.mackenzie@gov.scot

January 2018 – Dec 2021

SMARTFISH is a four year project funded through the European Union's Horizon 2020 research and innovation programme. Trials took place within Marine Scotland Science's Fish Behavior Unit (FBU) to investigate the reactions of three commercially important species of fish, Atlantic cod (*Gadus morhua* L.), haddock (*Melanogrammus aeglefinus* L.) and plaice (*Pleuronectes platessa* L.) to three colours of LED lights, blue, green and red. A strip of LED lights was positioned vertically at the end of a tank (7m x 3m x 1.5m). Video observations were made of the fish and analysis of the footage was used to measure the mean distance of the fish at set time points throughout the trials. The mean distances were used as the unit of measure for the statistical analysis. Three batches of 8 fish were used per species. The distance (m) from the light to each of the 8 fish were recorded prior to the light being turned on to get a baseline distribution of the fish to compare to the distribution fish once the light had been turned on.

It was found that the red light had little to no effect on the behaviour of all 3 species included in these trials (Figure 8.12.1).

Haddock show a brief attractive response to the green light but quickly appear to become habituated to the presence of the light and the distances then measured show no significant difference when compared to the control measurements. Cod show an immediate reaction to the green light by swimming away from the light and remaining distant for the remainder of the trial (Figure 1). Plaice show a very slight positive phototactic reaction to the green light by moving towards it, the distance's travelled were small but significant (Table 8.12.1)).

For the blue light colour haddock move away from the light when it is turned on and the distance from the light increases as the trial continues. Cod also move away from the blue light when it is turned on however the distance from the light reduces over the remainder of the trials (Figure 8.12.1). For Plaice no significant reaction to the blue light colour was seen (Table 8.12.1).

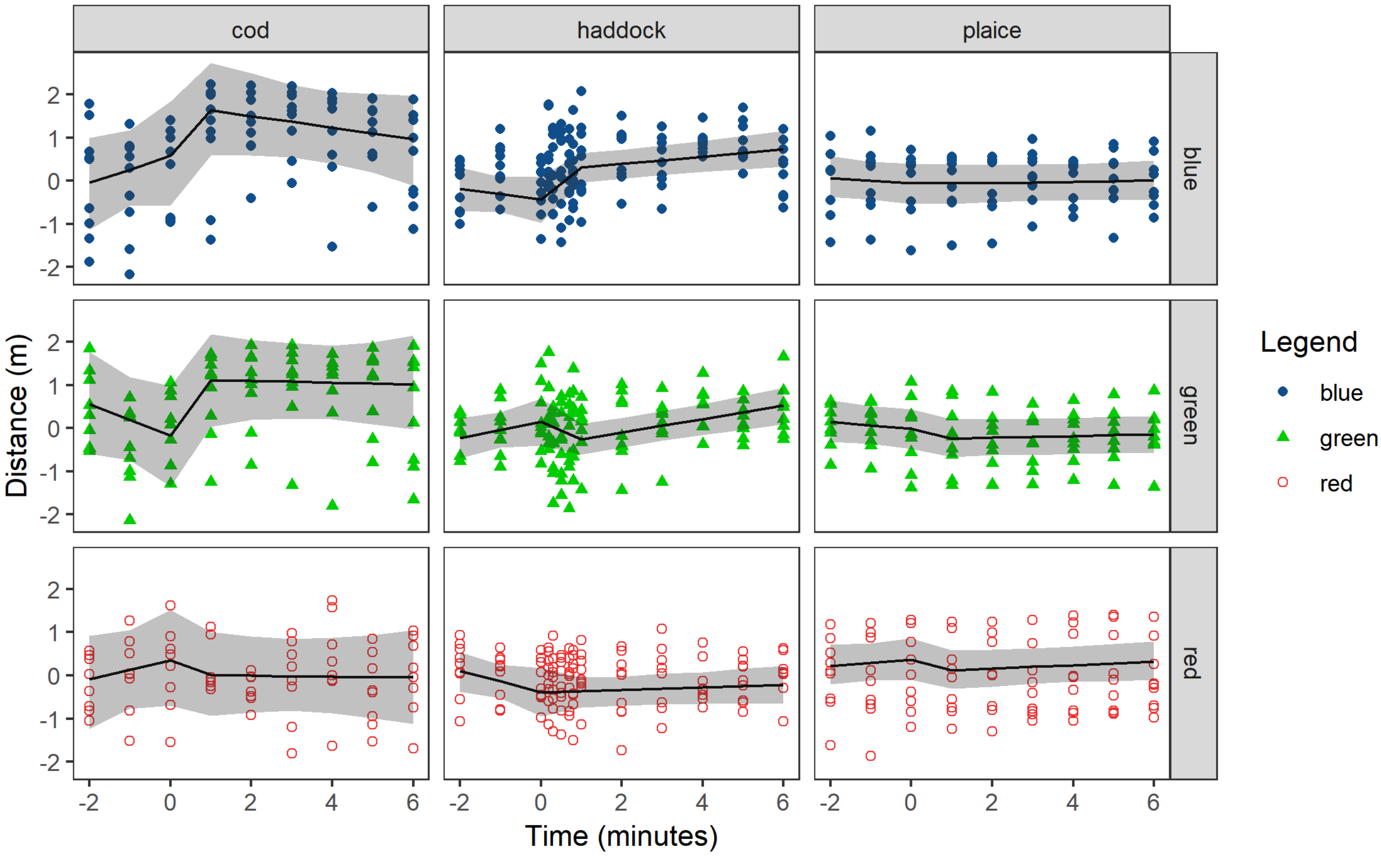


Figure 8.12.1. Plots of the observed values for the mean standardised distances (metres) of all species at each time interval throughout the experiment for each light configuration. The light was turned on at minute 0. Confidence intervals are represented by a shadow.

Tabel 8.12.1 Results of the individual analysis for each species and colour, when comparing control and treatment mean distances.

Species	Colour	Difference between control and treatment distance to light source (*p value*)	Fish behaviour
	Red	*P* = 0.1	*No reaction*
Haddock	Green	*P* < 0.001 **	*Attraction in the first minutes*
	Blue	*P* < 0.001 **	*Repulsion*
	Red	*P* = 0.9	*No reaction*
Cod	Green	*P* < 0.0001 ***	*Repulsion*
	Blue	*P* < 0.0001 ***	*Repulsion*
	Red	*P* = 0.34	*No reaction*
Plaice	Green	*P* < 0.01 *	*Attraction*
	Blue	*P* = 0.74	*No reaction*

H2020 – SMARTFISH: Investigating the use of light to promote the selectivity of towed gears – Sea Trials

Contact person: Emma Mackenzie emma.mackenzie@gov.scot

January 2018 – December 2021

Trials took place in March 2018 on RV *Alba na Mara* with a fibre optic cable attached to a rigid grid in the extension section of a trawl gear. The arrangement of the grid and netting can be seen in Figure 8.12.2.

All hauls during the trials had the grid positioned beneath. The cable illumination was either strobing at 4Hz, on constant, or off. A total of twenty eight deployments were completed during the cruise. Four hauls for testing/rigging, and twenty four hauls for carrying out selectivity/behaviour work. The main species caught were haddock, whiting, cod, Nephrops, lemon sole, plaice, witch, long rough dab, common dab, monkfish, bullrout, four bearded rockling, herring, lesser spotted dogfish, ling, Norway pout, poor cod, red gurnard, red mullet and sprat.

Results suggest that having lights either constant or strobing increases their willingness to pass through the grid and that there is little difference between the constant and strobing effects for most species (Figure 8.12.3). For cod and haddock both strobing and constantly on lighting was significantly different from no lights. For Nephrops only strobing light showed a significant difference to no lights. For lemon sole only constant light was significantly different to no lights. For plaice both strobing and constant lighting showed a slight significant difference compared to no lights. Long rough dab showed a slight significant difference between strobing and no light. In general, both strobing and constant lighting elicit a similar result within each species. For all species except common dab, lighting increases the fish's willingness to pass through the grid (all species bar whiting and common dab have significant or borderline significant differences).

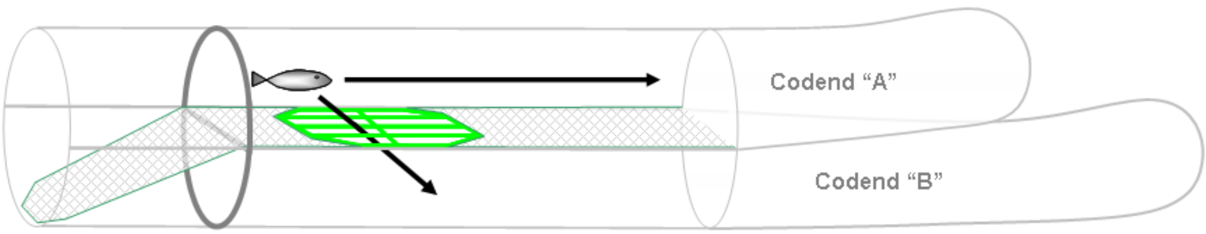


Figure 8.12.2. The netting panel separator and grid arrangement.

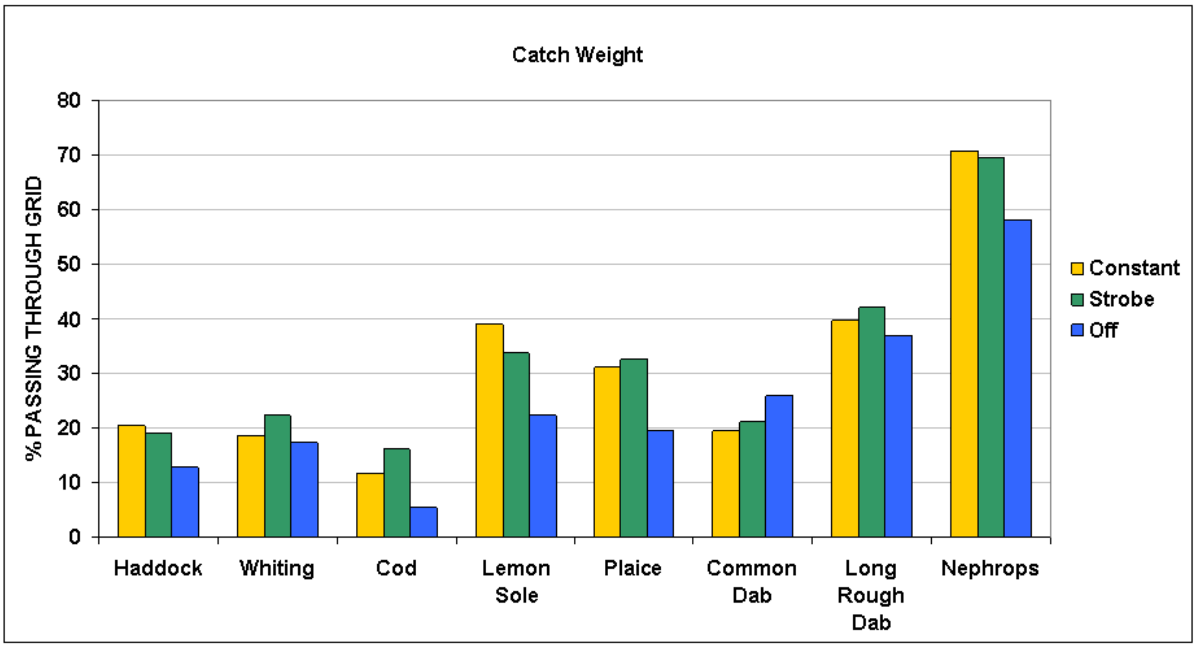


Figure 8.12.3. Percentage of fish passing through the grid by number during the 2018 trials.

H2020 – SMARTFISH: Investigating the use of light to promote the selectivity of towed gears – Sea Trials

Contact person: Emma Mackenzie emma.mackenzie@gov.scot or Rob Kynoch Rob-ert.Kynoch@gov.scot

January 2018 – December 2021

(At the time of writing these sea trials were underway)

Trials took place in March 2019 on RV *Alba na Mara* with a fibre optic cable attached to a rigid grid in the extension section of a trawl gear. The arrangement of the grid and netting was identical to that used in the March 2018 trials (Figure 8.12.2). There will be two light fibre lines permanently attached to the grid, one illuminating the upper half and one illuminating the lower half of the grid. The LED light unit will emit green or blue light and hauls will be conducted either with either light at high or low intensity. The grid will also be fished periodically without any lights to show the standard reaction to the grid. Hence 5 lighting variables will be tested during the trials (green High, green low, blue high, blue low and no light). A the trials were underway at the time of writing the results could not be included here.

8.13 Spain

AZTI-TECNALIA

Contact person: Esteban Puente (epuente@azti.es),Luis Arregi (larregi@azti.es), Mikel Basterretxea (mbasterretxea@azti.es), Iñigo Onandia (ionandia@azti.es) and Xabier Aboitiz (xaboitiz@azti.es).

Summary

The fishing technology area from AZTI-Tecnalia has been working last year on selectivity improvement on bottom trawl vessels operating in ICES divisions 8 and 6, survival studies of small pelagic species slipped during purse seining operations, the implications (increment of the workload to the crew, reducing the storage space) of a real simulation of the landing obligation in trawling fleet and the assessment of the landing obligation in small scale fisheries and possible mitigation measures.

Projects

SELAR

Contact person: Luis Arregi, larregi@azti.es

October 2016 – Dec 2018

SELAR is a three-year project funded by the Basque Government and European Maritime and Fisheries for Fund (EMFF). In the landing obligation context, this project started with the aim of improve selectivity for Basque trawl fisheries targeting demersal species like European hake (*Merluccius Merluccius)*, anglerfish (*Lophius spp*.) and Megrims (*Lepidorhombus spp*.) but some other species with quota considered potential choke species have been included in the study such us (haddock, saithe, ling and grater silver smelt). During 2017 and 2018 two selectivity cruises were carried out on board a commercial trawler in the ICES division 6. During these cruises a complete upper panel with square mesh in the extension piece has been tested. Moreover, the behavior of the choke species was assessed by using underwater video cameras. The results showed promising escaping rates for some choke species in the fishery, like saithe, haddock or greater silver smelt. However, some escapement for target species in commercial sizes was also observed. As a result of these trials, the tested square mesh panel has been implemented in the new regulation of 2020.

CASELEM

Contact person: Luis Arregi, larregi@azti.es

Jan 2017 – Dec 2018

CASELEM is the continuation of the SELEM project, started on January 2017. It is a two-year project funded by Spanish Fishing Directorate. During 2017 fish guiding devices such as ropes, ropes with floats, and blue led lights had been tested to improve the contact probability with a SMP onboard the R/V Emma Bardan. In June 2018 a new cruise was carried out in the same vessel to continue improving fish guiding devices. New LED lights were tested, as well as new configurations of the SMP. Configurations of lights with different frequencies (green and white lights), SMP situated in different position on the net and a SMP with higher surface were tested. A total of 36 valid hauls for selectivity experiments were performed. In 2019 another sea trial is planned in which new devices will be tested.

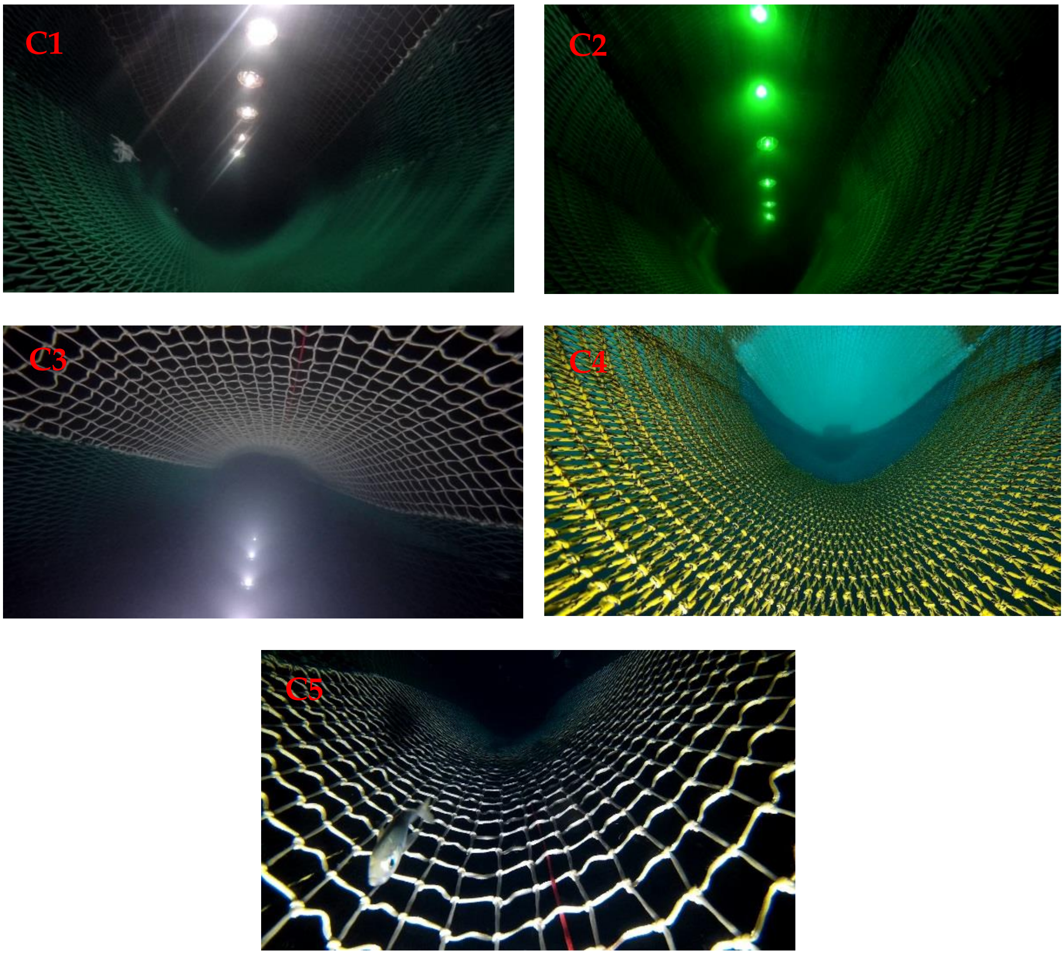


Figure 8.13.1. Five different configurations tested in the selective device during the cruise. SMP + white solid lights upper panel (Top left.), SMP + green solid lights upper panel (top right.), SMP upper panel + white solid lights lower panel (middle left), upper panel all in square mesh (Middle right) and SMP in the lower panel (down)

MENDES

Contact person: Esteban Puente, epuente@azti.es

Jan 2018 – Dec 2018

MENDES is a one-year project funded by the Biodiversity Foundation and European Maritime and Fisheries for Fund (EMFF). The aim of the project is to improve the selectivity of the trawl fleet operating in national waters, bottom trawl, bottom high vertical opening trawl and pair trawl. A quantitative and qualitative analysis of the discard in each fleet was performed according to the observer's data base to detect principal problematic species. Workshop with skippers to review and select the more suitable selective devices for each fishery/species were held. Sea trials in all fisheries (commercial vessels) were carried out to test the selective devices and analyze the socio-economic impact of the implementation of such technical measures. In 2019 more sea trials are planned to continue testing new selective devices with the same objective.

SMARTFISH

Contact person: Guzman Diez, gdiez@azti.es

In this context of the Landing Obligation (LO) included in the new Common Fisheries policy (CFP), some important operational changes to the trawl fleet operating in Bay of Biscay will be implemented, therefore it is highly interesting and necessary to apply measures to reduce the catch of the "choke species" in the trawl fleet fishing in this area. AZTI is the responsible partner for the implementation and coordination at-sea tests to assess the effect on selectivity by a SmartGear in the trawler fleet operating in the Bay of Biscay. During the experimental trials on board commercial vessels the effect of the LED light technology set on the mandatory Square Mesh Panel (SMP) and/or in the guiding ropes together with stimulators devices have been tested for maximising the escape response of fish in the fishing gear.

SUPERV

Contact person: Iñigo Onandia, ionandia@azti.es

Mar 2016 – Dec 2018

SUPERV was a two-year project funded by the Basque Government and European Fisheries for Fund (EFF) and the continuation of the project BIZI. An exemption to the landing obligation can be provided for species for which scientific evidence demonstrates high survival rates, considering the characteristics of the gear, the fishing practices and the ecosystem. This study presented the results of experimental tests on survivability of several species subject to slipping in southern European purse seine fisheries, i.e. mackerel (*Scomber scombrus*), horse mackerel (*Trachurus spp.)*, anchovy *(Engraulis encrasicolus*) and sardine (*Sardina pilchardus)*. Tests were carried out on board a commercial fishing vessel, which is representative of the purse seine fleet of European southern waters; and they were conducted during real commercial fishing activity. High survival rates were found in the tests, particularly for crowding times of less than 10 minutes.

This also suggests that the approach followed to simulate slipping, i.e. using fish tanks filled up with seawater on board to keep the catch in captivity, is suitable for discard survival studies as an alternative to other methods. Studies about Reflex Action Mortality Predictor (RAMP) and physiology for determining the recovery of slipped fish have been developed. In addition, a good practice manual collecting the best procedures to improve the survival during the slipping has also been created.

Figure 8.13.2: Captive anchovies (*Engraulis encrasicolus*) in water tanks for delayed mortality experiments onboard the F/V Agustin Deuna.

DESMEN

Contact person: Luis Arregi, larregi@azti.es

Jan 2018 – Dec 2018

DESMEN is a one-year project funded by the Basque Government and European Fisheries for Fund (EFF). By 2019 January 1st, the Landing Obligation (LO) will apply to all fleets that fish species with TAC. Small scale vessels can then be affected in certain fisheries, particularly in gillnets, when there are significant catches of mackerel and horse mackerel during some periods of the year. The Technology Committee between AZTI and small-scale fishermen in its meeting of March 6, 2017 agreed that it is necessary to take the initiative to investigate technical alternatives to deal with this problem. It tries to look for ways to make the application of regulation more flexible to ensure fishing activity as has already been done with other modalities that entered into the LO previously (purse seine and trawl).

SIBALO

Contact person: Xabier Aboitiz, xaboitiz@azti.es

Jan 2017 – Dec 2018

SIBALO is a two-year project funded by the Basque Government. The aim of the project is to simulate the implication of a real implementation of the Landing Obligation. It is supposed that there will be a significant increase in the workload of the crew as well as several problems for storing the former discards onboard. It will also include new limitations in the vessels and fishing trips. Physical condition of the crew has been monitored and measured with a motion suit and the increment in the workload analyzed and compared with current situation. The manage of discards at harbours (infrastructure and labor needed) and finding destination for the discarded fish has been another challenge of the project.

8.14 Sweden

Swedish University of Agricultural Sciences (SLU) Aqua

Contact person: Peter Ljungberg, peter.ljungberg@slu.se

Summary

Between 2014 and 2017, with prolongation also in 2018, the Swedish government has set aside dedicated funding for collaborative research on selective fishing gear. The main background was the need for a larger toolbox of documented and workable gear for the industry, when the landing obligation in EU fisheries is being implemented. In this venture, SLU Aqua has been contracted by the responsible authority (SwAM - Swedish Agency for Marine and Water Management) to set up a secretariat.

The aim of the secretariat has been to gather new ideas from fishers and industry. The industry´s initiative and engagement are crucial to the successful development of new ideas. Project proposals are worked out in close collaboration between fishers and scientists and are then evaluated and funded by SwAM.

Projects

During the project period between 2014 and 2018, in total 37 projects have been completed with a great diversity ranging from the gentle handling of salmon in traps in the northern Baltic Sea to large grids excluding saithe in the industrial pelagic trawl-fishery of herring in the Skagerrak. All projects from 2014 to 2017 are reported in Table 8.14.1 for active fishery and Table 8.14.2 for passive fishery. Each table is divided in gear, target species, main topic to solve, project title, outcome and contact.

The outcome of each project is summarized as a color code where:

Red = Unclear potential, not as intended
Orange = Further development needed
Yellow = Direct useable, management action needed
Light green = Direct implementable, incentive needed
Dark green = Already in use, no further actions needed
For 2018, projects are still to be evaluated for implementation potential, but are listed along with contact information in Table 8.14.3.

Table 8.14.1. Active gear, 2014-2017.

Active gear	Target species	Main topic	Project	Outcome	Contact
Baltic cod trawl	Cod	Size selectivity cod	Improved selectivity in T90-codends in the Baltic cod fishery		hans.nilsson@slu.se
Baltic cod trawl	Cod	Size selectivity cod	Improved selectivity in T90-codends in the Baltic cod fishery phase II		hans.nilsson@slu.se
Baltic cod trawl	Cod	Size selectivity cod, species selectivity flounder	Multifunction selective codend in the Baltic cod fishery		hans.nilsson@slu.se
Pandalus trawl	Pandalus	Size selectivity Pandalus	Increased mesh size 47 mm (diamond and square mesh) in Pandalus trawl		hans.nilsson@slu.se
Pandalus trawl	Pandalus	Size selectivity Pandalus	Testing a Norwegian design of sorting grid to improve Pandalus size selectivity		daniel.valentinsson@slu.se
Pandalus trawl	Pandalus	Size selectivity Pandalus	Sorting grid to improve Pandalus size selectivity		daniel.valentinsson@slu.se
Pandalus trawl	Pandalus	Size selectivity Pandalus	Improved size selectivity for small Pandalus trawlers phase I		daniel.valentinsson@slu.se
Pandalus trawl	Pandalus	Size selectivity Pandalus	Improved size selectivity for small Pandalus trawlers phase II		daniel.valentinsson@slu.se
Pandalus trawl	Pandalus	Size selectivity Pandalus	Flexible sorting grid to improve Pandalus size selectivity		daniel.valentinsson@slu.se
Nephrops trawl	Nephrops	Size- and species selectivity (Nephrops and fish by-catches)	Size selective sorting grid and improved codend design to reduce catches of small Nephrops and by-catch fish phase I		daniel.valentinsson@slu.se
Nephrops trawl	Nephrops	Size- and species selectivity(Nephrops and fish by-catches)	Size selective sorting grid and improved codend design to reduce catches of small Nephrops and by-catch fish phase II		daniel.valentinsson@slu.se
Nephrops trawl	Nephrops	Species selectivity - Reduced catch of roundfish	Low topless Nephrops trawl		mikael.ovegard@slu.se
Demersal trawl	Mixed demersals	Size- and species selectivity (Nephrops and fish by-catches)	Reduced bycatch of undersized Nephrops and fish		hans.nilsson@slu.se
Demersal trawl	Witch and cod	Speceis selectivity-Separation of catches	Separation of roundfish and flatfish by a grid and two cod-ends phase I		erika.andersson@slu.se
Demersal trawl	Cod, saithe, haddock	Species selectivity-Separation of catches	Vertical trouser trawl for separating cod from haddock and saithe		mikael.ovegard@slu.se
Demersal trawl	Mixed demersals	Size selectivity cod, whiting, haddock and plaice	Testing selectivity equivalence for three alternative legislated cod-ends in the Skagerrak-Kattegat mixed fishery		daniel.valentinsson@slu.se
Demersal trawl	Plaice and cod	Species selectivity-Separation of catches	Separation of roundfish and flatfish by a grid and two cod-ends phase II		erika.andersson@slu.se
Pelagic trawl	Herring	Species selectivity-minimize saithe by-catch	Reduced by-catch of saithe in herring trawls by a flexible grid phase I		andreas.sundelof@slu.se
Pelagic trawl	Herring	Species selectivity-minimize saithe by-catch	Reduced by-catch of saithe in herring trawls by a flexible grid phase II		andreas.sundelof@slu.se

Table 8.14.2. Passive gear, 2014-2017.

Passive gear	Target species	Main topic	Project	Outcome	Contact
Pontoon trap	Cod	Alternative, selective fishing method - trap	Increased selectivity in pontoon traps targeting cod		peter.ljungberg@slu.se
Pontoon trap	Atlantic mackerel	Alternative, selective fishing method - trap	Can seal safe selective traps targeting atlantic mackerel reduce the seal fishery		sven-gunnar.lunneryd@slu.se
Pontoon trap	Herring	Alternative, selective fishing method - trap	Development of a seal safe and selective trap for herring		sara.konigson@slu.se
Pontoon trap	Whitefish	Harmless treatment of salmon	Harmless method for emptying pontoon traps fishing salmon and whitefish		maria.hedgarde@slu.se
Pontoon trap	Whitefish	Harmless treatment of salmon	Harmless method for emptying pontoon traps fishing salmon and whitefish		maria.hedgarde@slu.se
Pontoon trap	Whitefish	Harmless treatment of salmon	Selective pontoon trap for whitefish		maria.hedgarde@slu.se
Pontoon trap	Whitefish	Harmless treatment of salmon	Ergonomic and selective method for emptying a pontoon trap		maria.hedgarde@slu.se
Pot	Cod	Alternative, selective fishing method - pot	Development of a selective pot for cod		sara.konigson@slu.se
Pot	Multi species	Alternative, selective fishing method - pot	Multi species pot		sven-gunnar.lunneryd@slu.se
Pot	Cod and flatfish	Alternative, selective fishing method - pot	Evalutaion of seal safe, selective pot fishing for cod and flatfish		peter.ljungberg@slu.se
Pot	Cod	Alternative, selective fishing method - pot	Evalutaion of seal safe, selective pot fishing for cod and flatfish		peter.ljungberg@slu.se
Pot	Flatfish	Alternative, selective fishing method - pot	Evalutaion of seal safe, selective pot fishing for cod and flatfish		peter.ljungberg@slu.se
Pot	Multi species	Alternative, selective fishing method - pot	Multi species pot		sven-gunnar.lunneryd@slu.se
Pot	Pandalus	Alternative, selective gear - pandalus	Pandalus pot		peter.ljungberg@slu.se
Pot	Pandalus	Alternative, selective gear - pandalus	Pandalus pot		peter.ljungberg@slu.se

Table 8.14.3. Projects 2018.

Gear	Target species	Main topic	Project	Outcome	Contact
Baltic cod trawl	Cod	Size selectivity cod	Improving selectivity in T90-codends in the Baltic cod fishery phase III		hans.nilsson@slu.se
Demersal trawl	Cod	Benthic impact	Low impact trawling, demersal fishery with pelagic trawlboards		hans.nilsson@slu.se
Demersal trawl	Cod	Benthic impact	Powerdoors – soft trawl boards without bottom contact		hans.nilsson@slu.se
Pontoon trap	Salmon and whitefish	Harmless treatment of salmon	Ergonomic method for emptying pontoon trap fishing salmon and whitefish		sven-gunnar.lunneryd@slu.se

8.15 United States of America

Massachusetts Division of Marine Fisheries - Conservation Engineering Program

Contact person: Mike Pol, (mike.pol@state.ma.us)

Summary

This year we continued focused on maintaining or increasing access to healthy stocks of fish and shellfish in multispecies fisheries where many stocks are in rebuilding programs. Improved access was sought through introduction of new gear types and modification of existing gears. Increasing attention was devoted to the impacts of offshore wind energy development on commercial fishing operations.

Projects

Off Bottom Trawl (OBT)

Contact person: David Chosid, david.chosid@state.ma.us

Jan 2017 – Dec 2019

In collaboration with the Gulf of Maine Research Institute and with input from Pingguo He, we initiated a project to equip two groundfish vessels with two different designs of pelagic trawl nets (one using self-spreading twine) and appropriate doors to fish for haddock (*Melanogrammus aeglefinus*) and other "groundfish" species (such as Acadian redfish *Sebastes fasciatus*) on Georges Bank; both stocks are currently underutilized. Pelagic nets are a new gear to New England fishermen and are anticipated to have low bycatch of weaker stocks, including Atlantic cod and yellowtail flounder, and to allow access to areas closed to bottom trawling. Despite numerous setbacks, this project continues, with planned fieldwork beginning as soon as April 2019.

Impacts to Eelgrass from Bay Scallop Dredging

Contact person: Mike Pol, mike.pol@state.ma.us

Mar 2018 – ongoing

Small dredges (<0.8 m in width) are used both commercially and recreationally in Massachusetts to harvest the estuarine species, bay scallops (*Argopecten irradians*), in small-scale fisheries. This species preferably attaches to eelgrass (Zostera sp.) during development. Beds of Zostera show a general decline in the region despite protection of varying types. Towing dredges for bay scallops in eelgrass beds is discouraged but not banned, and the effort in eelgrass beds is poorly monitored and not well-documented. We initated a multi-year project to expose eelgrass beds to repeated towing of a bay scallop dredge, and to measue impact on shoot density of marine grasses. An unexploited eelgrass bed as used as a study area, and subjected to varied amounts of dredging (including controls) in a controlled randomized block design.

Camera drops were used to monitor impact, with shoot density to be determined by divers during the growing season as the response variable. Exploited beds are also planned for monitoring.

Figure 8.15.11: A typical bay scallop dredge. Width is approx. 0.8 m

NOAA Fisheries, Northeast Fisheries Science Center (NEFSC), Conservation Engineering Group, Woods Hole, Massachusetts

Contact person: Henry Milliken, henry.milliken@noaa.gov; Eric Matzen, eric.matzen@noaa.gov http://www.nefsc.noaa.gov/read/protspp/PR_gear_research/.

Summary

In 2018, the NEFSC in collaboration with the Southeast Fisheries Science Center (Nick Hopkins) conducted two gear-related projects investigating methods to reduce sea turtle bycatch in fishing gear. In the future, Henry and Eric are devoting much of their time to helping the fishing industry reduce the probability of entanglement of North Atlantic right whales. We plan to assist the fishing industry with testing of gear modifications in 2019.

Projects

Comparative study of a cable-sorting grid to reduce turtle bycatch in the summer flounder fishery

Contact person: Henry Milliken, henry.milliken@noaa.gov, Eric Matzen

Previous studies comparing catch rates of Turtle Excluder Device (TED)-equipped trawls and standard flatfish trawls found an average of 25-30% loss in targeted summer flounder (*Paralichthys dentatus*) catch in the TED equipped trawl. In 2017, we did a full study of the NETIII (a type of cable grid) system in the most successful configuration from 2016 using a twin trawl out of Point Judith, RI. The vessel was able to complete 49-paired tows. The results, which were highly significant, showed that the NETIII Cable TED reduced that catch of the targeted summer flounder by almost 53% and reduced the targeted skate catch by almost 42%. In 2018, we made changes to this design and retested using the same vessel and methodology as in 2017. We were able to accomplish 47-paired tows. The targeted fluke loss was approximately 49% and the skate loss was approximately 20%. These results further suggest that the TIII cable TED design in this configuration was unsuccessful at maintaining the targeted catch.

Comparative cable TED study in the longfin inshore squid (*Doryteuthis pealeii*) fishery

Contact person: Henry Milliken, henry.milliken@noaa.gov, Eric Matzen

The cable TED [TI] tested is similar to a cable TED successfully tested in the croaker fishery. This work occurred in the southern New England waters in October of 2018 and matched work done in 2017 but tested a slight modification to the design used in 2017. The vessel was able to complete 30-paired tows. Results from this work, using a twin trawl configuration, showed that the cable equipped TED net did not effect the catch of the targeted longfin squid compared to an identical net without the cable TED attached. Additionally, the finfish bycatch, which was higher in the cable TED equipped trawl in 2017 was reduced so that it was also similar to the non- cable TED equipped trawl.

University of Massachusetts Dartmouth, School for Marine Science and Technology (SMAST), Fish Behavior and Conservation Engineering , New Bedford, MA

Contact person: Pingguo He, phe@umassd.edu
http://www.smast.umassd.edu/fish/

Projects

Swimming speed and reaction capability of yellowtail and windowpane flounder at different temperatures

This project is to measure swimming speed and reaction time of these two flounder species in relation to water temperature in an effort to understand their ability to escape from scallop dredges. Muscle contraction times of flounders are being measured at different temperatures to predict their swimming speed during different seasons. Reaction times of these species are measured by recording and analyzing fish reaction to electrical stimuli. While data are still being collected, there seems to be substantial delay of reaction at lower temperatures. Longer delayed reaction and lower swimming speed can have a large negative consequence when escaping from fast-approaching fishing gear such as scallop dredges.

Behavior of river herring and its predator as observed by acoustic camera

This project uses SoundMetrics Adaptive Resolution Imaging Sonar (ARIS, a successor of DIDSON) to examine movement and behavior of river herring (genus Alosa) in rivers and estuaries as they migrate upstream to spawn. The ARIS recording is also been used to count the number of fish passing through sections of the river, which is compared with counting data from other means (electronic counting, human observer counting).

Attraction of fish to light/bait at night as observed by ARIS camera

This project was to test whether light alone is as effective as bait in attracting fish. Six treatments were tested: squid bait, squid bait with red light, squid bait with green light, red light alone, green light alone, and no bait/no light. It was found that green light alone the most effective in attracting fish (probably scup and/or black seabass) and was just as effective as bait with green light. Further work will be carried out this summer to test if light alone can be used to catch fish with pots without any bait.

Developing stereo camera system for assessing biomass in structurally-complex habitat

A stereo camera system was developed and deployed to assess abundance of structure-oriented black seabass in Buzzards Bay, Massachusetts. The system was deployed together with fish pots in different seasons to document habitat-association of black seabass and seasonable variation. This project will be continued to collect more data throughout the year.

Anderson Cabot Center for Ocean Life – New England Aquarium (AC-COL/NEAq), Boston, Massachusetts

Contact person: Tim Werner, twerner@neaq.org; Richard Malloy, rmalloy@neaq.org

Projects

Testing a ropeless fishing prototype for eliminating large whale entanglements in pot fishing gear

The removal of ropes from the water column is the only assured way to prevent whale entanglements. Under a grant from NOAA-Fisheries the NEAq worked with engineers at the Woods Hole Oceanographic Institute (WHOI) to produce a novel prototype spool that uses syntactic foam for flotation and incorporates an acoustic release for retrieval. The goal of this project is to continue evaluating this ropeless fishing system for use in the pot fisheries targeting crustacean and benthic fishes. A total of 37 successful deployments using 75m rope cartridges were successfully carried out during preliminary dock tests in Woods Hole, MA. In the summer of 2019 we aim to conduct 42 additional deployments in offshore waters under actual commercial fishing conditions. In collaboration with the commercial lobster fishing industry in Massachusetts participants will test the ropeless fishing devices in waters of 300 feet and deeper to assess the feasibility of the devices.

Technical Evaluation of Breakaway Gear – Rope tensile strength/Mechanical weak links/ Time-tension line-cutter

Three forms of break-away gear with potential to reduce their risk of entanglement to large whales, primarily the North Atlantic right whale (NARW) are to be evaluated by the Association des Crabiers Acadiens (ACA): (1) ropes that have reduced breaking strength along their entire length; (2) ropes typically used by the fishery that will incorporate weak links tied or spliced into them at regular intervals; and (3) ropes that incorporate time-release line cutters. Using a customized computer model developed in collaboration with independent engineers, AC-COL/NEAq scientists are analyzing rope loads under different scenarios (including depth, rope diameter, sea floor friction, trap weight, water and hauling velocity) to evaluate the feasibility of using these breakaway methods in this specific fishery.

Field Testing an Electric Decoy for Reducing Elasmobranch Bycatch in Longline Fisheries

Contact person: Tim Werner (twerner@neaq.org), Richard Malloy (rmalloy@neaq.org)

This project evaluated the potential of a battery-powered bait decoy to reduce the bycatch of elasmobranchs in a pelagic and bottom longline fishery. Our work included: (1) refining the design of a prototype device for durability and feasibility in oceanic fishing conditions and (2) testing the efficiency of the electronic decoy in fisheries independent longline experiments to determine if there is significant reduction in shark bycatch. In May 2017, fishery independent demersal trials were conducted using a refined electronic decoy off the coast of Florida which totaled 56 experimental longline sets. Additionally, in the summer of 2018 we carried out experimental field trials that integrated the electric deterrents in pelagic longline sets off the coast of Eleuthera Island, Bahamas. Working out of the Cape Eleuthera Institute (CEI) as a base allowed these devices to be tested in areas containing diverse and densely populated species of elasmobranchs. Results suggested the effectiveness of the devices as shark bycatch deterrent were not significant when comparing catch rates of gangions with or without the deterrent. However, categorical video data captured during small scale behavioral trials provided some optimism for this bycatch reduction technique. Results of these brief trials displayed a significant difference when comparing the interest of sharks between active and inactive devices. Why this does not translate into actual fishing conditions as shown in this project merits further investigation.

Development and Evaluation of Reduced Breaking Strength Rope to Reduce Large Whale Entanglement Severity

With support from the Massachusetts Office of Energy and Environmental Affairs, we have had 1,700 lbf prototypes developed and tested both in a lab and at sea. The most promising prototype is the Novabraid sleeve design initially developed by the South Shore Lobster Fishermen's Association in collaboration with rope manufacturer Novatec Braid, Ltd. Both our lab and field testing showed the sleeves break at just below 1,700 lbf and are feasible during normal fishing activity as only 11.8% of experimental endlines were reported broken/missing in comparison to 8.5% of reported broken/missing control endlines. There is time involved (~ 5 minutes per sleeve) to integrate the sleeves every 40 feet into the endlines but the cost per sleeve is relatively low at just over $2 per sleeve and would allow fishermen to use their existing ropes. Efforts to build fully formed 1,700 lbf ropes were unsuccessful; however, initial testing of the most recent sample provided by a rope manufacturer seems promising. With this sample arriving in the coming weeks we aim to further assess the breaking strength (independently) and overall properties of this developed rope.

Modeling work was carried out to assess the tensions placed on ropes when hauling gear in normal fishing operations and to evaluate what forces a whale might put on gear during an entanglement provided a better understanding of what parameters influence rope tensions. Using results of at-sea testing integrated into OrcaFlex software showed that during the hauling of gear, the drag coefficient and the weight of gear in the water column had the most influence on endline rope tensions as water velocity and wave height increased. Operational changes such as increasing the groundline distance between the first and second pot, reducing hauler speed in high sea states and keeping the vessel over the top of the gear during hauling were all approaches that could be used to minimize rope tension. The Whale Entanglement Simulator, developed by BelleQuant Engineering to measure rope tensions when a whale gets entangled and rolls in response showed similar findings in that the weight of gear attached and the speed of the whale increased the simulated tensions in the three scenarios tested.

Based on the at-sea testing and the modeling studies, using 1,700 lbf ropes represent a suitable option that will allow fishing to occur without increasing gear loss but give whales the chance to more quickly part the entangling gear thereby reducing the negative impacts of entanglement. NovaBraid sleeves have been manufactured and could be deployed broadly into fixed gear fisheries to help address the right whale entanglement issue that is driving this species towards extinction.

Pacific States Marine Fisheries Commission (PSMFC)

Contact person: Mark J.M. Lomeli, mlomeli@psmfc.org
http://www.psmfc.org/bycatch/

Summary

In 2018, the Pacific States Marine Fisheries Commission and project collaborators conducted two studies. The first study occurred in the ocean shrimp (*Pandalus jordani*) trawl fishery where the efficacy of artificial illumination along an ocean shrimp trawl fishing line to reduce bycatch of eulachon (*Thaleichthys pacificus*) and groundfishes before trawl capture was evaluated. Results from this work showed eulachon and yellowtail rockfish (*Sebastes flavidus*) significantly avoided capture before trawl entrainment in the presence of illumination. For other rockfishes (Sebastes spp.) and flatfishes, however, the study did not see the same effect as the illuminated trawl caught similarly or significantly more fishes than the unilluminated trawl. In the second study, research examined in the West Coast groundfish bottom trawl fishery if changing from conventional bottom tending sweeps to modified sweeps (with sections elevated 6.5 cm off bottom) would affect catch efficiency of target groundfishes and seafloor interactions. Results from this study demonstrate that seafloor interactions can be substantially reduced using elevated sweeps in this fishery without impacting catch efficiency. In 2019, we have two studies occurring. The first study will evaluate the level of artificial illumination needed to achieve optimal Chinook salmon (*Oncorhynchus tshawytscha*) escapement out of a BRD outfitted on a Pacific hake (*Merluccius productus*) midwater trawl, while the second study seeks to determine if illumination along the upper bridles and wing tips of a low-rise selective flatfish trawl can reduce Pacific halibut bycatch by enhancing their ability to perceive escape areas around the trawl before trawl entrainment. Further summaries of these projects are depicted below.

Projects

Evaluating off-bottom sweeps of a U.S. west coast groundfish bottom trawl: effects on catch efficiency and seafloor interactions

Contact person: Mark J.M. Lomeli, mlomeli@psmfc.org

Mark J.M. Lomeli (PSMFC), W. Waldo Wakefield (NMFS NWFSC), Bent Herrmann (SINTEF), and groundfish fishers

In the U.S. West Coast groundfish bottom trawl fishery, lengthy sweeps (>85 m) that maintain seafloor contact are traditionally used. While these sweeps are effective at herding groundfishes, their bottom tending characteristics increase the potential to cause seafloor disturbances, and injury and unobserved mortality to benthic organisms. In this study, we examined if changing from conventional to modified sweeps (with sections elevated 6.5 cm off bottom) would affect catch efficiency of target groundfishes and seafloor interactions. We used a DIDSON imaging sonar to observe how each sweep configuration interacted with the seafloor. An altimeter was periodically placed on the modified sweep to measure height off bottom. Results detected no significant catch efficiency effect of changing from conventional to modified sweeps. The DIDSON and altimeter data showed the modified sweeps exhibit elevated sections where infaunal and lower-profile epifaunal organisms can pass under without disturbance. Results demonstrate that seafloor interactions can be substantially reduced using elevated sweeps in this fishery without impacting catch efficiency. Further, findings from this research could be potentially applicable to other fisheries nationally and internationally. Funding for this study is being provided by NOAA NMFS Bycatch Reduction Engineering Program.

The efficacy of illumination to reduce bycatch of eulachon and groundfishes before trawl capture in the eastern North Pacific ocean shrimp fishery

Contact person: Mark J.M. Lomeli, mlomeli@psmfc.org

Mark J.M. Lomeli (PSMFC), Scott D. Groth (ODFW), Matthew T.O. Blume (ODFW), W. Waldo Wakefield (OSU CIMRS), Bent Herrmann (SINTEF), and ocean shrimp fishers

This study examined the extent that eulachon (*Thaleichthys pacificus*) and groundfishes escape trawl entrainment in response to artificial illumination along an ocean shrimp (*Pandalus jordani*) trawl fishing line. Using a double-rigged trawler, we compared the catch efficiencies for ocean shrimp, eulachon, and groundfishes between an unilluminated trawl and a trawl illuminated with 5 green LEDs along its fishing line. Results showed a significant reduction in the bycatch of eulachon and yellowtail rockfish (*Sebastes flavidus*) in the presence of LED illumination. As eulachon are an Endangered Species Act listed species, this finding provides valuable information for fishery managers implementing recovery plans and evaluating potential fishery impacts on their recovery and conservation. For other rockfishes (*Sebastes* spp.) and flatfishes, however, we did not see the same effect as the illuminated trawl caught similarly or significantly more fishes than the unilluminated trawl. Prior to this research, the extent that eulachon and groundfishes escape trawl capture in response to illumination along an ocean shrimp trawl fishing line was unclear. This study has provided results to fill that data gap. Funding for this study is being provided by NOAA NMFS Bycatch Reduction Engineering Program.

Identifying the optimal level of artificial illumination necessary to achieve maximum Chinook salmon escapement rates out a bycatch reduction device integrated into a Pacific hake midwater trawl

Contact person: Mark J.M. Lomeli, mlomeli@psmfc.org

Mark J.M. Lomeli (PSMFC), Waldo Wakefield (OSU CIMRS), and Pacific hake fishers

May-October 2019

In this upcoming study, we will compare Chinook salmon (*Oncorhynchus tshawytscha*) escapement rates between tows made with quantities of 0, 6, and 18 LEDs attached along the BRD escape windows. We will use a recapture net to quantify escapement rates. A series of blue Lindgren-Pitman LED Electralume® fishing lights will be used to provide illumination. Ambient and artificial light levels will be measured using Wildlife Computers TDR-MK9 tags. We will use a multiple proportions test to determine if the proportion of Chinook salmon to escape for a given light quantity differs significantly between any two of the three quantities tested. Study results will provide new data on how much illumination is needed to achieve maximum Chinook salmon escapement rates out of a BRD outfitted on a Pacific hake (*Merluccius productus*) midwater trawl. Funding for this study is being provided by NOAA NMFS Bycatch Reduction Engineering Program.

Use of LEDs to reduce Pacific halibut catches before trawl entrainment

Contact person: Mark J.M. Lomeli, mlomeli@psmfc.org

Mark J.M. Lomeli (PSMFC), Waldo Wakefield (OSU CIMRS), Claude Dykstra (Int. Pacific Halibut Commission), Bent Herrmann (SINTEF), Jon McVeigh (NMFS NWFSC), and groundfish fishers

May-October 2019

In this upcoming study, we will evaluate if LEDs attached along the upper bridles and wings of a low-rise selective flatfish trawl can reduce Pacific halibut (*Hippoglossus stenolepis*) bycatch before trawl entrainment in the West Coast groundfish bottom trawl fishery. Green LED fishing lights will be used as the artificial light source. The trawl will be fished with- (*treatment*) and without-LEDs (*control*) in an alternate tow design. Length-dependent catch comparison and catch ratio analyses will be conducted to determine if mean fish length classes of Pacific halibut and other groundfishes differ between the *treatment* and *control* trawl. Biological data (e.g., L-W, fat content, body temperature, etc.) of Pacific halibut caught in the *treatment* and *control* trawls will also be collected to see if physiological condition could be related (or not) to their ability to engage in a visual response and avoid entrainment. Funding for this study is being provided by NOAA NMFS Bycatch Reduction Engineering Program.

Hawaii Pacific University, College of Natural and Computational Sciences, Fisheries Bycatch Program, Honolulu, Hawaii

Contact person: Eric Gilman, EricLGilman@gmail.com

Project
Hawaii pelagic longline branchline weighting to reduce seabird catch risk

Contact person: Eric Gilman, EricLGilman@gmail.com

Capture in global pelagic longline fisheries threatens the viability of some seabird populations. The Hawaii tuna longline fishery annually catches hundreds of seabirds, primarily Laysan (*Phoebastria immutabilis*) and black-footed (*P. nigripes*) albatrosses. Catch rates and levels of the black-footed albatross have steadily increased in Hawaii's tuna longline fishery over the past decade. The factors branchline weight amount and distance from the hook significantly affect seabird catch risk during setting and hauling. A demonstration will be conducted in 2019 to investigate the practicality and safety of alternative branchline weighting designs that place weights at or near the hook relative to conventional terminal tackle designs. Pending the outcome of the demonstration, a controlled experiment will be conducted to assess the effect of the experimental branchline weighting design on the baited hook sink rate and species-specific catch risks.

The Nature Conservancy, Indo-Pacific Tuna Program, Pelagic Fisheries Bycatch Program, Honolulu, Hawaii

Contact person: Eric Gilman, EricLGilman@gmail.com

Project
Effects of pelagic longline hook size on species- and size-selectivity and survival

Contact person: Eric Gilman, EricLGilman@gmail.com
Milani Chakoupka, Michael Musyl

Pelagic fisheries can have profound effects on ecosystem structure and functioning, affecting ecosystem services, including fisheries production, and threatening vulnerable bycatch species. Controlling hook size could improve the species- and size-selectivity and survival of target and incidental catch. To test this hypothesis, we conducted experimental pelagic longline fishing in the western tropical Pacific testing a control hook and two hooks with wider minimum widths. Catch rates of both retained and discarded species were significantly higher on medium hooks. Target tuna species were significantly larger and had significantly higher at-vessel survival rates on wider hooks. Significantly larger billfishes, also market species, were caught on narrowest hooks.

These effects of hook width on length and survival, however, are a much smaller determinant of economic value of the catch than effects on catch rates. In this fisheries management system, where input controls are limiting, relative to medium hooks, continued use of narrowest hooks would maintain current economic viability without causing a significant increase in discard catch levels, including of vulnerable sharks. If market species output controls were limiting, because the ratio of retained to discarded catch on medium hooks was greater than on narrowest hooks, medium hooks would generate lower discard levels.

8.16 Australia

Smart Fishing Consulting

Contact person: Steve Eayrs. Email. smartfishingcosulting@gmail.com

Summary

Limited fishing technology research has focused on prawn trawl fisheries, in part because of their importance to the Australian fishing industry, by value and geographical extent, and because of ongoing concerns over the environmental impact of prawn trawling. Australia is one of the few countries with one or more tropical prawn trawl fisheries certified by the Marine Stewardship Council, and this provides additional pressure for ongoing improvement in fishing gear.

Projects

Reducing the environmental impacts and improving the profitability of prawn trawling through a structured framework of anterior gear modifications

Contact person: Matt Broadhurst. Email. matt.broadhurst@dpi.nsw.gov.au; David Sterling. Email. djstgs@bigpond.com

Date: Sept 2011 – Sept 2015

This project represented an attempt to evaluate the efficacy of modifications to a prawn trawl to reduce bycatch, habitat impact, and fuel consumption, with a primary focus of modifications to anterior region of a prawn trawl. These modifications included alternative otter board designs, sweep-length modifications, ground gear modifications, hanging ratio and body taper variation, knot orientation, headline height reduction, and a simple anterior fish excluder (SAFE). The efficacy of multi-rig trawl systems was also evaluated.

Drag forces generated in a prawn trawl system were quantitatively evaluated and found to be generated primarily by the otter boards and trawl netting (Figure 8.16.1). Contemporary otter board designs were found to achieve fuel savings up to 20% compared to flat rectangular otter boards although the challenges board stability during deployment and while fishing means angle of attack must be set higher than optimum. A bat wing otter board has been developed to overcome this challenge and shows promise (Figure 8.16.2).

Ground gear modifications showed promise in terms of reduced habitat impacts with no reduction in prawn catch, while sweep reduction significantly reduced bycatch with no reduction in prawn catch. For some key bycatch species, catches were reduced up to 95%.

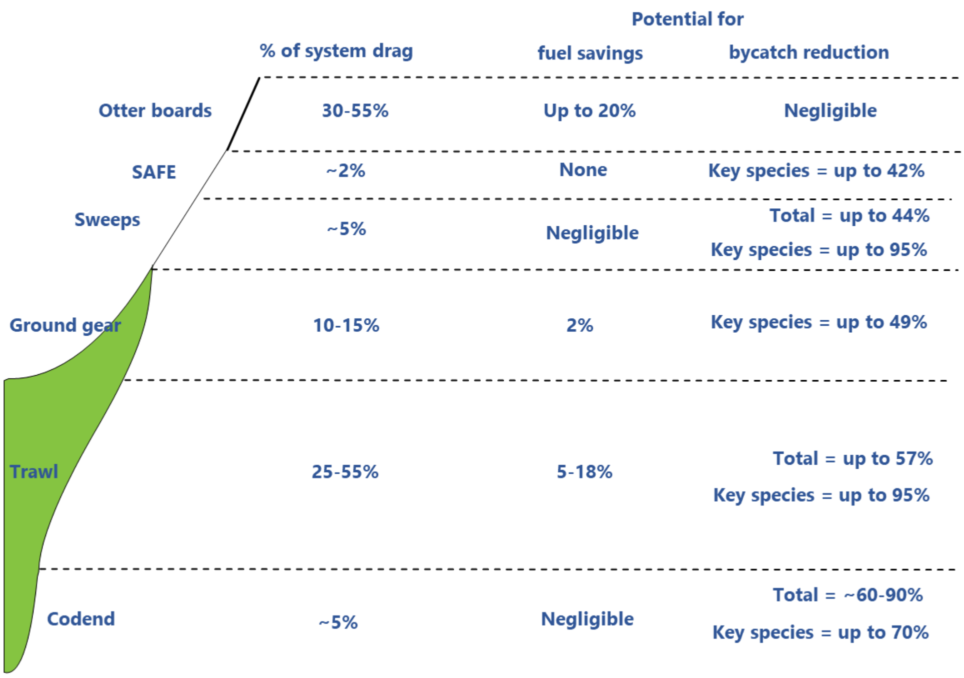


Figure 8.16.1. Summary of project results.

Figure 8.16.2. The bat wing otter board. This otter board is designed to be operated at an angle of attack of around 20 degrees, during trawl deployment and while on the seabed. In this way lift to drag ratio is optimised without compromising stability.

Evaluation of three new BRDs for Australia's Northern Prawn Fishery

Contact person: Adrianne Laird. Email. adrianne@npfindustry.com.au.

Date: May 2018 - November 2018

Two new Bycatch Reduction Devices (BRDs) were tested in May-June 2018 and a third new BRD in November 2018 against the currently approved BRD; the Square Mesh Panel BRD. The three new devices were modifications of the approved Kon's Covered Fisheye device and both were tested as single 'fisheyes' positioned at 60 or 65 meshes from the codend drawstrings while the control Square Mesh Panel BRD was positioned at 120 meshes from the codend drawstring. The objective was to reduce the capture of small bycatch by 30%. Testing occurred on commercial prawn trawlers and data was collected by AFMA scientific observers.

There was significantly less bycatch caught in the nets with all of the trialled BRDs; the Single Kon's Covered Fisheye (Figure 8.16.3), FishEX70 and Tom's Fisheye BRDs installed compared to the nets with the standard Square Mesh Panel BRD installed. In terms of bycatch reduction, the FishEX70 BRD and Tom's Fisheye BRD achieved a mean reduction in bycatch of 41% and 44% compared to the 23% of the Single Kon's Covered Fisheye BRD. There was no significant difference in mean commercial prawn catches between the nets fitted with either of the three trialled BRDs compared to nets with the standard Square Mesh Panel BRD.

Figure 8.16.3. The Kon's covered fisheye.

8.17 China

Shanghai Ocean University

Hydrodynamic characteristic of netting

Contact Person: Hao Tang (htang@shou.edu.cn)

May 2017- October 2019

The project aims to investigate the hydrodynamic characteristics of netting panels with various twine materials, knot types, and weave patterns. Flume tank experiments have been conducted to validate a self-designed setup, evaluate the hydrodynamic characteristics of netting panels made of three twine materials (PE netting, PES netting, PA netting), and quantify the effect of knot, weave pattern (twined and braided), and twine material on the drag coefficient at small attack angles.

The results indicate that the drag coefficient was determined by varying the attack angle, solidity ratio, Reynolds number, knot types, weave pattern, and twine materials at small attack angles. The drag coefficient increased as the attack angle increased, but decreased as the solidity ratio and Reynolds number increased. The drag generated by knot accounted for 21% of the total drag of nylon (PA) netting. For braided knotless netting, the drag coefficient of PA netting was about 8.4% lower than that of polythene netting (PE) and 7% lower than that of polyester netting (PES). Compared with twined netting, the braided netting exhibited a higher resistance to flow, corresponding to higher values of drag coefficient.

Sinking performance of tuna purse seine

Contact Person: Hao Tang (htang@shou.edu.cn), Liuxiong Xu (lxxu@shou.edu.cn)

October 2008 to May 2015

This project measured sinking performance of 88 purse seine sets on free-swimming skipjack (Katsuwonus pelamis) schools in the western and central Pacific Ocean from October 2008 to May 2015, and analyzed sinking depth and sinking speed under different sea conditions (current speed and direction at different layers), gear design (length-height ratio, towing line length and purse line length), and operational methods (shooting duration and setting speed). The results showed that the sinking performance of a purse seine with a lower length-height ratio was better than a seine with a higher ratio, current speed at 120 m depth was the most important environmental factor affecting sinking depth of the purse seine. Sinking depth was strongly associated with length-height ratio, shooting duration and purse line length. Sinking speed was related to length-height ratio, shooting duration, current speed at 60 m, purse line length and towing line length. The sinking performance models obtained from this study can be used to predict sinking behavior in relation to operational and environmental conditions, which is essential for the success of tuna purse seine operation on free-swimming tuna schools.

Gear modifications of tuna purse seine nets

Contact Person: Hao Tang (htang@shou.edu.cn), Liuxiong Xu (lxxu@shou.edu.cn)

2016 – ongoing

We tested two tuna purse seine model nets with different mesh sizes to obtain the lateral and drifting distance, spatial geometry, purse line tension and sinking speed of a purse seine under different operation conditions related to the current direction, three net shooting patterns and two current speeds. It was found that better spatial geometry and sinking behavior of the purse seine occurred by shooting the net normal to the current than shooting it with or against the current. Setting with the current was considered as the optimal strategy of shooting the net in terms of reducing the tension of the purse line. The net drifting distance decreased when the mesh size of the main body was increased, and the minimum lateral and drifting distances occurred when setting with the current. Increasing the mesh size helped reduce the enclosed area in the horizontal direction, especially of the bottom of net, and keep a better net shape. The pursing time and purse line tension reduced by 12% and 9.26% respectively when the mesh size of the lower part of the main body increased from 30 to 45mm. In general, larger mesh nets can decrease purse line tension and improve sinking performance and net geometry

Longline configuration model suitable for high sea bigeye tuna in the eastern Pacific Ocean

Contact Person: Liuxiong Xu (lxxu@shou.edu.cn), Cheng Zhou (zhoucheng286@126.com)

March 2018 – December 2019

The bycatch of non-target species in high Sea tuna longline fishing operations is a growing concern of the international community, particularly for endangered and protected species such as some shark species and turtles. To facilitate the effective release of sea turtles, t-RFMOs encourage the use of circle hooks instead of traditional J-style hooks. The project aims to develop a longline configuration model suitable for high sea bigeye tuna in the eastern Pacific Ocean by comparing different shapes and sizes of hooks in the water layer tuna habitats. The main works include the investigation of depth/time where/when fishes are caught, the influence of hook size/hook type (Japanese-style tuna hooks VS. circle hooks) on catchability, selectivity of fish size, caught condition at retrieval, and interaction with target species and by catch. In the first portion of this project during 2018, Temperature-Depth Recorders were attached at the end of branch lines as an analog substitution for hooks and baits for the purpose of hook depth monitoring. Japanese-style hooks (5.0 mm, 10° offset) and circle hooks (size 14/0, 15/0, and 16/0) were alternately used for comparison of effects of hook style and size on pelagic catches. In the follow-up phase of project in 2019, hook timers will be additionally settled on the branch lines to help us understand the time-of-capture of fish and inter-behavior of fish with hooks.

Scale effect issues of fishing gear model experiment

Contact Person: Cheng Zhou (zhoucheng286@126.com), Rong Wan (rwan@shou.edu.cn)

January 2019 – December 2021

An essential approach to obtain insights into the dynamics and kinetic behavior of prototype in actual fishing operations is reconstructing it with alternative model net of small scale in flume tank experiment. This practice has been widely used for the evaluation and optimization of fishing gears on their efficiencies of harvest, selectivity, and safety. In this project, we will further qualify the hydrodynamics and geometry deformation responded by mesh and net of multiple scaled models based on Tauti's law by combining with fluid dynamics, physical model experiment, and numerical simulation. The project aims to make a complement of Tauti's law and furthermore, to propose the correction method based on the dynamics of porous structural panels in order to reduce scale effect. A series of experiment theory and methodology to decrease the system bias under the restriction of test field, manufacture technology and confliction of similarities will be further refined to improve the ability of model test on predicting and evaluating the performance of fishing gear.

Degradability evaluation of natural material ropes

Contact Person: Liuxiong Xu (lxxu@shou.edu.cn), Cheng Zhou (zhoucheng286@126.com)

December 2018 – ongoing

The increasing use of fish aggregating devices (FADs) in tuna fisheries has raised concerns within the tuna Regional Fisheries Management Organizations (RFMOs) due to bycatch and incidental mortality of sharks and sea turtles caused by entanglement, including ghost-fishing. The developing trend in ecological FADs for tuna purse fisheries is to use non-entangling FADs and biodegradable FADs. WCPFC has adopted CMM on the minimum mesh size of netting for underwater structure of non-entangling FAD. This ongoing work was evaluating the degradability of three natural material ropes (3-ply 96-thread cotton, 3-ply 13-thread jute, and 3-ply 8-thread sisal) on the basis of an experiment measurement. These samples were deployed at China's offshore waters attached to the floating frame of net cage in Dec 2018 and retrieved per month for testing breaking strength in the laboratory. Preliminary tests conclude that (i) Jute presented wider variation in the initial breaking strength compared to cotton and sisal; (ii) Both jute and sisal experienced rapid reduction in breaking strength and were deprived of all strength in the sea by the fourth month; (iii) Cotton rope exhibited the most inertial degradation behavior characterized by obvious reduction of breaking strength during the first month and almost constant in the following months. This project will make some efforts on promoting Chinese tuna purse seine fishery moving away from synthetic to biodegradable materials used on FADs.

Performance of Antarctic krill trawl

Contact Person: Liuxiong Xu (lxxu@shou.edu.cn), Hao Tang（htang@shou.edu.cn）, Cheng Zhou (zhoucheng286@126.com)

January 2014- ongoing

The project aims to understand the performance of Antarctic krill trawl by investigating the drag characteristic, spread performance, mouth shape and fishing efficiency of trawl at different towing speeds and warp lengths through both field measurement and flume tank test. The measurement of prototype trawl at sea was conducted in 2018. The main results of sea trials show that: (1) During trawling, net position was controlled mainly by the length of warp. (2) Both warp length and towing speed have a significant impact on the net position and net mouth opening ($P<0.05$). (3) The average rate of the net position change decreased first and then increased with different ranges of towing speed under different warp lengths. Flume tank experiments indicate that: (1) With the increasing towing speed and door spread, the bridle tension of model net increases; (2) The heavy bob has significant impact on the net resistance, energy consumption coefficient and mouth height ($p<0.05$); (3) The net resistance increases with the twine area of the inner net, its increase level is related to towing speed. The difference is smaller at low towing speed and obviously bigger while towing speed is increasing.

The next step aims to measure the flow field inside and around the krill trawl and explain the mechanism and influencing factors of flow field distribution in different parts of trawl.

Selectivity of Antarctic krill trawl

Contact Person: XU Liuxiong (lxxu@shou.edu.cn, WANG Zhongqiu (gavin0815@foxmail.com),TANG Hao (htang@shou.edu.cn)

January 2019- ongoing

The project aims to study the selectivity of Antarctic krill trawl by understanding the behavior response of krill on the netting and its escape mode inside the trawl during towing process base on experimental observation and at sea measurement. The results can be used to optimize the selective prediction model of Antarctic krill trawl and provide a scientific basis for the development of green and efficient krill trawl. The main research content of the project consists of (1) Krill catch composition analysis; (2) Behavior of Antarctic to netting; (3) Behavior and escape of Antarctic krill after entering the net;(4) Effect of factors on the selectivity of Antarctic krill trawl; and (5)Construction of selectivity prediction model for Antarctic krill trawl.

This project is carried out on board Chinese large-scale factory trawler "Longteng" of China National Fisheries Corporation Ltd, which is operating at sub-area 48.2 of Antarctic water in March 2019. The experiments conducted so far as to March 18 include the escape rates of krill related to mesh sizes and open angles in a tank, survival rate of krill after escaping through mesh, and reaction of krill to netting.

Numerical Investigation on the Mechanical Properties of Otter Board

Contact person: Wenhua CHU, whchu@shou.edu.cn

March 2017-March 2019

Aiming at the mechanical characteristics of the trawling operation process, we conducted some numerical investigation on the mechanical properties of the otter board based on the fluid-solid coupling dynamics theory. The fluid-solid coupling numerical model of the otter board was established to study the hydrodynamic performance and structural dynamic response characteristics of it. The mechanical properties and the influence of typical structural and operating parameters in trawling process were analyzed and summarized.

Illumination model of fishing lamps for Pacific saury fishery

Contact Person: Chuanxiang Hua（cxhua@shou.edu.cn）

Jan 2017-Jan 2019

The incandescent light bulb fishing lamps are important traditional equipment in the Pacific saury fishery. In order to calculate the distribution of the illumination, we developed an illumination model based on the spherical source method. It was found that the linear fitting slope coefficient was closer to 1 by comparing the theoretical values and measured values of plane illuminance. The result also showed, the illuminance value increased first and then decreased with the increase of distance, and the decay rate of illumination decreased first, then increased and then decreased with the increase of distance, and finally approached to 0.

The application research of LED fish aggregation lamp in the squid jigging fishery

Contact Persons: Weiguo Qian (wgqian@shou.edu.cn) Weijie Wang (524253949@qq.com)

March 2013 – December 2016

The project aims to promote the application of LED lamp in the squid jigging fishery. In order to verify the application effect of LED fish-gathering lamps on squid fishing boats, we made fifty 600W LED fish-gathering lamps and installed them high above the right deck of the test squid jigging boat, replacing the original fifty 2000W LED metal halide lamps. The illumination in water measured indicates that the illumination distribution in the water on port side and starboard of the fishing boat was similar, while the attenuation rate in sea water of the light formed by the metal halide lamp was significantly higher than that of the LED fishing lamp. During the fishing comparison, the test vessel caught 286 tons of squid, while the control squid fishing vessel equipped with fifty 2000W metal halide lamps on both the starboard and starboard sides produced 263 tons. Furthermore, the fuel consumption of the test fishing boat is 60% less than that of the comparison boat.

Dynamic Simulation of Pelagic Longline Retrieval

Liming Song, Yukun Qi, Jie Li, Zhibin Shen, Xinfeng Zhang
Contact Person: Liming Song lmsong@shou.edu.cn

Duration: 2014 – 2016

To improve fishing gear efficiency, it is important to understand the interactions among sea current, fishing vessel, line hauler, and catches during pelagic longline gear retrieval. In this study, fishing gear configuration parameters, operational parameters, and 3D ocean current data were collected from Indian Ocean. Dynamic models of pelagic longline gear retrieval were built using the lumped mass method and solved using the Euler-Trapezoidal method. From the results, the pulling force of line hauler exerted on the gear was 2800–3600 N. There were no significant differences ($P > 0.05$) between the time of the hook retrieval measured at sea and that obtained from the simulation. The absolute values of the movement velocity at representative nodes along the X, Y, and Z axes were 0.01–25.5 m s^{-1}. These results suggest that the dynamic model of longline fishing gear retrieval can be used to analyze the interactions among sea current, fishing vessel, line hauler, longline gear, and catches, and to acquire the basic data for optimizing the design of the line hauler. Moreover, the model can serve as a reference to study the hydrodynamic performance of other fishing gears during the hauling process.

A comparison mechanical property of ring hook between tensile test and

ANSYS simulation

Haiyang Liu, Liming Song, Junting Yuan, Junchi Ma
Contact Person: Liming Song(lmsong@shou.edu.cn)

Duration: 2015 – 2016

In order to study the mechanical properties of tuna longline hooks, and to verify the accuracy of the finite element analysis method, this study conducted tensile test and ANSYS simulation on the ring hook (Type: 3.4-4.5). The results of tensile test and ANSYS simulation were compared and tested by ANOVA. The results showed that: (1) there were no significant differences of the mechanical characteristics e. g. displacement or strain, measured by two methods ($P>0.05$). The maximum strain area was around the back bent and rear side. The maximum total displacement area was around the front bent and front axle. The maximum displacement in X direction was around the bottom and rear side. The maximum displacement in Y direction was around the back bend and back axle; (2) when the tension was 500, 800, and 1200N, the ring hook's strain was 0.002 76, 0.008 14, and 0.069 94; the displacement in X direction was 1.8, 3.5, and 7. 2 mm; the displacement in Y direction was −2.4, −4.6, and −8.7 mm; the total displacement was 2.8, 5.4, and 10.6 mm, respectively; (3) there was a significant linear relationship between the results of tensile test and those of the ANSYS simulation. The displacement in total, X, Y direction, and strain of tensile test were 1.018 9, 1.027 2, 1.019 5, and 1.088 3 times the ANSYS simulation. This study suggested that the ANSYS finite element could be used to analyze tuna longline hooks' mechanical property.

The mechanical properties of ring hook and circle hook

Haiyang Liu, Liming Song, Junting Yuan, Junchi Ma
Contact Person: Liming Song lmsong@shou.edu.cn

Duration: 2015 – 2016

In order to popularize the circle hook in Chinese tuna longline fisheries, the mechanical properties of ring hook and circle hook must be understood. The tensile test was conducted by the universal testing machine.

The strain and displacement of the ring hook 3.4–4.5 and circle hook 14/0–4.5 during the tensile test were measured by the digital image correlation system. Results showed that: (1) While the tension acted on the circle hook 14/0-4.5 and ring hook 3.4-4.5 was 500N and 800N, the highest strain of circle hook 14/0-4.5 was 0.012 and 0.018, and that of the ring hook 3.4-4.5 was 0.010, and 0.025, respectively; (2) While the tension acted on the circle hook 14/0-4.5 and ring hook 3.4-4.5 was 500N and 800N, the highest displacement of circle hook 14/0-4.5 was 5.16mm and 8.50mm, and that of the ring hook 3.4-4.5 was 4.36mm and 6.01mm, respectively. Results of Chi-square test showed that there were no significant differences in the strain or displacement between circle hook 14/0–4.5 and ring hook 3.4–4.5 ($P>0.05$). Results suggested that the circle hook 14/0–4.5 should be popularized in the Chinese tuna longline fisheries.

Optimum soak time of tuna longline gear

Liming Song, Weiyun Xu, Daomei Cao, Changke Zhao
Contact Person: Liming Song lmsong@shou.edu.cn

Duration: 2010 – 2011

On the basis of the data collected from October 2010 to January 2011 in the tuna longline survey, the soak time calculation models of every branch line in each operation were developed by both modes of hook retrieval. The soak time of longline gear divided into one hour interval for the quantity of hooks and the individuals of bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacores*), respectively. The respective catch rates (CPUEs) of bigeye tuna and yellowfin tuna in each hour interval were calculated. The results showed that (1) both CPUE of bigeye tuna and yellowfin tuna presented increasing at first and then decreasing trend along the increase of soak time. The reason was the lure effect fluctuation of bait and the lose of hooked fish; (2) the quadratic curves can be fit the relationships between soak time and the CPUE of bigeye tuna, and yellowfin tuna; (3) the CPUE of bigeye tuna and yellowfin tuna was the highest when soak time was 9.9 h and 10.1 h, respectively. This study suggested that (1) the soak time of each hook lasted about 9.5-10.5 h in the tuna longline operation for improving the fishing efficiency and decreasing the bycatch; (2) the soak time of the longline gear could be considered as the effective fishing effort and used to standardize the CPUE. The results will be applied to improve the fishing efficiency and to decrease the bycatch and will be applied for the references to the fishing strategy and CPUE standardization.

East China Sea Fisheries Research Institute, Chinese academy of fishery sciences

Contact persons: HUANG Hongliang(ecshhl@163.com）,WANG Lumin(lmwang@ecsf.ac.cn)

Research and demonstration of fishing technology and fishing gear

Contact persons: XueZhong CHEN (xuezhong@ecsf.ac.cn),Hongliang HUANG (huanghl@ecsf.ac.cn), Xun Zhang, zhangx@ecsf.ac.cn

2015-ongoing

The project is supported by the Special Fund for Agro–scientific Research in the Public Interes. The East China Sea Fisheries Research Institute of the Chinese Academy of Fishery Sciences organized the Yellow Sea Fisheries Research Institute, the South China Sea Fisheries Research Institute, Shanghai Ocean University and other institutions, and in cooperation with the Ocean University of China and Dalian Ocean University, and conducted a research on the selectivity of main fishing gear, including trawl net, stow net and gill net in China's offshore waters. After the completion of the project, a total of 12 sets of selective release devices have been developed, 12 standard parameters of ecological fishing gear have been obtained, and 3 industry standards have been formulated.

Minimum mesh size implementation system support

Contact persons: Lumin WANG (lmwang@ecsf.ac.cn)

2015-ongoing

The project is supported by Agriculture ministry agriculture finance special project. The aim of the project is to provide the fisheries authority with the scientific advice in making decision for the comprehensive implementation of resource conservation fishing gear. The East China Sea Fisheries Research Institute of the Chinese Academy of Fishery Sciences organized the Yellow Sea Fisheries Research Institute, and provincial fisheries research institutes in Hainan, Fujian, Zhejiang and Jiangsu provinces to systematically classify and assess the ecological functions of all fishing gear in China's offshore waters based on selectivity test and catch sampling survey of different fishing gear.The catalogue of Marine fishing gear in China has been compiled based on the research. And in accordance with the characteristics of fishing gear operation, catch composition and the extent of its impact on the ecological environment, suggestions on the management of permitted fishing gear, transitional fishing gear and prohibited fishing gear have been put forward. On this basis, through the selective test and demonstration of the transitional fishing gear, the permission or prohibition of the transitional fishing gear is finally determined, and the transitional fishing gear is gradually eliminated, so as to provide a decision-making basis for the comprehensive implementation of resource conservation fishing gear.

Single Sheet Gillnet Mesh Selectivity for Pseudosciaena polyactis

Contact person: Linzh LI（lilz@ecsf.ac.cn）,Hongliang HUANG (huanghl@ecsf.ac.cn)

January 2012 – December 2014

Bimodal curve model was used to analyze the length distribution data collected by the single gillnet in the coastal water of Southern Yellow Sea in Qidong region from October 22 to November 25 in 2014. The reasonable catching length of 35, 40, 45, 50, 55 mm mesh size through gilled and wedged was 67 mm and 139 mm, 77 mm and 159 mm, 87 mm and 179 mm, 97 mm and 199 mm, 107 mm and 219 mm according to the selectivity curve of the gillnet for *Pseudosciaena polyactis*. Here the Poisson equation and the likelihood ratio chi-square were used to check the error and the goodness of the fit. The results showed that the ratio of the chi-square value to the degrees of freedom was 1.39, close to 1, indicating that the model fit better. Based on the result of the experiment, the juvenile fish percentage of 55 mm mesh size gillnet was 22%, which did better to the release of the juvenile fish. Taking into account the needs of production, here the minimum mesh size was made 55 mm.

The mesh size selectivity of gillnets

Contact persons: Linzh LI（lilz@ecsf.ac.cn）, Hongliang HUANG (huanghl@ecsf.ac.cn)

January 2012 – December 2016

The project aims to discover the selectivity of gillnets in the East China Sea. A production test using three mesh sizes (45mm,50mm and 55mm) and two gear heights (6m and 10m) was carried out. Three uni-models (Normal, Lognormal and Gamma) were used to analyze the selectivity. The parameters were estimated using maximum likelihood methods. Likelihood ratio Chi-square test and Akaike's information criterion (AIC) were used to compare the goodness of fit of the different models. The result showed that the 50% select body length of 50mm mesh size is 123mm, the select range is 123mm~209mm, the dominant length range is 125mm ~185mm. The select range of 50mm mesh size covered the estimated dominant range,50mm mesh size is the most efficient for *Chelidonich thysspinosus*. The influence of the mesh size on the fishery resource was not assessed due to the lack of knowledge about *Chelidonich thysspinosus* resource situation; The catches of the gill net with the height of 6m and 10m is similar in general.

Codend Mesh selectivity of *Trichiurus haumela* trawl in East China Sea

Contact person: Hongliang HUANG (huanghl@ecsf.ac.cn)， Linzh LI（lilz@ecsf.ac.cn）

January 2012 – December 2016

The study aims to understand the selectivity of hairtail (*Trichiurus haumela*) trawl in the East China Sea. A bottom trawl investigation was conducted by using diamond mesh 50, 55, 60, 65, 70, 75 and 80mm in the East China Sea in summer 2014.

Selectivity of different mesh size codend was analyzed and compared by using the method of set of network. The results show that: $L_{0.5} = 2.2419\ M + 17.503$ ($R = 0.930$). The minimum mesh size of female hairtail catch $L_{0.5}$ was 65.63 mm and that of male hairtail $L_{0.5}$ was 68.76 mm. Therefore, the research results suggest the minimum mesh size for trawl for hairtail trawl is at least 65 mm, against the current to standards and fishery production.

The performance analysis of Antarctic krill trawl

Contact person: Linzh LI（lilz@ecsf.ac.cn）; Hongliang HUANG (huanghl@ecsf.ac.cn)

January 2014– ongoing

In order to promote the development of the Antarctic krill (*Euphausia superba Dana*) fishery, 2 designs of the 4-panels trawl (dh256-1 and dh256-2) were put forward. The net mouth perimeter of the 2 trawls were same, and the width ratio of belly panels to side panel (WRBS) is different. The WRBS of the dh256-1 is 1.00, and dh256-2 is 1.10. Model experiments were used to study the trawl performance and the match optimized between nets and the accessories which include the sum of buoyance and sinker weight (SBSW), bridle length, horizontal opening coefficient(L/S). The result show that: Under the test condition, when the L/S was between 0.5 and 0.6 or when the trawl speed was under 1.5m/s and the L/S was 0.45 or 0.65, there were significant difference in the vertical net opening between two trawls , the vertical net opening of dh256-2 is obviously higher than dh256-1; For improving the trawl performance , the larger SBSW should be configured for dh256-1, the minimum SBSW for dh256-1was 4.59tf, and for dh256-2 1.98tf was enough. These differences may be related to the flow attack angle of nets. The WRBS of dh256-2 is larger than dh256-1, the flow attack angle and head surface of belly panels increased, and improved the vertical nets opening. Conversely When the WRBS is smaller, the flow attack angle and head surface of side panels increased, the pull of sideline to bridle will strengthen and limit the vertical nets opening. So, when the WRBS is smaller, the SBSW should be larger. There was no significant difference in C_e between dh256-1 and dh256-2. L/S was inverse related to the coefficient of the energy consumption (C_e). The stable relationship of bridle length to C_e has not been found; When the bridle length≥50m, the effect of bridle length to both trawls was not obvious. So 50m bridle is suggested for two trawls. The effect of SBSW to the C_e of 256-1 was related to the trawl speeds, when the speed ≤1.5 m/s, the effect of SBSW to C_e was not obvious; when the speed ＞1.5 m/s, the Ce declined obviously with the increase of SBSW. According to the trawl speed of the Antarctic krill were usually around 1.5 m/s, so the 256-2 was recommended for the Antarctic krill fishery. These results can provide reference for Antarctic krill trawl design.

Effect of Aspect Ratio and Maximum Relative Camber on Hydrodynamic Performance of Antarctic Krill Trawl Otter Board

Contact person: Jian LIU（liuj@ecsf.ac.cn）,Hongliang HUANG (huanghl@ecsf.ac.cn)

January 2014– December 2018

The resource of Antarctic krill is very abundant surrounding the Antarctic area, and its development potential is taken more and more attention around the world. A key factor to enhance the Antarctic krill trawl productivity is to improve the expansion performance of trawl net in low trawling speed. To study the effect of different aspect ratio and maximum relative camber on hydrodynamic performance of a high aspect ratio otter board with hollow structure, a flume model experiment was conducted to analyze the change rules of main hydrodynamic performance parameters, such as the critical angle of attack (α_0), maximum lift coefficient (C_{Lmax}), maximum lift to drag ratio at α_0 ($K_{\alpha 0}$) and maximum lift to drag ratio (K_{max}). The experimental design scheme was constructed with two categories of variables that are the aspect ratio and maximum relative camber. The factor of the aspect ratio designed for 5 levels, and the factor of the maximum relative camber designed for 4 levels. According to the two factors experiment method, 20 experimental models were designed. The experimental models were made by stereo light curing process. The experimental results are as follows: (1) the impacts of the aspect ratio on the C_{Lmax}, K_{max} and $K_{\alpha 0}$ value were extremely significant (P<0.01), but there is no significant impact on the α_0 value (P>0.05). While the aspect ratio was ascending, the C_{Lmax} and K_{max} value showed the tendency of rising, but the $K_{\alpha 0}$ value had a trend of rise first then fall. When λ=2.0, the $K_{\alpha 0}$ value is relatively higher than other otter boards. With the aspect ratio ascending, the α_0 value respectively showed an uptrend (for the maximum relative camber is 12% or 14%) and a downtrend (for the maximum relative camber is 8%). When the maximum relative camber is 10%, the α_0 value fluctuated between 27.5° and 30°, and the trend line remained unchanged generally. (2) The maximum relative camber had extremely significant impact on the C_{Lmax} and K_{max} value and significant impact on the α_0 value (0.01<P<0.05), but no significant impact on the $K_{\alpha 0}$ value (P>0.05). The interaction terms between the aspect ratio and maximum relative camber had extremely significant impact on the $K_{\alpha 0}$ value (P<0.01), but no significant impact on C_{Lmax} and K_{max} value (P>0.05). The C_{Lmax} and α_0 value shows an uptrend with the increase of the maximum relative camber, but the K_{max} value shows a downtrend. Considering the hydrodynamic performance of the otter board, the results suggests that the aspect ratio should be designed as 2.0 and maximum relative camber should be 12% in the practical application. In that case, the main hydrodynamic performance parameters of the otter board are the top 40% levels, and the Antarctic krill trawl otter board has advantages of lower drag coefficient and higher maximum lift to drag ratio and maximum lift coefficient.

Analysis on the hydrodynamic characteristics of Antarctic krill trawl otter board

Contact person: Jian LIU（liuj@ecsf.ac.cn）,Hongliang HUANG (huanghl@ecsf.ac.cn)

January 2012 – December 2016

For improving the expansion performance of trawl net in low trawling speed and enhancing the Antarctic krill trawl productivity, a high aspect ratio otter board with hollow structure was developed. A flume model experiment was conducted to measure the lift coefficient (C_L), drag coefficient (C_D) and lift to drag ratio (K) in different angle of attack (α). The experimental results are as follows: The C_L and K value show a trend of increasing at the beginning and then decreasing with the increase of angle of attack, C_D value reflects an upward trend with the increase of angle of attack; when α=30°, the max lift coefficient (C_{Lmax}) is 1.436, in this case C_D =0.649, K=2.213; When α=10°, the max lift to drag ratio (K_{max}) is 4.671, in this case C_L =0.981, C_D =0.210. Suggest the best working scope of angle of attack is between 10°~30°, in which case, C_L>0.98 and K>2.21. Through comparative analysis of the hydrodynamic performance of different types of otter boards, the Antarctic krill trawl otter board has advantages of lower drag coefficient and higher lift to drag ratio, which can provide a reference basis for further optimization of the Antarctic krill trawl otter board.

Model test of the hydrodynamic characteristics of two vertical cambered V type otter boards

Contact person: Jian LIU（liuj@ecsf.ac.cn）， Hongliang HUANG (huanghl@ecsf.ac.cn)

January 2012 – December 2016

To compare the hydrodynamic performance of two low aspect ratio vertical cambered V type otter boards, a flume model experiment was conducted to measure the resistance and lift force of model otter board, then calculated the drag coefficient, lift coefficient and lift to drag ratio. The experimental results are as follows: Parameters C_L and K show a trend of first increasing and then decreasing with the increase of angle of attack α, C_D reflects an upward trend with the increase of angle of attack; For No.1 otter board, when $\alpha = 30^o$, the maximum lift coefficient $C_{L\max}$ of No.1 otter board is 1.509, in this case $C_D = 0.686$, $K = 2.198$. When $\alpha = 20^o$, the maximum lift to drag ratio $K_{\max}$ is 2.892, in this case $C_L = 1.158$, $C_D = 0.400$; For No.2 otter board, when $\alpha = 30^o$, $C_{L\max} = 1.603$, in this case $C_D = 0.765$, $K = 2.095$. When $\alpha = 15°$, $K_{\max} = 2.555$, in this case $C_L = 1.013$, $C_D = 0.397$. According to above-mentioned results, the best suggesting work scope of angle of attack is between 15°–30°, in which case, for No.1 otter board $C_L > 0.8$ and $K > 2.0$; for No.2 otter board $C_L > 1.0$ and $K > 2.0$. The K value and expansion efficiency of No.1 otter board are higher than No.2 otter board under each angle of attack. The C_L value and expansion efficiency of No.2 otter board are higher than No.1 otter board in the range of 10°–30°.

Model test of the hydrodynamic characteristics of 2 types vertical cambered slotted otter boards

Contact person: Jian LIU(liuj@ecsf.ac.cn）,Hongliang HUANG (huanghl@ecsf.ac.cn)

January 2012 – December 2016

To study the effect of flow deflector angle on the hydrodynamic performance of otter board, a flume model experiment was conducted to measure the lift coefficient (C_L), drag coefficient (C_D) and lift to drag ratio (K) of two flow deflector vertical cambered otter boards, each with 3 kinds of flow deflector angle. The experimental results are as follows: 1) For the single flow deflector vertical cambered otter board, when the angle of attack is between 20°~35°, the C_L and C_D value shows a downtrend with the increase of the flow deflector angle. In this case the otter board D1 (the flow deflector angle is 35°) shows a better hydrodynamic performance. 2) For the double flow deflector vertical cambered otter board, when the angle of attack is between 25°~35°, the otter board S3 (the front flow deflector angle is 20° and the middle flow deflector angle is 25°) shows a better hydrodynamic performance. Suggest the best working scope of angle of attack of otter board D1 is between 15°~30°, in which case, C_L>1.2 and K>2.0; the best working scope of angle of attack of otter board S3 is between 20°~30°, in which case, C_L>0.8 and K>3.0. The critical angle of attack of lift coefficient increases with the increase of the flow deflector angle. Properly regulating the flow deflector angle can achieve the purpose of optimizing the hydrodynamic performance of otter board.

Influence of main-panel angle on the hydrodynamic performance of a single-slotted cambered otter-board

Contact person:Le WANG (wangl@ecsf.ac.cn)

January 2013 – December 2018

The effect of the main-panel angle of a single-slotted cambered otter-board was investigated using engineering models in a wind tunnel. Three different angles (0°, 6°, and 12°) were evaluated at a wind speed of 28 m/s. Parameters measured included: drag coefficient C_x, lift coefficient C_y, pitch moment coefficient C_m, center of pressure coefficient C_p, and the lift–drag ratio C_y/C_x, over a range of angle of attack (0° to 70°). These coefficients were used in analyzing the differences in the performance among the three otter-board models. Results showed that the maximum lift coefficient C_y of the otter-board model with a main-panel angle of 0° was highest (1.875 at α=25°). However, when the angle of attack was smaller (0 < α < 22.5°), the lift coefficient of the otter-board increased as the angle of the main-panel increased. The maximum C_y/C_x of the otter-board with a main-panel angle of 12° was highest (7.417 at α=2.5°), and the lift–drag ratio increased when the angle of the main-panel increased within the angle of attack at small angles (0 < α < 12.5°). A comparative analysis of C_m and C_p showed that the stability of the otter-board with a main-panel angle of 0° is better than those of the other models. Therefore, the comparative analysis of C_m and C_p, shows that a larger angle of the main-panel can reduce the stability of single-slotted otter-board. The findings of this study offer useful reference data for the structural optimization of otter-boards for trawling.

Research of deflector shape on hydrodynamic performances of double-slotted cambered otter-board

Contact person:Le WANG (wangl@ecsf.ac.cn)

January 2013 – December 2018

In order to improve the hydrodynamic performance of double-slotted cambered otter board by optimizing the deflector structure, the effect of the deflector shape of double-slotted cambered otter board on hydrodynamic performances was investigated by model wind tunnel test. Four deflector shapes were designed in otter-board models, there were rectangle, fan shape, convex trapezoid and concave trapezoid. The basic structural parameters of four otter-board models were the same, the aspect ratio was 2.5, the camber ratio was 12%, the angle of double-layer deflector was 30° and 25°, and the angle of main-panel was 12°. The otter-boards models were installed on the six-component mechanical tower-balance separately, and the test was conducted in wind tunnel with the flow velocity at 28 $m\cdot s^{-1}$ and the angle of attack α measured from 0° to 70° to obtain drag coefficients C_x, lift coefficient C_y, pressure-center coefficient C_p, calculated lift to drag ratio C_y/C_x and give the relations curve of these value and angle of attack α. For comparison in the lift coefficient of four otter-board models, the result showed that the relationship of the maximum lift coefficient C_y between four otter-board models was C_y (convex trapezoid) > C_y （rectangle）> C_y （fan shape）> C_y （concave trapezoid）, the maximum lift coefficient C_y of the otter-board model with convex trapezoid structure was higher, there was 1.946（α=47.5°）; For comparison in the drag coefficient of four otter-board models, the result showed that the relationship of the drag coefficient C_x between four otter-board models at the attack angel of 30° was C_x （fan shape）> C_x （rectangle）> C_x （concave trapezoid）>C_x (convex trapezoid), the drag coefficient C_x of the otter-board model with convex trapezoid structure was lower. For comparison in the lift to drag ratio of four otter-board models, the result showed that the relationship of the maximum lift to drag ratio C_y/C_x between four otter-board models was C_y/C_x (convex trapezoid) > C_y/C_x （rectangle）> C_y/C_x （fan shape）> C_y/C_x （concave trapezoid）, the maximum lift to drag ratio C_y/C_x of the otter-board model with convex trapezoid structure was higher, there was 7.486（α=30°）; In contrast stability, the stability of otter board model with double fan deflector structure was better, and its lower absolute value of C_m and variable coefficient C_p were 0.061 and 5.43% respectively. Therefore, the double-slotted cambered otter-board with convex trapezoidal deflector could provide larger lift and had good working effect, the double-slotted cambered otter-board with fan shaped deflector had the higher stability. The results would offer the reference for the structural optimization design of trawl otter board.

Degradation properties of fishery polylactic acid monofilament modified by nano-montmorillonite

Contact person:Minghua MIN (mingmh@ecsf.ac.cn)

January 2014– December 2018

Degradation properties of fishery polylactic acid monofilament modified by nano-montmorillonite (nano-MMT/PLA) were studied in the seawater near the Zhoushan sea arear. It was found that at the first 9 months of the degradation process in the seawater, the mechanical properties and number-average molecular weight of nano-MMT/PLA fishery monofilament decreased slowly. However, when the degradation time was more than 9 months, the mechanical properties and number-average molecular weight of nano-MMT/PLA fishery monofilament were decreased rapidly. It was showed that after 9 months, the degradation of nano-MMT/PLA fishery monofilament was in an accelerated process, and it was concluded that the optimum lifetime of modified PLA monofilament in seawater environment was 9 months. Furthermore, after 15 months degradation, the breaking strength and number-average molecular weight of 0.5wt% nano-MMT/PLA monofilament were decreased by 21.9% and 50.0%, respectively. However, the breaking strength and number-average molecular weight of pure PLA monofilament were decreased by 20.4% and 30.6%, respectively. Addition of nano-MMT would cause the interface defects generated between PLA and nano-MMT, which could become channels for water molecules entering the interior of polylactic acid molecules. Thus, the degradation of modified PLA monofilament in seawater was accelerated, and the wear durability of the modified PLA monofilament was also decreased rapidly. After degradation in the seawater for 15 months, the wear resistance of pure PLA monofilament was decreased from 2.20 F/tex to1.32 F/tex, and the decreased of wear resistance was 40.0%. Nevertheless, the wear resistance of 0.5wt% nano-MMT/PLA monofilament was decreased from 2.34 F/tex to 0.70 F/tex, and the decreased of wear resistance was 70.1%.

Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences

Comprehensive survey and analysis of main fishing gears

Contact Person: Xiansen Li (lixs@ysfri.ac.cn)

May 2010- October 2019

The project aims to survey the main fishing gear used in the Yellow and Bohai Seas. Situation of main fishing gear and fishing methods were investigated in terms of fishing operation type, fishing grounds, catch composition, fishing gear structure, number and distribution of fishing vessels. Results showed that the main fishery production in Yellow Sea and Bohai sea is in autumn. Small mesh size results in poor selectivity, while large mesh gill nets have good selectivity. The number of trawlers in the surroundings of the Yellow Sea and Bohai sea is 12,358, only 30% of which were exceeding 110.3kw, and the number of fishing vessels reduced as the power increases.

Analysis of fishery structure of gillnets

Contact Person: Xiansen Li (lixs@ysfri.ac.cn)

May 2012- October 2017

In order to study the fishing performance of trammel net, the trammel net fishery was investigated in the area of the Yellow Sea and Bohai Sea. Base on the investigation of gillnetters fishing state and kinds of trammel net, catch composition, fishing capacity and economic benefits of trammel net were analyzed. Results showed that there were mainly 4 kinds of trammel net in the coastal regions of the Yellow Sea and the Bohai Sea, their target species were *Oratosguilla Oratoria, Fenneropenaeus chinensis*, *Portunus trituberculatus* and *Cleisthenes herzensteini*, respectively. There were more than 50% crustanceans in the captures of squilla or prawn trammel net, and more than 70% *Portunus trituberculatus* in crab trammel net. By-catches of trammel net consisted mainly of demersal fish, such as *Cynoglossus joyneri*, *Paralichthys olivaceus*, *Platycephalus indicus*, *Lateolabrax maculatus*, etc. It was revealed that trammel net had advantages of the highly selective ability and fine fishing effects for crustanceans and flatfishes compared to single gillnet. Trammel net was currently a better fishing gear than trawl net and filter net showed relatively lower ratio of by-catched juveniles, but the string of the inner net of trammel net was fine and had strong entanglement, it would cause great damage to fishery resources if there were many juveniles of economic fishes in the fishing grounds, especially for squilla and prawn trammel net with the inner mesh sizes of 50 mm to 60 mm.

Selectivity of fishing gears

Contact Person: Xiansen Li (lixs@ysfri.ac.cn)

May 2015- October 2020

The project aims at studying the cod-end selectivity of the main fishing gears in the area of the Yellow Sea and Bohai Sea. Sea trials were carried out and the selectivity of trawls, gillnets and stow nets was studied using Logistic selection model, Gamma model and body circumference estimation method. Results showed that the escape rate was increased significantly with the increase of cod-end mesh size. The minimum mesh sizes of cod-end allowed for some important commercial fished in the Yellow Sea and Bohai Sea were estimated based on their minimum allowable sizes, which were 60 mm for pelagic trawls and 43.77±3.19 mm for Tanzi net (a kind of stow net) in order to protect the stock population of small and medium size fished, such as *P. polyactis*, *T. haunela* and D. *maraudsi*, under the present situation of fishery resource in the Yellow Sea and Bohai Sea.

Parameters optimization of gillnets

Contact Person: Xiansen Li (lixs@ysfri.ac.cn)

Jan. 2013- Oct. 2015

In this project, 10 typical types of *Scomberomorus niphonius* gillnets used in the Bohai Sea and the Yellow Sea area were identified and investigated. Based on the analysis of the main parameters of the 10 net types mentioned above, we selected nets with 4 different mesh sizes (110 mm, 115 mm, 120 mm, and 125 mm) to perform a comparative experiment on the fishing boat "Luchangyu-64068" operated in the central and southern Yellow Sea. Results showed that the main parameters of a net of 120 mm mesh size were optimized as follows: 33.00 m×18.54 m in the principal dimension of fishing gear, 500 mesh×175 mesh, 120 mm in mesh size, PA monofilament (Φ=0.48 mm) as the netting material, T-direction hanging ratio 0.55, static buoyancy distribution 267.9 g/m, and buoyancy to sinker-weight ratio 1.768: 1.

Parameters optimization of the otter boards using numerical simulation

Contact Person: Xiansen Li (lixs@ysfri.ac.cn), Qingchang Xu (xuqc@ysfri.ac.cn)

Jan. 2017- Jun. 2019

An otter board is an important device that provides a desired horizontal opening of a trawl net. A high lift-todrag ratio is required for an otter board to maintain fishing efficiency. This projest optimized the parameters of V type otter board and rectangular cambered otter board based on the maximum lift coefficient and lift-to-drag ratio and studied the hydrodynamic performance of the optimal otter board. Computational fluid dynamics (CFD) analysis was used (verified by a flume tank experiment) in the optimization process. Simulation results showed that the aspect ratios, dihedral angles and deflectors had a significant influence on the hydrodynamic performance of an otter board. The main results were described in the paper "Study on the hydrodynamic characteristics of the rectangular V-type otter board using computational fluid dynamics (Xu, et al., 2017, *Fisheries Science*)" and "Parameter optimization of a double-deflector rectangular cambered otter board: Numerical simulation study (Xu, et al., 2018, *Ocean Engineering*)".

Study on resource-conservation fishing gears

Contact Person: Xiansen Li (lixs@ysfri.ac.cn), Qingchang Xu (xuqc@ysfri.ac.cn)

Jan. 2019- Dec. 2021

The stow net, which is one of the widely used fishing gears in China for its lower cost and stable output, causes great damage to the offshore fisheries resources due to its poor selectivity and high juvenile fish proportion. In order to protect the offshore fishery resources, this project aims to design a kind of resource-conservation stow net. Based on the fishing methods, fishing performance, structure of catch and selectivity of fishing gears, we will carry out sea trials to optimize the structure of the net and design the bycatch reduction device (BRD) for juvenile fishes.

Marine Fisheries Research Institute of Zhejiang

Contact persom: ZHU Wenbin(foolse@126.com)

Improvement of marine fishing gear management system

Contact persons: ZHU Wen-bin (foolse@126.com), XU Guo-qiang (xuguoqiang732@126.com), CHEN Feng(cf0421223@163.com), ZHANG Hong-liang(hidalgo310@163.com)

January 2015- December 2018:

The project is supported by Ministry of Agriculture Fishery Fund Management Project. The aim of the project is to provide scientific advice for the establishment of a catalogue of permitted fishing gear in the East China Sea. The research content of the project includes investing the use status of fishing gear, the main dimension of the fishing gear and the quantity carried or used by each fishing boat. The mesh size selectivity tests of the three *B.japonicus* gill net (single layer net, semi-trammel net and trammel net) with mesh size of 50mm, 60mm and 70mm, little yellow croaker gillnet and swimming crab gill net, and codend mesh size selectivity of pair trawl, single trawl and canvas stow net with the codend mesh size of 35mm, 45mm, 55mm, 60mm and 65mm respectively were carried out. During the field experiment, *B.japonicus* gill net caught 33 fish species in total, *B.japonicas* was the most dominant, and indicating that the fishing gears had strong selectivity. The optimal mesh size of the three gillnets was 77.57mm, 74.84mm and 70.91mm respectively as determined with the selective curve method. Our findings indicates that 70.91mm mesh size of the *B.japonicas* trammel net can effectively protect the current fishery resources.

We also conducted the codend mesh selectivity of canvas spreader stow net for *Larimichthys polyactis* by the cover net method. Five mesh size(35mm,45mm,55mm,60mm,65mm) codend was tested during the field comparison in the middle Zhoushan fishing ground in April 2017. The results showed that:(1) the number and weight of *Larimichthys polyactis* accounted for 66.94% and 84.48% in the catch respectively, the body length range was 71 to 190mm with the mean value of 124mm (2) When using the mesh size of 35mm,45mm,55mm,60mm and 65mm,the L_{50} was 80.4mm,103.5mm,119.7mm,122. 7mm and 137.0mm, and the SR was 50.2mm,52.5,mm,61.1mm,41.7mm and 63.6mm, respectively; (3) The relationship between the codend mesh size and L_{50} of *Larimichthys polyactis* : L_{50}=1.776mm +20.300 (R^2=0.980); (5) The escape rate in number was higher than that in weight when the mesh size of codend ≤45mm; the escape rate in both number and weight was less than 5%, when the mesh size ≥55mm; escape rate in number and weight of *Larimichthys polyactis* more than 10%, even up to 50% Comprehensive analysis shows that the mesh size of 55mm can effectively release juvenile *Larimichthys polyactis*, though the mesh size still need to expand.

Research and application demonstration of standard single boat trawl net

Contact persons: ZHU Wen-bin (foolse@126.com), XU Guo-qiang

January 2018-December 2019

The project aims to develop the one boat trawl net which meets the permitted operation standard after demonstration application. The main research contents include design of standard trawl net meeting the fishery management requirement based on survey of single trawl in Wenzhou Area; Codend mesh selectivity test (35mm,45mm,54mm,60mm,65mm) by the cover net method; Evaluation of the selectivity, catch and economic benefit of the existing trawl net and designed net. model net test and fishing operation test on the designed trawl net and measurement of the net performance. Improvement of the designed trawl net and fishing demonstration in Wenzhou Area.

Research and application demonstration of standard beam shrimp trawl net

Contact persons: ZHU Wen-bin (foolse@126.com), XU Guo-qiang

January 2018-December 2019

The project aims to develop the beam shrimp trawl net which meets the permitted operation standard after demonstration application. The main research contents include design of standard beam shrimp trawl net meeting the fishery management requirement based on survey of beam shrimp trawl used by Zhoushan fishermen; codend mesh selectivity test (20mm,25mm,28mm,31mm,35mm) by the cover net method; Evaluation of the selectivity, catch and economic benefit of the existing trawl net and designed net. model net test and fishing operation test on the designed trawl net and measurement of the net performance. Improvement of the designed trawl net and fishing demonstration in Zhoushan Area.

Ocean University of China

Contact person: Liuyi Huang, huanglyi@ouc.edu.cn

Summary

Recent years, Fishery Technique Laboratory of College of fisheries, Ocean University of China, has mainly carried out studies about design and hydrodynamics of Antarctic krill mid-water trawl, hydrodynamic characteristics and structural optimization of trawl doors, analysis of composition of stow net fishing catches and selectivity of stow net.

Hydrodynamic performance of a newly-designed Antarctic krill trawl-net

Contact person: Rong Wan (rwan@shou.edu.cn) ; Qinglong Guan(gql@stu.ouc.edu.cn); Liuyi Huang(huanglyi@ouc.edu.cn)

Jan 2015 – Dec 2018

The project is granted by China National Fisheries Corporation Ltd and aims to develop a high efficient environmental friendly krill trawl-net. On the demand of Chinese large-scale trawl vessels for Antarctic krill ((*Euphausia superba*), a four-piece mid-water trawl was designed. Study about hydrodynamic performance and structure optimization of the trawl were carried out by flume test and numerical simulation. A large Antarctic krill trawl with a net opening circumference of 200m was designed for a fishing vessel (2855 kW) and analyzed by numerical simulation and physical model tests. A numerical model of Antarctic krill trawl was established based on the finite element method. The principle of minimum potential energy was employed to determine the equilibrium configuration and the tension distribution of the trawl in a uniform current. The Newton–Raphson method was applied to solve the equilibrium equation. A series of physical model tests were conducted in a flume tank to verify the result from numerical simulation. The results showed that the trawl with a net opening circumference of 200m had superior hydrodynamic performance and could be well matched with fishing vessels of the class for the efficient production of Antarctic krill. Study result of this project demonstrates the use of scientific methods for the design of large.

Stow net selectivity in the Haizhou Bay

Contact person: Liuyi Huang(huanglyi@ouc.edu.cn)

January 2012-December 2016

The Haizhou Bay is one of China's famous traditional fishing grounds, and also marine spawning grounds, feeding grounds and migration field. Stow net is the main fishing gear in Haizhou Bay and mainly catches shrimp and small fish with the bycatch of crab and other shrimps. It is of great significance to study on the selectivity of stow net for the admittance of stow net and the protection of marine fishery resources in this area. Comparisons of three mesh size (30mm, 35mm, and 40mm) codend and four square mesh (35mm, 40mm, 45mm and 50mm) escape windows were carried out by the cover-net method.

The selection lengths L50 and selection ranges (SR) of three main targeting species, *P.polyactis. T. curvirostris* and *O. oratoria de Haan* were obtained. The results can be used as reference to determine the minimum mesh and design the selective device for stow net in Haizhou Bay.

Development and demonstration of resource conservation set net

Contact persons: Qinglong Guan(gql@stu.ouc.edu.cn), Rong Wan(rwan@shou.edu.cn), Fuxiang Hu(fuxiang@kaiyodai.ac.jp)

2017-December 2019

The project is a joint research project between Ocean University of China and Shanghai Ocean University. The aim of the project is to develop and demonstrate the use of resource conservation set net along Chinese coastal water. The hydrodynamic performance of a large Japanese style set-net in current was studied by means of numerical simulation and physical model test. A numerical model of the set-net was established based on the finite element method. The pipe element was used to model nets and cables and the equilibrium configuration and the tension distribution of the set-net was determined. A serious of physical model tests were conducted at flume tank based on Tauti's law and the numerical method was verified by comparing the simulated results with the experimental results. The tension of the cables and the shape of the set-net were analyzed. The results showed the tension of the main cable was about 70 kN at current velocity of 1 kn. With the increase of current velocity, the headline of the set-net was sinking, and the ground rope was floating upward. The deformation degree of the lead net was the largest, followed by the playground, and the deformation degree of the box chamber net was the smallest. The set-net was suggested to be placed in the sea area where the current velocity should not exceed 0.7 kn. The simulated values of the set-net hydrodynamic performance were very close to the experimental values from the model test, which can provide a scientific reference for the design and application of the Japanese style set-net.

Selectivity of fish trap for *Sebastes schlegeliis*

Contact person: Yanli Tang (tangyanli@ouc.edu.cn)

Jan 2016 – Dec 2018

This study was supported by the project of marine and fishery technology innovation of Shandong. *Sebastes schlegeliis*, which occurs in the coastal waters of China, including Yellow and East China Seas, is a delicious seafood and has great economic value. In the past few years, *S.schlegeliis* resources have rapidly declined, as a result of the use of smaller net size fishing gears, which has resulted in large numbers of fish fry being caught. To better develop and protect resources, the goal of this study was to determine the differences in selectivity of various mesh sizes and hanging ratios for *Sebastes schlegelii.* The biological features of *Sebastes schlegeliis* were collected by using simulated cover-net method in flume tank. A logistic curve was fitted as selectivity model to obtain selective curves of different mesh sizes and hanging ratios. Selective parameters were estimated by MLE (Maximum Likelihood Estimate). The results indicated that the L_{50} were 17.81, 3.90 and 25.12 cm for *Sebastes schlegelii* when the mesh sizes were 63,82 and 93mm. SRs are 2.05, 3.6, 3.85 and SFs are 2.83, 2.72, 2.70, respectively.

The SR increased with an increase in the mesh size whereas the SF decreased. Three groups of hanging ratios (0.5, 0.6, 0.707) of 82mm mesh size were chosen for studying the impact of hanging ratio. The respective of L_{50}s are 21.47, 23.90, 22.02 cm, and SRs are 3.23, 3.6, 3.38, SFs are 2.65, 2.91, 2.68, respectively. With an increase in the hanging ratio of meshes, the L_{50},SR and SF increased first and then decreased, and obtained the maximum value at the hanging ratio of 0.6. It was concluded that suitable size of fishing gear for protecting masked greenling resources was of 7cm mesh size and the hanging ratio of 0.6.

Longline selectivity for white-spotted conger *Conger myriaster* in Haizhou Bay, China

Contact person: Yanli Tang (tangyanli@ouc.edu.cn)

Jan 2012 – Dec 2015

Conger myriaster is one of the most commercially important fish stocks in the Haizhou Bay, China. As the main gear to catch *C.myriaster*, the type of longline hook has a significant effect on the selection. Comparative fishing experiments using three hook sizes (No. 302, 303, 304) were carried out along the Haizhou Bay from September to November 2012. The selection for C.myriaster with different hook widths is obtained by analyzing the catch rate, CPUE, TL distribution and selection curves. The log-normal model equation is used to explore the selection of longline, and the ANOVA is used to analyze the difference of catch rate and CPUE among three hook sizes. It is found that the longline selectivity for C.myriaster may be well described by log-normal model equation and hook No. 303 has the highest catch rate, CPUE and the estimated model lengths within three types of hooks tested in the experiments which is in accordance with the fact that No. 303 is the most popular hook used the local fishermen. Overall, the present study indicates that hook No. 303 has the best selection and is an appropriate size for sustainable utilisation of the C.myriaster.

Dalian Ocean University

Comparison of Gillnet fishing capacity in Liaodong Bay

Contact person：XING Binbin, xingbinbin@dlou.edu.cn

January 2015-December 2018

The project is supported by the Special Scientific Research Fund of Agricultural Pubic Welfare Profession of China. The aim of the project is to improve the fishing techniques for and management level of offshore fishery resources. selectivity among single gillnet (with the mesh sizes 40 mm, 50 mm, 60 mm), double gillnet, trammel gillnet and productive fishing gear (control group) was compared in the Liaodong Bay during October to November 2018.

The results showed that there were significant differences on yields of the same kind nets with different mesh size (P=0.0003, P=0.001, P=0.002), compared the CPUE of 60 mm with 40 mm, the single gillnet is 800%, the double gillnet is 650% and the trammel gillnet is 500%; but the influence on catch yields of the different kind nets with same mesh size was relatively small（Tab 1）. The average similarity of intra-group catch composition of the network was: single gillnet 59.24%, double gillnet 62.63%, and trammel gillnet 66.51%; Meanwhile, the average similarity of the inter-group was 71.44%, 67.50% and 70.58% respectively; The species which had the highest contribution to intra-group and inter-group average similarity were *O*. oratoria and L. japonicas.

Selectivity study of multi-anchor single sheet set net in Liaodong Bay

Contact person：XING Binbin (xingbinbin@dlou.edu.cn)

January 2018-December 2019

Multi-anchor single sheet set net is one of the important fishing gear in Liaodong Bay. The mesh size of fishing gear is generally smaller than the standard set by the state, consequently the proportion of juvenile fish and shrimp in the catch is higher, which is adverse to fishery resources conservation. The project is supported by Ministry of Agriculture Department Special Business Expenses Project Fishery Management Project and its purpose is to understand the impact of the mesh size of the net on the catch quantity, size and species composition of the catch, so as to provide operable scientific advice for the improvement of fishing gear management system. We conducted experiment during October to November 2018 and compared the production of the test net with the mesh size of 25mm,35mm and 45mm respectively and the comparison net with the mesh size of 18mm.

The experimental results showed that the total catch of each test net was 12.81%, 51.50% and 60.81% less than that of the production net, respectively. Although the catch of 35 mm and 45 mm mesh net was significantly reduced, the quantity of main economic species in catch was not significantly reduced (except for shrimp). The number of species in the catch decreased with the increase of the mesh and from 29 species in the production net down to 24 species (25 mm), 17 species (35 mm) and 14 species (45 mm) respectively in the test net. With the increase of the mesh size (main net), the shrimps were released, and the release ratio of the smallest body length groups of various dominant species increased with the increase of the mesh size. This study can provide scientific basis for the structural optimization of multi-anchor single sheet set net and the protection of fishery resources.

Guangdong Ocean University

Hydrodynamic characteristics of the double-winged otter board

Contact persons: LU Huosheng（lhs@gdou.edu.cn）, FENG Bo （258008970@qq.com）,YAN Yunrong（tuna_ps@126.com）

January 2014-December 2016

We tested the hydrodynamic characteristics of a new, double-winged otter board that consists of a forewing, a leading edge slat and a trailing edge flap. Flume experiments were conducted in a circulating flume tank by using a model with an aspect ratio (AR) of 0.85 and a horizontal platform area (S) of 0.09 m^2. The results indicated that the critical angle (α_{cr}) of the model was 44°, whereas the maximum lift coefficient (C_{Lmax}) was up to 1.715, and the door efficiency (K) was 1.122. The attack angle (α) ranged from 30° to 48° and from 10° to 46° when the lift coefficient (C_L) and door efficiency (K) were greater than 1.2 and 1.0, respectively. To compare the difference between double-winged otter board and traditional Morgere Polyvalent Ovale, same model of Morgere Polyvalent Ovale was also tested under the same experimental conditions. The critical angle (α_{cr}) and maximum of lift coefficient (C_{Lmax}) of the doublewinged otter board were 37.5% and 14.6% larger than those of the Morgere Polyvalent Ovale. Therefore, we concluded that the novel, double-winged otter board was more suitable for bottom trawling fisheries in the deep water of the Mauretania Sea due to its better hydrodynamic characteristics and stability.

Zhejiang Ocean University

The research on influence mechanism of cod-end and catch on hydrodynamic characteristics of trawl with serial multiple codends

Contact Person: Lili Liu (lililiuxing@hotmail.com)

January 2017 – December 2019

Serial multiple cod-ends trawl is a new kind of trawl which is improved contraposing the problem of traditional trawl that catch is not fresh and energy consumption is high caused by long time haul and catch heaping up in cod-end. It connects multiple detachable cod-ends in series and removes the cod-ends duly and successively during hauling process, so as to short the hauling time of each cod-end, and achieve the aim that enhance catch quality, conserve energy and reduce emission. Thereof, mastering the influence mechanism of cod-end and catch on hydrodynamic characteristics of trawl will play a crucial role on improving trawl. Combined with the research foundation of traditional ocean engineering and fishing gear dynamics, the study make use of finite element method and lumped mass method to construct a numerical model of serial multiple coed-ends trawl in current to perform three-dimensional simulation, integrate with numerical simulation and flume experiment methods to discuss hydrodynamic characteristics changing law of trawl influenced by cod-end and catch, take advantage of dimensionless processing and multiple regression method to reveal multi-factors evaluation functional relationship of cod-end, catch and velocity factors influencing hydrodynamic characteristics of serial multiple cod-ends trawl.

Dynamic visualization for tuna purse seine gear

Contact Person: Cheng Zhou (zhoucheng286@126.com)

January 2015 – June 2016

Combining with fishing gear mechanics, structural mechanics and computer aid design, the virtual numerical simulation can be used to provide references for the design, kind selection and optimization of net gear system. In this project, the dynamic numerical model of tuna purse seine net will be established to realize the visualization of operation process.

Multi-parameter intelligent aided designer will be developed, which can implement the virtual design and modification of gear, environment and operation. It also can predict the movement characteristics and spatial shape under various sea conditions and working conditions, so as to provide technical guidance for actual fishing operation.

8.18 Italy

Institute for Biological Resources and Marine Biotechnologies (IRBIM) – Fishing Technology Unit, Ancona – Italy

Projects

TARTALIFE (LIFE12 NAT/IT/000937)

Contact person: Alessandro Lucchetti, alessandro.lucchetti@cnr.it

(Alessandro Lucchetti, Massimo Virgili, Andrea Petetta, Claudio Vasapollo, Giada Bargione)

Oct 2013 – Sep 2019

http://www.tartalife.eu/en

Project overview

The impact of fishing activities is considered as the most important anthropogenic mortality factor for marine turtle populations in the Mediterranean Sea. The conservation of *Caretta caretta*, a priority species included in App. II/IV of the Habitat Directive and protected in various international Conventions, has been representing a strategic issue for the whole Mediterranean basin, with professional fishing being the main threat for the survival of marine turtles.

In this complicated scenario the TartaLife project aims at reducing sea turtle mortality by reducing bycatches caused by pelagic longline, bottom trawl and fixed nets disseminating circle hooks and TEDs (Turtle Excluder Devices) and testing UV lamps as deterrent for sea turtles and a new type of pot. The second goal is to reduce post-capture mortality, by training fishermen and strengthening the Marine turtles First Aid/Rescue Centres.

BRDs trials

Circle hooks

Sea trials carried out with drift longline equipped with circular hooks were carried out along the Sicilian, Calabrian, Apulian, Campania, Ligurian and Sardinian coasts during the swordfish (*Xiphias gladius*) fishing activities. 45 vessels for a total of more than 120 fishermen have been directly involved in sea trials. At the moment, no significant differences were found in commercial catches using circular hooks. During the tests at sea 12 turtles were caught; the 4 turtles caught with circular hooks were directly released in good conditions by fishermen themselves. The hooking position on the mouth allowed an easy removal of the hook itself and the subsequent release of the turtle. On the other hand, some of the 8 specimens caught with traditional hooks, swallowed the hook and needed surgery.

TEDs

The sorting grid chosen in TARTALIFE is the TED Mod. FLEXGRID. The FLEXGRID is a very light grid built with a particular plastic alloy characterized by a noteworthy elasticity. It is also able to withstand considerable bending and to resume its natural shape when the mechanical stresses are over. This type of grid is suitable for winding on the net winch. Sea trials were conducted on board 11 trawlers from the central-northern Adriatic Sea. 11 sea turtles (*C. caretta*) were captured, all of which occurred with the traditional net in the absence of TED. Fishing performance in terms of commercial catches did not change.

UV Led

The visual deterrents tested in TartaLife areultraviolet emission electronic lights (UV-LED). 40 sea trials were carried out in the area of the Po Delta. The UV-LEDs were rigged directly on the headline of the traditional set net, at a distance of approximately 15 m from each other. The results obtained show that there is no significant difference in terms of commercial catches. The reduction of sea turtle bycatch in the presence of UV-LEDs was total. All 11 turtles fished were caught in the absence of visual deterrents with a mortality rate of 30%.

Collapsible pot

The ‘Trapula’ fish traps are foldable pots made of stainless steel bars and propylene rope externally reinforced with a plastic or nylon net with square mesh. The entrance represents a peculiar feature of this gear and is realized thanks to the radial arrangement of thin steel bars that start from two of the steel bars which are part of the main framework. The Trapula pots showed promising results: the catches of cuttlefish and other species such as sand steenbras, corvines and breams are comparable and sometimes even higher, if compared with those obtained with traditional trammel nets. This shows that the new type of pot can be a valid alternative gear to gillnets during the spring-summer period, a period in which incidental catches of sea turtles are recorded, not only in terms of capture performance but also bycatch reduction.

Life+ EFFICIENTSHIP (LIFE13 ENV/FR/000851)

Contact person: Emilio Notti, emilio.notti@cnr.it
(Antonello Sala, Fabrizio Moro, Jacopo Pulcinella)

June 2014 – June 2018

www.efficientship.eu

Scope

The LIFE+ EfficientShip project aims to demonstrate the efficiency of the ORC (Organic Rankine cycle) technology for reducing fuel consumption and greenhouse gases emissions of fishing vessel thermal engines, contributing therefore in the reduction of the carbon footprint of human activities while offering a solution for sustaining an important European economic activity, endangered by the increase of fuel costs.

The heat from the exhaust gases of the propulsion system is recovered through a heat exchanger and transformed in electric energy by means of a microgenerator conceived for the use of organic fluid as thermal vector fluid.

This approach allowed for te miniaturization of the technology adopted for the turbine and the exchanger, making it possible to install the system on existing vessel and thus overcoming technical constraints deriving from the avilability of space onboard the vessel and installation possibilities.

The monitoring tool

The complexity of the monitoring phase has requested the development of a data management tool and database, composed of a number of different modules. The role of the data management tool is to handle properly the huge amount of data collected and to allow the post-processing software to access to correct data.

The data collected allowed also for feeding the numerical simulation tool that has been then utilized for evaluation the adaptation option of the ORC system. The numerical simulation has been based on a specific fishing trip that is representative of the average working activity of the case study vessel.

Results

The system has been observed for a period of 6 months and it has been evaluated in terms of energy profile comparison. During the monitoring period the system worked alternatively due to a series of technical issues. Although the technical issues reduced the number of observation days with the system running properly, this allowed for a comparison along the same fishing seaon.

The impact of the ORC technology in fishing vessel has been evaluated in terms of technical environmental and economic perspectives.

The technical impact was evaluated through a comparative approach which compared the fuel consumption with the system running and without along similar fishing trips. This allowed for the emasurement of 1-2% of fuel saving (Figure 8.18.12, Figure 8.18.13).

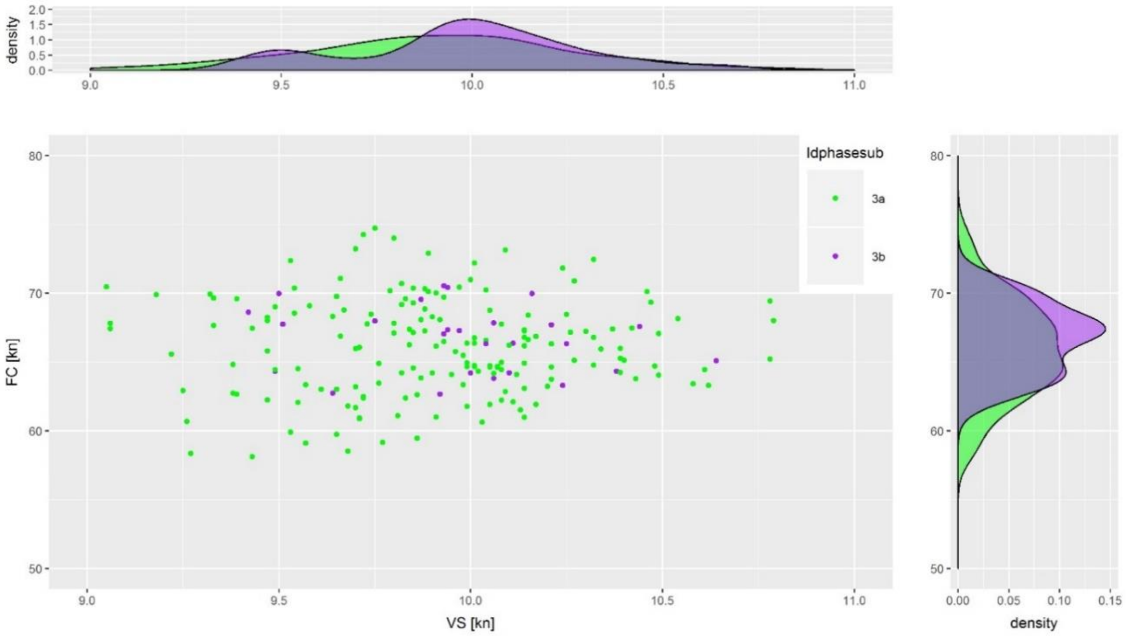


Figure 8.18.12. Comparison of subphases 3a (ORC off) and 3b (ORC on) during cruising.

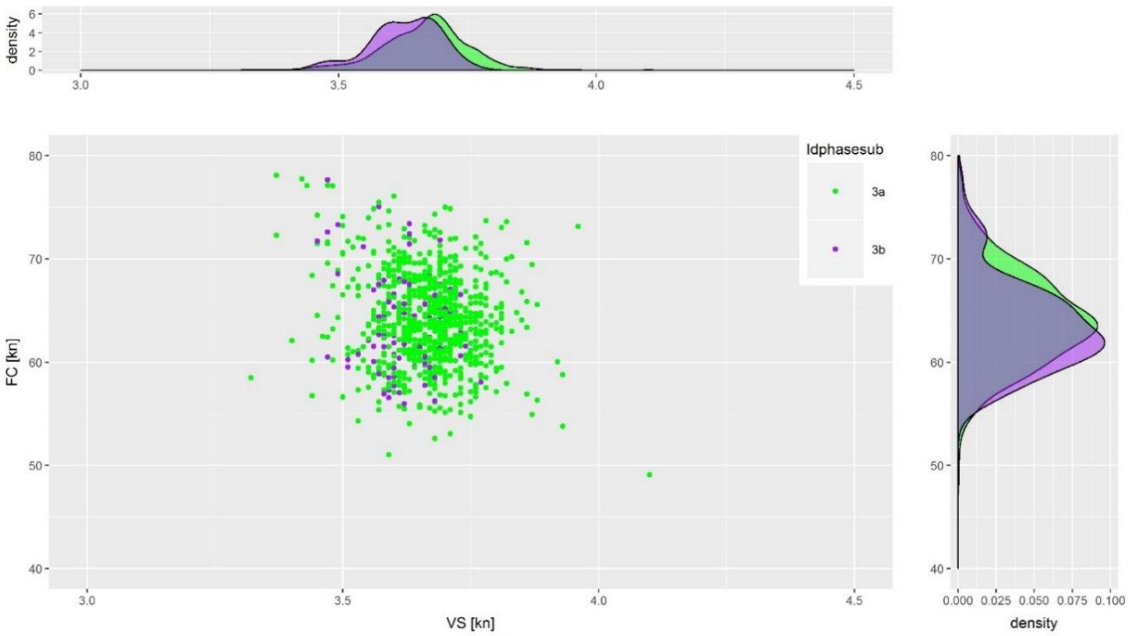


Figure 8.18.13. Comparison of subphases 3a (ORC off) and 3b (ORC on) during cruising.

The environmental impact focused mainly on the production of GHG. The quantity of CO_2 emitted by the case study vessel was calculated per unit of time (kCO_2/h) and per unit of nautical miles (kCO_2/NM) in order to give spatio-temporal quantification of the emissionsobserved. On average, the kCO_2/h ranged from 165.96 kg/h to 178.20 kg/h during cruising and from 157.39 kg/h to 171.32 kg/h during trawling.

During cruising, according to the trend of fuel consumption, the kCO2/h of subphase 3a during cruising increased from 169.89 kg/h to 178.20 kg/h. On contrary, during trawling the kilograms of CO_2 per unit of time decreased from 171.32 kg/h to 166.47 kg/h.

The emission of CO2 per unit of mile (CO2/NM) ranged differently between cruising and trawling. During cruising values varied from 25.18 to 27.02 kg/NM, while during trawling the range was between 64.65 to 69.75 kg/NM.

The economic impact of the ORC technology was evaluated through a CBA (cost-benefit analysis) which demonstrated a potential money saving up to ~ 7kEUR/year for the case study vessel monitored.

Overall, the impact of the Orc technology is intimately influenced by the reliability and robustness of the system and by the working profile of the boat. The higher the fuel consumption (l/h) along the fishng day, the more the saving achievable. Fishing techniques such as pots and static gears demonostrated less conveince in such technology as the installation and running cost of the system are not covered by the fuel saving achievable as the ORC system cannot run during those working pahse in which the main engine is not higly loaded (i.e. shooting/haulign the pots). The trawl fishery resulted the preferable fishing technique for the implementation of the ORC technology.

MED_UNITS - Study on Advancing fisheries assessment and management advice in the Mediterranean and Black Sea by aligning biological and management units of priority species (EASME/EMFF/2017/1.3.2.3/01/SI2.792333-SC03)

Contact person: Anna Nora Tassetti, Giuseppe Scarcella (annanora.tassetti@cnr.it, giuseppe.scarcella@cnr.it)
(Anna Nora Tassetti, Carmen Ferrà, Enrico Nicola Armelloni, Giuseppe Scarcella, Gianna Fabi)

Jan 2019 – Dec 2020
Service overview

EASME wishes to identify management units that represent meaningful biological entities and to acquire sufficient information on population structure of priority species to allow updating and, if deemed necessary, redrawing stock boundaries to improve the alignment of biological and management units. The ultimate objective of the study is to identify and match the biological with the management stock units of several of the most important demersal species in the Mediterranean, included also among the priority species at GFCM level; European hake (*Merluccius merluccius*), red mullet (*Mullus barbatus*), deep water rose shrimp (*Parapenaeus longlrostrls*), red shrimp (*Aristaeomorpha foliáceo*), blue and red shrimp (*Aristeus antennatus*), Norway lobster (*Nephrops norvegicus*). The study must cover priority fish stocks in waters of the Geographical Sub-Areas (GSAs) 1-27 (Mediterranean Sea).

Among the specific objectives of the study, CNR-IRBIM is called upon to identify and delimit the more important fishing grounds in the Mediterranean with associated main origin of the operating fleet in order to delineate spatial units for fisheries management purposes in the Mediterranean and, based on the results obtained, to propose areas for assessment and management purposes for the species examined (WP3 - DELINEATE FISHING GROUNDS AND STOCK ASSESSMENT). These proposals should be based primarily on biological evidence (biological stock boundaries as identified in the current study) rather than the current political and statistical considerations that are used for the GSAs. Based on AIS/VMS data and thier integration, the expected outputs of this task will be represented by seasonal maps of the fishing grounds distribution, together with an analysis of the relationships between the different fishing grounds and the different fleets exploiting them and, finally, a preliminary estimation of fluxes from the fishing grounds (catches) to the harbours (landings).

EMODnet - Mediterranean Sea Basin Checkpoint: Growth and Innovation in Ocean Economy – Gaps and Priorities in sea basin observation and data (DG MARE – EMFF European Maritime and Fisheries Fund - Tender MARE/2012/11 - Lot 2 The Mediterranean Sea)

Contact person: Anna Nora Tassetti, Gianna Fabi (annanora.tassetti@cnr.it, gianna.fabi@cnr.it)
(Anna Nora Tassetti, Carmen Ferrà, Giuseppe Scarcella, Giulio Pellini, Antonello Sala, Emilio Notti, Fabrizio Moro, Jacopo Pulcinella, Gianna Fabi)

Sept 2014 – Sept 2018

http://www.emodnet-mediterranean.eu/portfolio/fisheries/

Project overview

The EMODnet MedSea Checkpoint evaluates the quality of the data from current monitoring systems in terms of their accessibility, availability, multiple-use, efficiency, reliability, time consistency, space consistency, as well as the planning of technological advancements, new accessibility, new assembly protocols and observational priorities required to meet 7 end-user applications/challenges. These are of paramount importance for: (i) the blue economy sector (offshore industries, fisheries); (ii) marine environment variability and change (eutrophication, river inputs and ocean climate change impacts); (iii) emergency management (oil spills); and (iv) preservation of natural resources and biodiversity (MPAs).

Among the 7 challanges of the project, CNR-IRBIM was placed in charge of Challenge 5 (Fisheries management) and its two main tasks: (1) construct fishery datasets of fish landings, discards and by-catch for assessing the quality, extracting the synergies and identifying the gaps of the fishery data collection systems in the Mediterranean Sea; (2) deliver maps showing the extent of the trawling fishing grounds for identifying the areas which are most disturbed by bottom trawling and the changes in level of disturbance over the past ten years and identifying the gaps of fishing vessels' tracking systems in the Mediterranean Sea

For the first task the landing, discard and by-catch data are compiled using the information gathered in the framework of DCR/DCF, FAO-FishStat and ICCAT databases (MEDSEA_CH5_Products 1-2-3).

For the second task the impact of trawling on the sea bed is estimated using data recorded by Vessel Monitoring System (VMS), Automatic Identification System (AIS) and GPS logger data collected by the ESIF system (developed within EU project "Energy Saving In Fisheries" financed in the framework of the open call for tenders Fish/2006/17-LOT3). Biota-biology and seabed layers (seabed habitats and substrate) are considered to evaluate the impact on the bottom (MEDSEA_CH5_Products 4-5-6-7-8).

NORA – Development of tools to support a sustainable and shared governance of the Chioggia coastal sector (GAC CHIOGGIA DELTA DEL PO ACTION 5.B.1 – MSP)

Contact person: Anna Nora Tassetti (annanora.tassetti@cnr.it)
(Anna Nora Tassetti, Carmen Ferrà, Fabio Grati, Gianna Fabi)

Feb 2018 – March 2019
Project overview

That project aims to analyse fishing activities in the Chioggia coastal sector using two complementary and integrated approaches: (1) web and open source tools developed to support the implementation of Maritime Spatial Planning (MSP), with a specific focus on the analysis of conflicts between marine uses (SEAGRID tool: *http://seagrid2017.an.ismar.cnr.it*), and the assessment of related cumulative impacts on marine environments (Tools4MSP Geoplatform: *http://data.adriplan.eu/tools4msp*), (2) participatory approach with the direct involvement of local fishermen and stakeholders in a sort of a co-management process oriented towards the communication/validation of the MSP tools and related information layers and the identification of new suitable fisheries management measures (i.e. SIC and AMP). It is crucial for improving management through use of local knowledge, enhancing sense of ownership and perception of regulatory legitimacy, encouraging responsible fishing, and increasing compliance with regulations through peer pressure.

Italian National Programme BYCATCH

Contact person: Antonello Sala (antonello.sala@cnr.it)
(Barbato Matteo, Berto Daniela, Bonanomi Sara, Bueloni Elia, Buoninsegni Joana, Cani Maria Valentina, Ciofi Claudio, Colombelli Alessandro, Corti Rachele, D'Acunto Simone, Filiciotto Francesco, Giovanardi Otello, Mazzola Antonio, Mazzoldi Carlotta, Moro Fabrizio, Notti Emilio, Olivieri Luigi, Palermino Antonio, Pulcinella Jacopo, Raicevich Saša, Rampazzo Federico, Vizzini Salvatrice, Zane Lorenzo)

Period: 2017-2019

Project overview

The project is a monitoring programme of accidental catches of cetaceans in Italian pelagic trawlers in the northern central Adriatic Sea and in the Sicilian Channel. The programme is funded by the Italian Ministry of Agriculture, Food and Forestry, in compliance with Regulation (EC) No. 812/2004. Under this regulation, 'Member states shall design and implement monitoring schemes for accidental catches of cetaceans […]'.

The programme also includes monitoring of other species of conservation concern such as sea turtles and elasmobranchs which are considered vulnerable species to commercial fishing.

The main objectives of the project are listed below:

- training of fisheries observers;
- evaluate the presence/absence of cetaceans during fishing operations on board pelagic trawlers;
- data collection of accidental catches of cetaceans and species of conservation concern (sea turtle and elasmobranch) on board pelagic trawlers;
- tissue sampling of cetaceans, sea turtle and elasmobranch for genetic and stable isotope analysis;
- create a database for data management;
- evaluate accidental catches of cetaceans in the northern central Adriatic Sea at population level (population genetic analysis);
- evaluate the acoustic behaviour of cetaceans using specific bioacustic field techniques during fishing operations;
- investigate the group structure, movement patterns and site fidelity of cetaceans with photo-identification of individuals'dorsal fins;
- test mitigation measures (grids and innovative acoustic devices) to minimise bycatch of protected species and species of conservation concern in pelagic trawl fisheries;
- identify the distribution and movement patterns of different elasmobranch species accidentally taken during pelagic trawl fisheries operations by recording geo-referenced data (mark-recapture method);
- discuss together with local authorities a management plan for bottlenose dolphin (*Tursiops truncatus)* in the Adriatic;
- attend the ICES Working Group on Bycatch of Protected Species (WGBYC).

8.19 Japan

National Research Institute of Fisheries Engineering (NRIFE), Japan Fisheries Research and Education Agency (FRA)

Contact person: Go Takayama, golgo13@affrc.go.jp

Summary

NRIFE has been conducting research to elucidate the capture process of squid jigging fisheries in order to improve the efficiency of LED fishing lights for squid jigging. Behavioral experiments were conducted in the aquarium tank to investigate the squid response against artificial light. Also, the behavior of squid moving toward fishing lights in the field was verified by bio-telemetry survey.

Projects

Development of research method on squid behavior to realize advanced squid igging fisheries

Contact person: Go Takayama, golgo13@affrc.go.jp

Apr 2017 – Mar 2019

In this project, behavioral experiments were conducted in aquarium tank to verify responses of Japanese flying squid (*Todarodes pacificus*) to various light environments (Figure 8.19.1). As a result, it was inferred that the behavior of squid aggregating under fishing lights is caused by two autonomous responses; positive phototaxis and dorsal light reflex. In addition, Bio-telemetry surveys were conducted in the fishing grounds to verify squid behavior. In the observation, the squid moved a maximum 4 nautical miles from the release point to the squid jigging boat. This project was funded by Marine Fisheries Research and Development Center (JAMARC).

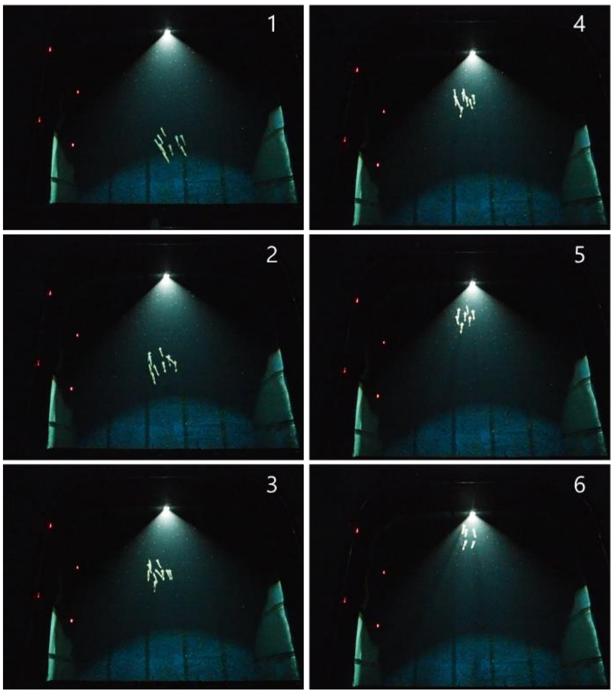


Figure 8.19.1 The squid school moving toward the light source in the aquarium tank.

Tokyo University of Marine Science and Technology

Contact person: Daisuke Shiode, shiode@kaiyodai.ac.jp

Summary

Development of bycatch reduction and sorting/releasing techniques, and utilization of LED lights in set nets, and research on separator trawl nets and hydrodynamic characteristics of aquaculture fish cage have been conducted in Tokyo University of Marine Science and Technology.

Projects

Development of technology for sorting and releasing small bluefin tuna trapped in set nets

Contact person: Seiji Akiyama, akiyama@kaiyodai.ac.jp

FY 2016 to FY 2021

The population of Pacific bluefin tuna has decreased to a record-low level, requiring urgent measures to restore their number. Tokyo University of Marine Science and Technology has formed a consortium with the Japan Fisheries Research and Education Agency, Aomori Prefectural Industrial Technology Research Center, and HORIEI Co., Ltd. to develop technology for sorting and releasing small bluefin tuna trapped in set nets. Through this project we seek to develop technology to sort only small bluefin tuna from various species caught in set nets without risk to their lives and to release them from the nets in a sound state. Such technology is expected to help restore the number of bluefin tuna rapidly and realize sustainable operation of set net fishery, contributing greatly to the steady supply of a variety of seafood and the development of local economies.

Figure 8.19.2 Small bluefin tuna swimming in the set net.

Nagasaki University

Contact person: Yoshiki Matsushita, yoshiki@nagasaki-u.ac.jp

Summary

Impact of Marine Renewable Energy facilities (MREs) on fishing operations are prioritized research in Nagasaki University. Connectivity of MREs and surrounding fish habitats has been studied by using various techniques. In addition, development of underwater lighting system for the setnet fishing gear and evaluation of catch performance of survey trawl gear are ongoing.

Projects

Development of underwater fish attraction lighting system for the mid-water setnet

Contact person: Yoshiki Matsushita, yoshiki@nagasaki-u.ac.jp

Aug 2017 – Mar 2020

This is a three-year project funded by Sai-village of Aomori Prefecture Japan. The village has developed the new fishing ground for mid-water setnet fishery in 2017. The project aims to support the setnet fishery by maintaining catch level. For the midwater use, below water-proof (up to 50 m) lighting system containing 20W LED, lithium battery, and timer is developed and tested in the field.

Figure 8.19.3 Underwater fish attraction lighting system for mid-water setnet.

9 OTHER BUSINESS

9.1 Chairman changes and Meeting date and Venue

At the meeting was a resolution to continue the work of WGFTFB for the next three-year term (2020-22), with chair Daniel Stepputtis (Germany) and co-chair Antonello Sala (Italy) has been submitted (Annex 2). In the 2011 FAO-ICES exchange of letters, FAO agreed to co-chair the WGFTFB and Pingguo He will further co-chair WGFTFB as he has since 2018. WGFTFB proposes that its 2020 meeting will be in Bergen, Norway from 20-24 April 2020. This meeting will be held in association with WGFAST and JFTAB.

9.2 Proposed Topic Groups for the 2020 WGFTFB Meeting

Two Topic Group will pass on the work to the next year, that is the light going for the third year and passive for the second year. At the meeting a new Topic Groups was suggested; New Manual of Methods of Measuring the selectivity of towed gears. The response was a discussion on whether it can be integrated with the passive gear manual but agree to investigate the possibility. The meeting agreed to not select this topic at TG at this stage, but further work will be done to use next year to plan how this could be achieved. Another suggestion for Topic Group or a session about instruments and new technologies in fishing gear and after discussion it was agreed it should be proposed to have it as a joint session theme in plenary and therefore not selected for a Topic Group. Finally, a suggestion for a new Topic Group was an ETP bycatch mitigation meta-analysis for large pelagic fisheries. The idea to develop a database of records from literature to support meta-analyses of capture risk. In the discussion was talking about the possibility to appeal a broader audience to encourage attendance from those that may not otherwise attend. Suggestion to extend from proposed 1 yr. to 2 yrs. agreed. Agreed to be a Topic Group in 2020.

9.3 Next year Topic Groups

New Topic Group: ETP Bycatch Mitigation Meta-analyses for Large Pelagic Fisheries (Pelagic)

A WGFTFB Topic Group convened by Eric Gilman (Hawaii Pacific University, USA – EricLGilman@gmail.com), Liming Song (Shanghai Ocean University, China – lmsong@shou.edu.cn), Antonello Sala (Italian Research Council, Antonello.sala@cnr.it), Martin Hall (Inter-American Tropical Tuna Commission, MHall@iattc.org), and potentially additional co-leads, will be formed in 2020 to develop an open source database to support robust meta-analyses of endangered, threatened and protected (ETP) species bycatch mitigation in pelagic fisheries. Due to the larger sample size plus the number of independent studies, correctly designed meta-analyses can provide estimates with increased precision and accuracy overestimates from single studies, with increased statistical power to detect a real effect.

Terms of Reference

1. Develop a database of records from compiled literature to support robust meta-analyses on the relative risk of ETP capture by gear design factor. Each database record would include summary statistics required for inclusion in a meta-analysis, including the number of captured organisms by species or higher taxonomic grouping and amount of observed effort, by treatment (e.g., number of leatherback sea turtles caught on pelagic longline circle hooks, and number of circle hooks observed). These records would be derived from publications and grey literature, including from research experiments, at-sea observer programs, electronic monitoring programs, survey fishing, and logbook data. The database would be open source and designed to be a living document, supporting continuous entry of new records making it efficient to conduct updated meta-analyses as new records accumulate.
2. During 2020 the Topic Group will have:
   a. Compiled sufficient records to complete a meta-analysis on the pooled (overall) relative risk of capture of ETP species by pelagic longline bait type (small species of fish, squid species, pieces of incidental catch large pelagic species); and
   b. Will have developed a database structure and entered records from pelagic trawl fisheries.
3. By the WGFTFB 2021 annual meeting, the Topic Group will have finalized and published the database for pelagic longline and pelagic trawl fisheries.

Second year Topic Group: Passive fishing gears (Passive)

A WGFTFB Topic group convened by Peter Ljungberg (Sweden), Isabella Kratzer (Germany) and Lotte Kindt-Larsen (Denmark) was formed in 2019 on passive gears and will continue the work to 2020.

Terms of Reference:

1. Summarize current and past work in relation to fish pot and trap development, plus gillnet and longline modifications in order to avoid bycatch of protected species (hereunder marine mammals, sea birds and sea turtles).
2. Discuss and describe methods and their limitations, hereunder catch efficiency and depredations risks. Furthermore compare newly developed bycatch mitigation efforts and their efficiency to standard gear and compare different types of passive gears (e.g. gillnets vs. fish pots/traps) and the processes of depredation.
3. Identify and make recommendations on how to improve passive gears including unwanted bycatch, high variability in catches and mitigation of depredation from different predators.
4. Identify potential synergies in developing new approaches to promote sustainability (economically and ecologically) of passive gears

Justification

Passive fishing gears such as gillnets, longlines, traps and pots, belong to the most common fishing methods worldwide. These methods have naturally advantages like efficiency, simple use and size selectiveness. Nevertheless, they have been criticized due to bycatches of higher taxa like sea turtles, sea birds and marine mammals, ghost fishing and their vulnerability to depredation by marine mammals. In recent years, a lot of effort has been put into the optimization of fish traps and pots, mainly due to gillnet-raiding seals and studies on how to mitigate bycatch in gillnet and longline fisheries have been carried out with differing success, but a scientifically proven management tool or technical solution working across taxa has yet to be developed.

The "Passive" topic group will thus aim to investigate selectivity, efficiency and sturdiness of passive gears, such as gillnets and longlines (mainly species selectivity), fish pots and large scale fish traps (mainly efficiency and sturdiness). It will document and evaluate current and past work regarding gillnet and longline modifications as well as fish pot and fish trap development. This will include a wide range of fields such as species behaviour, gear design and hydroacoustics. Ongoing and future projects regarding enhanced economical, ecological and social sustainability of passive gears will be discussed and potential synergies identified that will hopefully stimulate new ideas and innovation.

Third year Topic Group: Evaluating the application of artificial light for bycatch mitigation (Light)

A WGFTFB Topic Group convened by Noëlle Yochum (USA) and Junita Karlsen (Denmark) was formed at the 2018 meeting in Hirtshals Denmark, to evaluate the application of light as a mechanism for bycatch mitigation. At the 2019 ICES-FAO WGFTFB meeting the 'Light' Topic Group of experts the group meet for the second year and the final year for the Topic Group is planned to be 2020.

Terms of Reference:

1. Describe and summarize completed and ongoing research, successes and 'failures', related to the application of light for bycatch mitigation.
2. Identify patterns with respect to species and fishery/ gear types, noting fish behavior in response to light (attraction, repulsion, guidance), and other variables that play a role in the efficacy of using artificial light for bycatch mitigation (e.g. vision, depth, etc.).
3. Describe best sampling techniques for testing the application of artificial light under varying circumstances, including guidance for dealing with common experimental challenges.
4. Highlight areas of needed research in the field of fish behavior with respect to light, and fisheries that might benefit from the application of artificial light.

Justification:

Essential to the study of fishing gear design and use is fish behavior. The success of bycatch mitigation is linked with understanding how fish interact with fishing gear and respond to the micro-environment in and around the gear. A component of fish behavior that is increasingly being evaluated is the reaction of fish to artificial light. To that end, from 2012-2014, Heui-Chun An, Mike Breen, Odd-Børre Humborstad, and Yoshkiki Matsushita convened a WGFTFB Topic Group (TG) titled "Use of Artificial Light in Fishing". The focus of this TG was to evaluate the use of artificial light to affect fish behavior and stimulate catch, and to research and synthesize information on fish vision and behavior with respect to light. They also summarized the use of artificial light in fisheries globally and regionally.

The aim of the 2018-2020 'Light' TG is to build on the foundation that has been laid, and to focus on the use of artificial light to enhance bycatch mitigation (e.g. illuminating escape ports or the footrope in trawl gear). Specifically, this TG will focus on creating a community of researchers using light as a fisheries selectivity tool, will develop resources to support this community, and will aggregate and synthesize information from global projects. Through collective review of this research, we will identify variables that play a role in the efficacy of using artificial light for bycatch mitigation (e.g. species, gear type, fish behaviour). We will also discuss common experimental, technological, and analytical challenges when doing this research, and identify gaps in knowledge and other fisheries that might benefit from the application of artificial light. Through the analysis of completed and on-going research, and collective knowledge of the TG experts, we will also consider guidelines for conducting research on the application of artificial light for bycatch mitigation. We hope that these meetings will also foster an exchange of ideas and support, and stimulate innovation.

Further work to end outstanding work

At the meeting discussion it was agreement to that the Working Group would decides in plenary whether it wants to continue producing factsheets. It was agreed that the topic group would continue for one more year with a short session/meeting during the 2020 meeting. The topic group GroundGear ending this year are reporting this year with conclusions, but no recommendations. During the next year, the topic group GroundGroup will table recommendations for discussion and approval by the topic group and the entire WGFTFB.

Annex 1: List of participants

Name	Institute / Organization
Australia	
Kelsey Richardson	University of Tasmania and the Commonwealth Scientific and Industrial Research Organisation
Stephen Eayrs	Smart Fishing Consulting
Belgium	
Maarten Soetaert	Institute for Agricultural and Fisheries Research
Mattiasvan Opstal	Institute for Agricultural and Fisheries Research
Brazil	
Dérien Lucie Vernetti Duarte	Centro Nacional de Pesquisa e Conservação da Biodiversida de Marinha do Sudeste e Sul do Brasil
Canada	
Shannon Bayse	Memorial University of Newfoundland
Zhaohai Cheng	Memorial University of Newfoundland
China	
Binbin Xing	Dalian Ocean University
Cheng Zhou	Ocean University of China
Chunyi Zhong	Shanghai Ocean University
Congda Yu	Zhejiang Ocean University
Daomei Cao	Shanghai Ocean University
Di Wang	Shanghai Ocean University
Ebango Ngando Narcisse	Shanghai Ocean University
Fei Yang	Shanghai Ocean University
Guoping Zhu	Shanghai Ocean University
Hao Tang	Shanghai Ocean University

Heng Zhang	Chinese Academy of Fishery Sciences
Hongliang Huang	Chinese Academy of Fishery Sciences
Huajie Lu	Shanghai Ocean University
Huihui Shen	Shanghai Ocean University
Ji Zhen	Zhejiang Ocean University
Jian Zhang	Shanghai Ocean University
Jianfeng Tong	Shanghai Ocean University
Jianhua Tang	Institute of Oceanology & Marine Fisheries, Jiangsu
Jing Wang	Global Environment Institute
Jingjing Zhang	Ludong University
Jintao Wang	Shanghai Ocean University
Keji Jiang	Chinese academy of fishery sciences
Kexiang Lu	Shanghai Ocean University
Lei Yan	Chinese Academy of Fishery Sciences
Leiming Yin	Dalian Ocean University
Lili Liu	Zhejiang Ocean University
Liuyi Huang	Ocean university of China
Min Zhang	Shanghai Ocean University
Mingrui Chen	Shanghai Ocean University
Mingyun Dai	Shanghai Ocean University
Peng Zhang	Chinese Academy of Fishery Sciences
Qingyan Deng	Shanghai Ocean University
Rong Hua	JESSN Marine Equipment
Ruizhi Ding	Shanghai Ocean University
Shengmao Zhang	Chinese Academy of Fisheries Science
Shiyu Ren	Shanghai Ocean University
Shuangquan Xu	Shanghai Ocean University
Teng Wang	Chinese Academy of Fishery Sciences
Wang Liu	HUNAN XINHAI CO., LTD.
Wang Zhou	Shanghai Ocean University
Wei Fan	Chinese Academy of Fisheries Science
Weiguo Qian	Shanghai Ocean University
Weihua Song	Zhejiang Ocean University
Weiping Jiang	Shanghai Ocean University
Weiyao Tang	Zhejiang Ocean University
Wenbin Zhu	Zhejiang Marine Fisheries Research Institute
Wenhua Chu	Shanghai Ocean University
Xiaming Zhong	Institute of Oceanology & Marine Fisheries, Jiangsu
Xiaoli Zhu	JESSN Marine Equipment
Xiaorong Zou	Shanghai Ocean University
Xinjun Chen	Shanghai Ocean University
Xuchang Ye	Shanghai Ocean University
Xuefeng Wang	Guangdong Ocean University
Xueqing Zhang	HUNAN XINHAI CO., LTD.

Xun Zhang	Chinese academy of fishery sciences
Yanjie Gao	Ludong University
Yanli Tang	Ocean University of China
Ying Dai	Dalian University of Foreign Languages
Ying Liu	Dalian Ocean University
Yingqi Zhou	Shanghai Ocean University
Yinliang Zang	Zhejiang Ocean University
Yiping Ren	Ocean University of China
Yiting Li	Shanghai Ocean University
Yongdong Zhou	Zhejiang Marine Fisheries Research Institute
Yongjin Wang	Chinese academy of fishery sciences
Yongsong Qiu	Chinese Academy of Fisheries Science
Yu Zhang	Chinese academy of fishery sciences
Yukun Qi	Shanghai Ocean University
Yuwei Li	Shanghai Ocean University
Zengguang Li	Shanghai Ocean University
Zhihai Chen	Zhejiang Ocean University
Denmark	
Junita Karlsen	DTU Aqua
Lotte Kindt-Larsen	DTU Aqua
Ludvig Ahm Krag	DTU Aqua
Mollie Brooks	DTU Aqua
Valentina Melli	DTU Aqua
Germany	
Breddermann Karsten	University of Rostock
Kratzer Isabella Maria Friederike	Thünen Institute of Baltic Sea Fisheries
Uwe Lichtenstein	Thünen Institute of Baltic Sea Fisheries
Juan Santos	Thünen Institute of Baltic Sea Fisheries
Stephan Schacht	University of Rostock
Daniel Stepputtis	Thünen Institute of Baltic Sea Fisheries
Iceland	
Haraldur Arnar Einarsson	Marine and Freshwater Research Institute
Georg Haney	Marine and Freshwater Research Institute
India	
Ema Fatima	WWF-India
Ireland	
Matthew McHugh	IrishSeafood Development Agency
Italy	

Antonello Sala	Italian National Research Council
Raymon van Anrooij	Food and Agriculture Organization of the United Nations
Japan	
Daisuke Shiode	Tokyo University of Marine Science and Technology
Go Takayama	National Research Institute of Fisheries Engineering
Yoshiki Matsushita	Nagasaki University
Malaysia	
MohdFadzliee bin Asmat	WWF-Malaysia
Serena Binti Adam	WWF-Malaysia
Mexico	
Daniel Aguilar Ramirez	InstitutoNacional De Pesca
Netherlands	
Pieke Molenaar	Wageningen Marine Research
New Zealand	
Carol Scott	Southern Inshore Fisheries Management Company Limited
Norway	
Aud Vold	Institute of Marine Research
Åsmund Bjordal	Institute of Marine Research
Maria Tenningen	Institute of Marine Research
Terje Jørgensen	Institute of Marine Research
Ólafur Ingolfsson	Institute of Marine Research
Portugal	
Pedro Sá	Lankhorst Euronete
Republic of Korea	
Hyun Young Kim	National Institute of Fisheries Science
Subong Park	National Institute of Fisheries Science
Sweden	
Peter Ljungberg	Swedish University of Agricultural Sciences
Thailand	
Isara Chanrachkij	Southeast Asian Fisheries Development Center
Taweekiet Amornpiyakrit	Southeast Asian Fisheries Development Center
UK	
Daniel Watson	SafetyNet Technologies
Thomas Catchpole	Centre for Environment, Fisheries and Aquatic Sciences

USA	
Eric Gilman	Hawaii Pacific University
Lauren Fields	NOAA Fisheries
Michael Pol	Massachusetts Division of Marine Fisheries
Noëlle Yochum	NOAA Alaska Fisheries Science Center
Pingguo He	Food and Agriculture Organization (FAO) / University of Massachusetts Dartmouth
Timothy Werner	Anderson Cabot Center for Ocean Life, New England Aquarium
Lists of attending meetings but Unregistered	
China	
Gang Wang	Ocean University of China
Yuyan Li	Ocean University of China
Jiazhi Ma	Zhejiang Ocean University
Jie Li	Chinese Academy of Fisheries Science
Lei Wang	Chinese Academy of Fisheries Science
Tao Tian	Dalian Ocean University
Guoqiang Xu	Zhejiang Marine Fisheries Research Institute
Lingzhi Li	Chinese Academy of Fisheries Science
Leilei Zou	Shanghai Ocean University
Atika Arifati	Shanghai Ocean University
Feng Wu	Shanghai Ocean University
Liang Chang	Shanghai Ocean University
Yangyang Chen	Shanghai Ocean University
Fenghong Guo	Shanghai Ocean University
Xiaoxue Du	Shanghai Ocean University
Fang Wang	Shanghai Ocean University
Binbin Pan	Shanghai Ocean University
Chenglin Zhang	Shanghai Ocean University
Yang Wang	Shanghai Ocean University
Na Liu	Shanghai Ocean University
Huifang Xu	Shanghai Ocean University
Lijin Zou	Shanghai Ocean University
Jintao Chen	Shanghai Ocean University
Zhijian Hao	Shanghai Ocean University

Annex 2: Resolutions

Working group on Fishing Technology and Fish Behaviour. multi-annual ToR (category 2)

The ICES-FAO **Working Group on Fishing Technology and Fish Behaviour** (WGFTFB), chaired by Daniel Stepputtis, Germany, co-chair by Antonello Sala, Italy and Pingguo He, Italy (FAO), will meet to work on the following Terms of References (ToRs) and produce deliverables as listed in the following table for the years 2020 through 2022. This multiyear ToRs will be updated annually. WGFTFB will report on the activities and findings by 25 June each year to SSGIEOM.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2020	20 – 24 April	Bergen, Norway	Interim report by 25 June to SSGIEOM	Incoming Chair Daniel Stepputtis, and co-chair Antonello Sala Pingguo He Chair of behalf of FAO
Year 2021			Interim report by Date Month to SSGXXX	
Year 2022		Potential Turkey	Final report by Date Month to SSGXXX	Funded by FAO

ToR descriptors

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
A	Deliberate, discuss and synthesize recent research on topics related to: i) Designing, planning, and testing of fishing gears used in abundance estimation; ii) Selective fishing gears for the reduction of bycatch, discard and unaccounted mortality, especially as they relate to EU Landing Obligation; iii) Environmentally benign fishing gears and methods, iv) Improving fuel efficiency and reduction of emission from fisheries, and v) Summaries of research activities by nation	Through open sessions and focused, multiyear topic groups, the Working Group provides opportunities for collaboratively developing research proposals, producing reports and manuscripts, and creating technical manuals on current developments and innovations.	3.3, 4.5, 5.4	3 Years	ICES report
B	Organize a FAO-hosted FAO-ICES mini-symposium with thematic issues. Symposium themes will be determined at Year 2, and included in the updated ToR.	Under mutual agreement between ICES and FAO, FAO develops and leads a mini-symposium of relevant topics, while also continuing ICES commitments.	2.1, 4.5, 5.4	Year 3	FAO report, ICES report

C	Deliberate, discuss and synthesize recent research on topics of mutual interest between WGFTFB and WGFAST	Every three years, WGFAST and WGFTFB meet for one day to share information on topics of mutual interest (JFATB).	3.2, 4.5, 5.4	Year 1	JFATB report
D	Help organize an ICES-sponsored international fishing technology and fish behaviour symposium	The last similar symposium was 13 years ago (2006).	2.1, 4.5, 5.4	Fall 2020	Symposium and special issue in ICES JMS
E	Support survey working group with gear expertise support upon request	SSGIEOM has identified gear expertise gaps in survey working groups.	3.2	Year 1,2	Including possible survey trawl workshop

Summary of the Work Plan

Year 1	PRODUCE THE ANNUAL REPORT; HOLD JOINT SESSION WITH WGFAST; CONNECT TO SURVEY WGS
Year 2	Produce annual report; Continue development of relationships with survey WGs
Year 3	Produce the annual report; organize FAO-ICES mini-symposium

Supporting information

Priority	The activities of WGFTFB will provide ICES with knowledge and expertise on issues related to the ecosystem effects of fisheries, especially the evaluation and reduction of the impact of fishing on marine resources and ecosystems and the sustainable use of living marine resources and other topics related to the performance of commercial fishing gears and survey gears.
Resource requirements	The research programmes that provide the main input to this working group already exist, and resources are already committed by individual institutions. The additional resource required to undertake activities in the framework of this group is negligible. However, each institution is encouraged to support participation of experts from their institution.
Participants	The group is normally attended by about 60–100 regular members and chair-invited members. Participation is about 100 - 140 in the year when FAO-ICES mini-symposium is held. The numbers of attendees to the meeting have been growing last years.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	Linkages to advisory groups via reports on changes to fleets and fleet effort.
Linkages to other committees or groups	There is a very close working relationship with other groups of SSGIEOM, e.g. WGFAST, and the survey groups.
Linkages to other organizations	The WG is jointly sponsored with the FAO.

Annex 3: Opening speech

Opening and Welcome – Introduced by Jiale Li, Vice President of Shanghai Ocean University

Distinguished guests, ladies and gentlemen,

Good morning everyone!

Today, the 2019 Annual Meeting of the ICES-FAO Working Group on Fishing Technology and Fish Behavior (WGFTFB) is held in our school. Here, on behalf of Shanghai Ocean University, I would like to express my heartfelt congratulations on the successful convening of the symposium sessions, and sincere greetings to the UN FAO officials, experts and scholars from all over the world! First of all, let me introduce the leaders and experts attended in this meeting: Professor **Yudong Cheng,** President of Shanghai Ocean University. **Raymon Edward van Anrooij,** representative of the UN Food and Agriculture Organization. **Haraldur Arnar Einarsson,** representative of the International Council for the Exploration of the Sea. **Professor He Pingguo,** Chairman of the meeting. Foreign experts and scholars from 24 countries like Australia, Belgium and Brazil, and etc. Experts and scholars from 13 domestic institutions including Ocean University of China, Dalian Ocean University and Zhejiang Ocean University. Welcome to the meeting!

The development in many aspects of our school has always been strongly supported by the Ministry of Agriculture and Rural Affairs Fisheries and Fisheries Administration. Our school's fishing science has been rated as the key discipline of the Ministry of Agriculture and Rural Affairs, and Chinese Oceanic Fisheries Data Center has been established in our school.

The meeting was also highly valued by the Ministry of Agriculture and Rural Affairs Fisheries and Fisheries Administration. Because the leader of the ministry and bureau has foreign affairs visit, he could not be in the presence himself. And he has sent us a letter of congratulation congratulatory in particular. I will read the letter on behalf of the ministry.

The Fishing discipline in our school has a long history and is a traditional special discipline of our school. It has received strong support from school leaders in the development process. Next, Let us welcome our President Yudong Cheng to give a speech for this meeting!

The meeting has received high attention and strong support from the UN Food and Agriculture Organization, which has specially sent high-level officials to attend the meeting. Now, I would like to invite the representative of the Food and Agriculture Organization of the United Nations, Raymon Edward van Anrooij, to speak. Let's welcome!

The International Council for the Exploration of the Sea is the initiator of the Working Group on Fishing Technology and Fish Behavior. It has a history of about 50 years and the meeting has also received great attention from the committee. Next, please welcome Haraldur Arnar Einarsson, representative of the International Council for the Exploration of the Sea, to give us a speech. Let's welcome!

Professor Pingguo He is a consultant of FAO and a distinguished visiting professor of our school. The meeting was contacted and planned by Professor He who devoted a lot of effort. Next, please call Professor Pingguo He, chairman of the meeting, please welcome!

Now, I announce the opening of this meeting!

Of behalf of the host, Yudong Cheng, President, Shanghai Ocean University

Distinguished guests, ladies and gentle-men,

Good morning everyone!

Today, the 2019 Annual Meeting of the ICES-FAO Working Group on Fishing Technology and Fish Behavior (WGFTFB) is held in our school. On behalf of Shanghai Ocean University, I would like to express my heartfelt congratulations on the successful convening of the symposium sessions, and sincere greetings to the UN FAO officials, experts and scholars from all over the world!

Shanghai Ocean University is one of the most prestigious aquatic universities in China. The Fishing discipline has been established since the founding of our school in 1912. After more than a hundred year of development, men of talent come forward in succession and the achievements are remarkable, and the school is known as "the cradle of modern Chinese aquatic education". In September 2017, our school was selected as one of the national "world-class discipline-building universities", the selected discipline was Aquatic Sciences, which was A+ (Top 2) grade in the fourth round of Chinese discipline evaluation. Concerning the discipline, there are a great deal of research centers, platforms, and laboratories of high level in our school: national and ministerial scientific research platforms as the National Engineering Research Center of Oceanic Fisheries, The Key Laboratory of Ministry of Education for Sustainable Development of the Oceanic Fisheries Resources, The Key Laboratory of Ministry of Agriculture for Oceanic Fisheries Development, and Chinese Oceanic Fisheries Data Center, etc.; teaching platform such as the National Teaching Demonstration Center for Aquatic Science.

As a college with 107 years of history and of distinctive characteristics, our school is taking a new journey in building a high-level university with unique characteristics under the requirements of "double first-class". We will continue to practice the school spirit of "diligence and loyalty" and to insist on the tradition of "writing papers on oceans and seas of the world and on the rivers and lakes of the motherland". We will also focus on the discipline's main line of "sustainable development and utilization of aquatic resources in the waters and protection of the earth's environment and ecology", and aim at the world's frontier to deepen comprehensive education reform. By building a world-class discipline, it can be strongly supported and motivated to achieve the dual tasks of school's transforming development as well as improving quality and efficiency, and to construct a world-class university with special characteristics.

Under the requirements in build-ing a "double first-class" school, the construction and development of fishing discipline has become the focus of school's discipline building. It is hoped that through this international meeting, communication with the ICES-FAO will be strengthened, exchanges and discussions with experts and scholars at home and abroad will be reinforced to promote the progress of fishing technology and fish behavior research in our school. At the same time, it's also a good chance to display achievements of the first-class discipline construction in our school, to deepen the international aware-ness and vision of teachers and students in the school, and jointly to promote the cooperation and development of global fishing technology and fish behavior research. Taking this opportunity, I hope that the participating experts and scholars will have an in-depth understanding of the research results of relevant disciplines in our school.

Finally, I wish the meeting a complete success! And wish all the experts and guests a happy time and all the best during our participation in the school! Thank you all!

Opening Address by: Mr. Raymon van Anrooy Senior Fishery Officer Food and Agriculture Organization of the United Nations (FAO)

Chairmen, Distinguished delegates, Ladies and gentlemen

It is a great pleasure and honour to welcome you on behalf of the FAO Assistant Director General for Fisheries and Aquaculture, Dr Arni Mathiesen, to the 2019 meeting of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour and this symposium.

At the outset, I would like to express my sincere gratitude to the Government of China, in particular the Shanghai Ocean University, for hosting this Working Group meeting and symposium. The commitment of China to the work of ICES and FAO is very much appreciated, and I am sure all experts share with me the pleasure to be in Shanghai as the venue of our symposium.

The ICES–FAO Working Group on Fishing Technology and Fish Behaviour was established in 2002. Prior to this time, the working group was comprised primarily of individuals from the member countries of the ICES in Europe and North America. In 2011, ICES and FAO further discussed the purpose and methods of collaboration at the Working Group. It was agreed that FAO would co-chair the annual meeting and host the meeting every third year at a location chosen by FAO. In 2013 the joint meeting and Symposium were held in Thailand, followed by Mexico in 2016. This meeting in Shanghai is thus the 3rd meeting of the ICES-FAO Working Group that is being organized by FAO. We hope to do so many more times in the future and further strengthen collaboration between our institutions.

The Working Group meetings in recent years have shown that technological advances in fisheries, and particularly gear technology, have increased fishing efficiency tremendously.

Technologies such as GPS and Fishfinders, Bycatch Reduction Devices, and smart FADs (Fish Aggregating Devices) of which trials and research findings were once discussed in the Working Group are now widely applied by industrial, small-scale and recreational fisheries. These technologies have changed the fishing sector and continue to do so. It is clear that some of the research of the ICES-FAO Working Group members has had major positive effects on profitability of the fishing fleets.

There are however also many promising technologies tested and developed for commercial use that do not seem to reach the fishers. They remain undistributed and their uptake is low. FAO considers it among its tasks to facilitate technology transfer and uptake of responsible and sustainable fishing technologies and operations by the fishing fleets worldwide.

Through our data and information collection and sharing, technical guidelines and best practices, global standard setting, policy development, management and technical advisory services we try to contribute to more sustainable fisheries. The FAO Code of Conduct for Responsible Fisheries remains the guiding document for our member states and FAO.

Examples of international guidelines under The Code that have been adopted or endorsed at global level in recent years, include the 2011 FAO International Guidelines on Bycatch Management and Reduction of Discards, the Voluntary guidelines on Catch Documentation Schemes, and the 2018 FAO Voluntary Guidelines on the Marking of Fishing Gear. The latter will be presented during the symposium.

FAO produces every two year a State of Fisheries and Aquaculture (SOFIA) report, and its latest version in 2018 showed that fish production was at an all-time high with 171 million tonnes, of which around 80 million tonnes is generated annually by capture fisheries. The global capture fisheries production level has been stable since the beginning of the 1990s.

The same SOFIA report illustrated that in the year 2000 nearly 25 percent of the global fish stocks were overfished. The latest figures of 2016/2017 suggest that now some 33 percent of the globally targeted fishing stocks are overfished. The global fishing fleet, which consisted in 2016 consisting of about 4.6 million vessels, has grown since 2000 with 500 thousand vessels. The overfishing and continued increase in fleet capacity is a concern to FAO and its members.

It is however clear that despite reductions in a few regions (notably EU and North America) the fishing fleets have continued to increase at global level. It appears that the International Plan of Action (IPOA) on the Management of Fishing Capacity, which was globally endorsed at end of the 1990s, is not being implemented by many countries. The consequences for the fish stocks are clearly visible.

The improvements in fishing technology have contributed to the more efficient harvesting of fish, supporting Catch Per Unit of Effort increases in many cases.

However, preliminary findings from a global study into the economic performance of fishing fleets indicate that the profitability of many fishing fleets is at stake. Consequences of lower profitability are not just seen in the reduction of stocks and profits, but also in the deterioration of maintenance/repair regimes of vessel, and in cost savings related to working conditions of the crew and safety at sea.

These findings demonstrate the important work of fishing gear technologists (you) to continue develop not just more efficient fishing gears, but gears that contribute to selectivity in fishing, responsible harvesting and safer working environments in fishing. Your work can save fish stocks, contribute to food security and coastal livelihoods, as well as reduce accidents and casualties in the fishing industry.

Ladies and gentlemen,

FAO stands ready to disseminate your research findings to the world so that the fishers and stocks will truly benefit and that your research makes an impact, not just in a scientific journal. The work of this group can clearly contribute to the Sustainable Development Goals (SDGs) and particularly Goal 14, "Conserve and Sustainably Use the Oceans, Seas and Marine Resources for Sustainable Development".

On behalf of FAO, I would like to express my gratitude especially to Prof Liming Song and his team at the Shanghai Ocean University for the organization of this event and to the two chairpersons of this ICES-FAO Working group, Dr Pingguo He and Dr Haraldur Einarsson, for the excellent work in preparation of this important event. Please rest assured that the FAO will assist you with the best of our ability over the next few days and into the future. I wish you a fruitful symposium and working group meeting.

Thank you for your attention.

Opening Address by: Dr. Pingguo He, Food and Agriculture Organization of the United Nations (FAO), Professor of Fisheries School for Marine Science and Technology University of Massachusetts Dartmouth. Symposium Chair and FAO WGFTFB Co-Chair

Mr. Zhang, President Cheng, Vice President Li, Dr. van Anrooy, Dr. Einarsson, other dignitaries on stage and on the floor, scientists and technologists from overseas and from within China, colleagues and friends, I am speaking today, representing the organizing committee for this symposium, and as a co-chair of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour, to welcome all of you to Shanghai for this important meeting.

We have more than 120 scientists and technologists from 23 different countries around the world registered for the meeting. This will likely be the largest WGFTFB meeting in the history of the working group. This is also the first time that WGFTFB meets in China. I hope that this meeting will further foster collaborations between Chinese scientists and those from other countries. I also hope that, by holding this meeting here, more Chinese colleagues will continue to attend WGFTFB meetings in the future.

As the title of the symposium implies, the marine capture fisheries have come to a stage where pressing issues have seriously challenged the sustainability and further development of the capture fisheries, which calls for dramatic actions to reduce collateral impacts of harvesting fish from the sea. The environment and the ecosystem, where our fish reside, is the uttermost important for the long-term and sustainable supply of protein from the sea, so that we can continue to provide healthy seafood to the growing population, to contribute to global food security, and to alleviate poverty and hunger in many coastal countries, especially developing countries. Sustainable fisheries require sustainable ecosystems.

There are great challenges in front of each of us, whether to understand sciences that underly sustainable fisheries, or to solve practical problems that face fishery managers and fishers. This week, we are gathering here to further the work that has already started, and to explore new ideas and practices on some of the most pressing issues that undermine clean oceans and sustainable fisheries.

On this occasion, I would like to thank Food and Agriculture Organization of the United Nations, Shanghai Ocean University, and other sponsors, for financial and logistic support for this meeting. I want to particularly mention Prof. Liming Song, for his tireless work during the past year to make this meeting successful. Last but not least, I want to thank all of you for taking time out of your busy schedule to attend the meeting and to contribute your knowledge and wisdom towards healthy oceans and sustainable fisheries. Thank you.

Opening Address by: Mr. Haraldur Arnar Einarsson, Marine and Freshwater institute. ICES WGFTFB Co-Chair

Dear President of Shanghai Ocean University Mr Yudong Cheng

Good morning, Ladies and Gentlemen, Dear Colleagues,

I am pleased to welcome you to our annual meeting of the I.C.E.S.-F.A.O. Working Group on Fishing Technology and Fish Behaviour.

This group was first formed in the 70s as an I.C.E.S. group of experts from countries around the North Atlantic, focusing on the effect of mesh sizes on length composition of fish in the catch from bottom trawls.

Since then the group has developed into a working group with a wider perspective addressing all kinds of solutions in using fishing gears in a more responsible and effective way so that both the fisherman and nature could benefit from our findings.

There are currently almost 150 expert groups in the ICES network. The groups meet regularly focusing on a wide range of tasks regarding fishery and science connected to the ocean.

But we, the FTFB are an organisation which has strong international connections and joint cooperation with the FAO.

Every third year we have a special meeting where we place the FAO. in the forefront and focus on issues of global interest or on regional problems which need special attention.

Previously we have held these meeting in Rome Italy, Bangkok Thailand, and Merida Mexico, and now we are here in the wonderful city of Shanghai in China.

I know I'm not alone amongst the experts gathered here in feeling what an amazing experience it is to be here in China to discuss fishery-related issues with fishing gear as our focus.

China is a great fishing nation and we all are very curious to learn more about the Chinese fishery and share what we have learned in our own regions.

Dear Colleagues,

This meeting is attended by delegates from 23 countries, we are experts and students in fishery and the development of fishing gears from all around the world.

We know the problems the fishermen and management are dealing with. We have some solutions or concepts which might work to make the fishery more sustainable.

I´d like to share a secret with you all! This comes from my many years of working all around the world I see it as a magic solution for fisheries and the secret is that the special knowledge we have gained from our work and experience in our own fisheries might just as well work at the other side of the world.

It is therefore very important to share this knowledge and learn from each other. So, let's build a sharing network of fishing gear experts from all-around the world!

Therefore, use your time over the week wisely, don't be shy, make contacts, share information, learn from each other. This week is a unique opportunity to meet other experts with exactly the same interests as you have.

This group of experts are like a family. You can discuss with anyone here about the angle of mesh, sinking speed of line, smell of the bait, or anything regarding fishing gears. And the person will actually understand what you are talking about and share with you a similar story.

That is what a family is all about!

Dear Colleagues,

To organise a meeting like this takes a lot of planning and work. It is far more than one man's work. We have just under 50 lectures and approximately 20 posters with topics of great interest to the world fishery.

We are talking about problems regarding ghost nets, using artificial light in fishing, mitigating unwanted bycatch and reducing discards, the selectivity of fishing gear, new technologies in science, and last but not least, about the status and challenges in the Chinese fishery.

I am grateful to all the experts who have worked hard to prepare a presentation, either in the form of a lecture or poster. You are all contributing to make this meeting successful.

We can all be very grateful for a well-prepared meeting where Dr Liming Song and many others have made a great effort to bring this about. Thank you, Dr Liming Song, and please convey our great gratitude to all involved in preparing this meeting.

The sponsors of the meeting are important for us, so let´s recognise their contribution, which helped to make this meeting possible.

We are gathered here in this wonderful environment for our meeting hosted by the Shanghai Ocean University. I'm sure it will instil in us a spirit of science for our work for the meeting.

Mr Yudong Cheng, I want to thank you on behalf of ICES. for hosting our meeting here in the Shanghai Ocean University and for warm welcome to Shanghai, China.

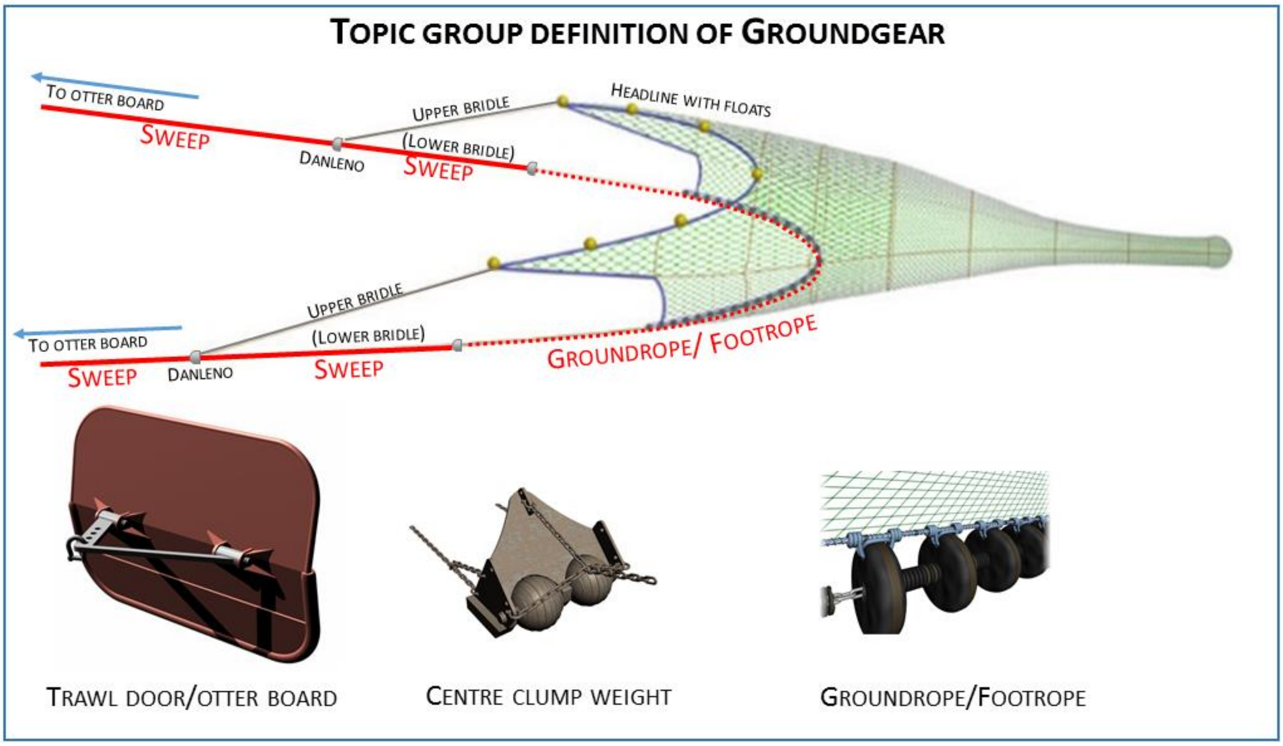
Ladies and Gentlemen, Dear Colleagues,

I wish you all fruitful and rewarding exchanges over the coming week, where you will make new friends and gain new and valuable knowledge.

Thank you.

Annex 4: Topic Group final report

Evaluation of Trawl Groundgear for Efficiency, By-catch and Impact on the Seabed (TOPIC GROUP GROUNDGEAR)



By
Roger B. Larsen[1]
Pingguo He[2]
Antonello Sala[3]

June 15, 2019

[1] UiT The Arctic University of Norway, Tromsø, Norway
[2] School for Marine Science and Technology, University of Massachusetts Dartmouth, New Bedford, USA
[3] Institute of Marine Biological Resources and Biotechnologies (CNR-IRBIM), Ancona, Italy

Content Page

Preface

The potential negative effects on benthic fauna, biodiversity and fish community as a result of dragging fishing gears along the seabed[1] has been discussed within ICES-FAO Working Group on Fish Behaviour and Fishing Technology over many decades. The 2018 edition of The State of World Fisheries and Aquaculture (FAO, 2018) again showed that various forms of bottom trawls have been important gear types for gradually increasing the global landings of fish.

Trawling for fish in rivers, lakes and inshore marine environments is a fish capture method that has existed for thousands of years old. These early trawls are various forms of beam trawls towed by sailing or man-power vessels. Modern trawling however, which uses otter boards to achieve horizontal spread was first tested in Scotland more than 130 years ago. The success of otter trawling spread very fast throughout Europe. Few years later and by the end of the 19th century fisheries biologist were worried about the impact of this modern trawling technique on the North Sea fish stocks. This was one of the reasons for the establishment of the International Council for the Exploration of the Sea in 1902[2]. With the industrialization of global fisheries from the early 1950s, the bottom otter trawling technique in particular gained importance for fuelling fish processing plants along coastlines as well as factory vessels with sufficient raw materials. Today, bottom otter trawling remains one of the most important fishing methods in the world, contributing ca. 25% of the global capture fisheries.

Despite its contribution to food security, debates on the impact of bottom trawling remains. One area of particular concern about the bottom trawling is the trawl's groundgear which contacts the seabed and modifies its physical and biological characteristics. However, there is no comprehensive review on various types of groundgear and their relative performance regarding their efficiency, seabed impact and bycatch. This topic group was formed to address these issues. Our aim was therefore to describe bottom trawling in detail, produce a precise definition of the groundgear used in bottom trawling and evaluate their performances.

In this report, we also provided some examples on groundgear types and their configurations from various parts of the world to develop a broad overview on designs used in commercial fisheries with drawings and references on how they have been used. In addition, we also provide some examples of new groundgear designs that are being tested, but have not necessarily been adopted by the industry. With inputs from topic group members and through extensive literature search, we provided a section containing short summaries (fact sheets) of selected groundgear types used or tested around the world. This section will be updated as materials and human resource become available.

This report is a result of contributions from topic group members who provided reports, factsheets and comments during the ICES-FTFB working group meetings in Nelsen (New Zealand) in 2017), Hirtshals (Denmark) in 2018), and Shanghai (China) in 2019). Their names and affiliations are listed in Table 1. We would also like to thank Dr. Jesse Brinkhof for assisting in compiling chapter 6 of this report and Ms. Nadine Jacques for language editing.

We are grateful to Seafish Assetbank for letting us use their illustrations of trawls and components of ground gears. Other photos and drawings are from the open web or produced by the authors. We will use the FAO International Standard Statistical Classification of Fishing Gear (ISSCFG) and its gear codes for the classification of trawl types[3].

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[1] Bottom trawling is performed in marine, fresh and brackish waters. Throughout the text we will mainly us the word "seabed" to cover these three options for bottom trawling.

[2] Walsh, S. J., Engas, A., Ferro, R., Fonteyne, R., & Marlen, B. v. (2002). To catch or conserve more fish: the evolution of fishing technology in fisheries science. Paper presented at the ICES Marine Science Symposia.

[3] FAO International standard statistical classification of fishing gear (ISSCFG rev. 1, 2013)

Abstract

This report is a result of input we have had from members of the topic group during three FTFB WG meetings with participation of 52 individuals (see Table 1). We have organized the report into eight main sections.

Section 1: In this section we explain the background for the topic group and give brief summaries of agendas and recommendations from the three topic group meetings. The topic group was proposed in 2016 during the FAO-ICES FTFB WG meeting in Mérida, Mexico and met three times thereafter, i.e. 2017 (Nelson, New Zealand), 2018 (Hirtshals, Denmark) and 2019 (Shanghai, China).

Section 2: There is a wide range of bottom trawl types and they are operated differently due to gear size, vessel size and design, target species, seabed conditions, etc. To avoid confusion about trawl systems we chose to make an introduction about the various bottom trawl systems, including semipelagic trawling. The topic group decided to not include beam trawls, nor dredges.

Section 3: In this section we explain the function of the groundgear in bottom trawls. We describe in more detail various components of the full groundgear as defined by the topic group, i.e. all bottom tending sections of the bottom trawl. Because designs of trawl systems and combinations of components applied in groundgears vary a lot, we can only provide a few examples of otter boards, sweep lines, groundropes and accessories.

Section 4: In this section we explain some of the important features of operating bottom trawls and how various component play an important part for catchability, seabed (bottom) impact, drag and fuel consumption. We have also added brief descriptions on gear designs for various types of bottom trawls.

Section 5: In this section we show some examples on experimental designs tested to mitigate some of the negative effects created by the groundrope. These examples are from North-America and Europe and they describe trials with bottom trawls targeting Deep-water shrimp and demersal fish.

Section 6: This section is based on factsheets showing examples of groundgears being used in Europe, North-America, Asia and Oceania. Despite most of the factsheets show techniques being used by member-nations of ICES, the variety shown in the added factsheets cover bottom trawl designs and ways of operation in many areas of the world. In Table 2 we have summed some of the main features of these examples. Most of the factsheets show groundgears being used commercially, but we also included some experimental designs and designs used in survey trawls.

Section 7: In this section we have added extracts from relevant literature dealing with various designs of groundgears. The (full) articles describe in detail the various set-up and riggings used and discuss the effects of the designs. Many of these studies were performed to enhance by-catch reduction or reduction in fuel consumption.

Section 8: In this section we have added some abstracts from recent studies dealing in depth with the impact from bottom trawling on sediments and seabed fauna. It is evident that we need more validated knowledge about the possible negative impact from bottom trawling for the sound development of a sustainable bottom trawl fishery.

Tromsø (Norway), New Bedford (USA) and Ancona (Italy), June 15 2019

1. The background for the topic group groundgear

The topic group was proposed in 2016 during the FAO-ICES FTFB WG meeting in Mérida, Mexico and met three times thereafter, i.e. 2017 (Nelson, New Zealand), 2018 (Hirtshals, Denmark) and 2019 (Shanghai, China).

1.1 The initiation of the topic group in 2016

During the WGFTFB meeting in Mérida, Mexico on 29 April 2016 (Appendix 1), it was suggested to form a new WGFTFB topic group to be convened by Roger B. Larsen (Norway), Antonello Sala (Italy) and Pingguo He (USA).

1.2 The first meeting in 2017

The topic group convened by Pingguo He met for the first time during 3-7 April 2017 in Nelson, New Zealand (Appendix 2) to discuss and summarize status, progress, knowledge of designs of groundgear and other components dragged along the seabed during bottom trawling.

The topic group planned to evaluate current and past work regarding groundgear efficiency for target and bycatch species, the effect on the seabed, and energy use. It was agreed that this topic would include past, current and future studies from a wide range of scientific fields, such as hydrodynamics, drag and gear design, strategies and technology enhancing reduced fuel consumption and reduction in gas emissions as well as selectivity of the gear and behaviour of fish, shrimp and crab.

1.3 The second meeting in 2018

The WGFTFB topic group convened by Roger B. Larsen and Pingguo He (with remote support from Antonello Sala) met during 4–8 June 2018 in Hirtshals, Denmark (Appendix 3). The group continued their work on the knowledge of designs of groundgear and other components dragged along the seabed, started during the 2017 WGFTFB meeting in Nelson, New Zealand.

After new and thorough discussion, the terms of reference were revised to:

- Creating a collection of example-factsheets of selected/commonly used types of bottom-trawl groundgear.
- Discussing and describing methods to reduce bottom contact and fuel use.
- Discussing and providing examples on the effect of trawl groundgear on the efficiency and selectivity of target and bycatch species.
- Making recommendations on future experimental and theoretical work to understand and improve the function of groundgear in bottom trawls.
- Discussing implications (trade-offs and legislation requirements) regarding the design and operation of groundgear to have a reduced effect on the seabed and greenhouse gas emissions in order to contribute to the development of best practices in bottom trawling.

It was determined that the Groundgear topic group would focus on otter trawls, pair trawls and other unspecified bottom trawls for fish and crustaceans (shrimp and

Nephrops). It would cover single, twin, triple and multi-rig trawls towed on the seabed. However, other bottom-tendering gears such as beam trawls and dredges would not be included in the topic group's work.

1.4. The third meeting in 2019

The WGFTFB topic group convened by Antonello Sala and Pingguo He (with remote support from Roger B. Larsen) met during 8–12 April 2019 in Shanghai, China (Appendix 4). The group continued their work on the knowledge of designs of groundgear and other components dragged along the seabed as discussed during the 2017 WGFTFB meeting in Nelson, New Zealand and 2018 WGFTFB meeting in Hirtshals, Denmark.

The discussion on definitions of ground gear again continued in this meeting. It was decided that if new definitions were being recommended by the topic group, they would need to be agreed upon by the full WGFTFB group. It was decided that standard definitions and parameters should be included when describing fishing gears in technical reports and papers (e.g. defining mesh size measurement used). The following summarizes findings from this meeting:

(1) Factsheets on groundgear used around the world have been assembled to provide examples of the diversity and variety of groundgears used for different species and bottom types but the latter information was insufficiently provided
(2) Bottom trawls towing over seabed with its groundgear touching the seabed, while semi-pelagic trawls may either have trawl doors or the groundgear touching the bottom, but not both.
(3) A variety of groundgears are used in trawls, ranging from combination ropes, chains, rubber cookies, discs, rockhoppers, and bobbins. The sizes of the elements are typically related to the type of seabed
(4) A variety of rigging of groundgear is used for different types of trawls, such as single bottom otter trawls, twin trawls, triple trawls, or multiple trawls
(5) Research on groundgear is often related to the bottom handling capability of the gear, catch efficiency and the selectivity on bottom-dwelling species
(6) More recently, some research has focussed on energy efficiency and seabed friendliness
(7) Historically, comparative fishing trials are carried out to compare catch (efficiency and selectivity) and robustness
(8) Optical methods are used to document fish reactions to different groundgears, and their escape under the groundgear
(9) Flume tank tests and numerical simulations are used to understand drag forces of different groundgears and their effect on trawl geometry. Numerical tools are also used to examine the flow pattern and the force of the groundgear on the sediments

It was agreed that the topic group would continue for one more year with a short session/meeting during the 2020 meeting. The topic group would report this year with conclusions, but no recommendations. During the next year, the topic group will table recommendations for discussion and approval by the topic group and the entire WGFTFB.

1.5 Topic group members

Over the last three topic group "groundgear" meetings (Nelson, Hirtshals and Shanghai), a total of 52 individuals participated in the meeting and provided valuable information and comments to the progress and direction of the work. Their names, affiliation, country and email address are listed in Table 1.

Table 1. List of participants in the ICES-FAO WG FTFB topic group groundgear (Evaluation of trawl groundgear for efficiency, bycatch and impact on the seabed)

First name	Last name	Country	Work	Email
Jure	Brčić	Croatia	University of Split	jure.brcic@unist.hr
Karsten	Breddermann	Germany	University of Rostock	karsten.breddermann@uni-rostock.de
Jesse	Brinkhof	Norway	The Arctic University of Norway UIT	jesse.brinkhof@uit.no
Josh	Cahill	Australia	Australian Fisheries Management Authority	josh.cahill@afma.gov.au
Daomei	Cao	China	Shanghai Ocean University	dmcao@shou.edu.cn
Carolyn	Collier	New Zealand	Hampidjan NZ	carolyn@hampidjan.co.nz
Isara	Chanrachkij	Thailand	Southeast Asian Fisheries Development Center	isara@seafdec.org
Cheng Zhou	Cheng Zhou	China	Ocean University of China	zhoucheng286@126.com
Ying	Dai	China	Dalian University of Foreign Languages	jftong@shou.edu.cn
Dérien L. V.	Duarte	Brazil	Centro Nacional de Pesquisa e Conservação da Biodiv. Mar. do Sudeste e Sul do Brasil	derienvernetti@yahoo.com.br
Haraldur	Einarsson	Iceland	Marine and Freshwater Research Institute	haraldur.arnar.einarsson@hafogvatn.is
Yunus Emre	Fakıoğlu	Turkey	Fisheries Faculty, Mersin	emrefakioglu@gmail.com
Ema	Fatima	India	WWF-India	efatima@wwfindia.net
Rikke Petri	Frandsen	Denmark	Technical University of Denmak, DTU Aqua	rif@aqua.dtu.dk
Paul	Freeman	New Zealand	Hampidjan NZ	paul@hampidjan.co.nz
Geir	Gudmundsson	Iceland	Optitog ehf/Innovation Center Iceland	geir@nmi.is
Ulrik Jes	Hansen	Denmark	CATch-Fish	ujh@catch-fish.net
Bradley	Harris	USA	Alaska Pacicific University, Ancorage	bharris@alaskapacific.edu
Pingguo	He	USA	University of Massachusetts Dartmouth	pingguo.he@fao.org
Darcie E.	Hunt	Australia	IMAS	darcieh@utas.edu.au
Gebremeskel	Kebede	Canada	Memorial University, Newfoundland	Gebre.Kebede@mi.mun.ca
Steve	Kennelly	Australia	IC Independent Consulting	steve.kennelly@icic.net.au
Hyun Young	Kim	South-Korea	National Institute of Fisheries Research	sys9318@hotmail.com
Brianna	King	USA	Alaska Pacific University	bking@alaskapacific.edu
Ludvig Ahm	Krag	Denmark	DTU Aqua, Danish Technical University	lak@aqua.dtu.dk
Roger B.	Larsen	Norway	The Arctic University of Norway UIT	roger.larsen@uit.no
Chun Woo	Lee	South-Korea	Pukyong National University	cwlee@pknu.ac.kr
George	Legge	Canada	Memorial University, Newfoundland	george.legge@mi.mun.ca
Uwe	Lichtenstein	Germany	University of Rostock	uwe.lichtenstein@uni-rostock.de
Mark J.	Lomeli	USA	Pacific States Marine Fisheries Commission	mlomeli@psmfc.org
Matthew	McHugh	Ireland	Board Iascaigh Mhara	matthew.mchugh@bim.ie
Valentina	Melli	Denmark	DTU Aqua, Danish Technical University	vmel@aqua.dtu.dk
Pieke	Molenaar	Netherlands	Wageningen Marine Research	pieke.molenaar@wur.nl
Hans	Nilsson	Sweden	Swedish University of Agricultural Sciences	Hans.Nilsson@slu.se
Aileen	Nimick	USA	Alaska Pacific University	animick@alaskapacific.edu
Thomas	Noack	Denmark	Technical University of Denmak, DTU Aqua	thno@aqua.dtu.dk
Mathias	Paschen	Germany	University of Rostock	mathias.paschen@uni-rostock.de
Daniel A.	Ramirez	Mexico	Instituto Nacional De Pesca	daniel.aguilar@inapesca.gob.mx
Craig S.	Rose	USA	FishNext Research	fishnextresearch@gmail.com
Antonello	Sala	Italy	Italian National Research Council	a.sala@ismar.cnr.it
Stephan	Schacht	Germany	University of Rostock	stephan.schacht@uni-rostock.de
Tomas A.	Schmidt	Canada	Memorial University of Newfoundland	tomas.schmidt@mi.mun.ca
Suresh	Sethi	USA	Cornell University, Ithaca (New York)	suresh.sethi@cornell.edu
T. Scott	Smeltz	USA	Cornell University, Ithaca (New York)	ts428@cornell.edu
Liming	Song	China	Shanghai Ocean University	lmsong@shou.edu.cn
Petri	Suuronen	Italy/Finland	FAO Fisheries and Aquaculture	p.suuronen@outlook.com
Hao	Tang	China	Shanghai Ocean University	htang@shou.edu.cn
Paul	Winger	Canada	Memorial University of Newfoundland	paul.winger@mi.mun.ca

Liuxiong	Xu	China	Shanghai Ocean University	lxxu@shou.edu.cn
Noëlle	Yochum	USA	NOAA Alaska Fisheries Science Center	noelle.yochum@noaa.gov
Yu	Zhang	China	Chinese academy of fishery sciences	zhang-yu@126.com

2. Bottom trawl systems (TB, ISSCFG code: 03.19)

We will use the 2013 revision of FAO International Standard Statistical Classification of Fishing Gear (ISSCFG) and gear codes as the reference to describe various types of trawl systems commonly used in the global fisheries for this report. Trawl nets are usually built with an entrance consisting of wings, a headline and a groundrope, and followed by a cone-shaped body (belly), ending in a codend to retain the catch. Trawls can be operated as midwater (pelagic) trawls, bottom trawls or semi-pelagic trawls. Trawls are typically used in marine fisheries, but the technique can also be used in lake and river fisheries.

This report mainly focuses on bottom trawls which are towed over the seabed. Bottom trawls are mainly used to harvest various species of finfish and crustaceans in oceans and freshwater lakes. On a global scale, the landings from bottom trawls are very important by volume (ca. 25%), and bottom trawling is dominant gear in most large-scale Nephrops, shrimp and prawn fisheries.

Bottom trawls are divided into three categories: single boat bottom otter trawls, twin bottom trawls, multiple bottom trawls, bottom pair trawls and beam trawls. Beam trawls are not included in this report.

2.1 Single boat otter trawl system (OTB, ISSCFG code: 03.12).

The vast majority of global bottom trawling is done as a single boat operation. This trawl system is characterised by the use of two otter boards (trawl doors) to open and spread the net horizontally (Fig. 2.1).

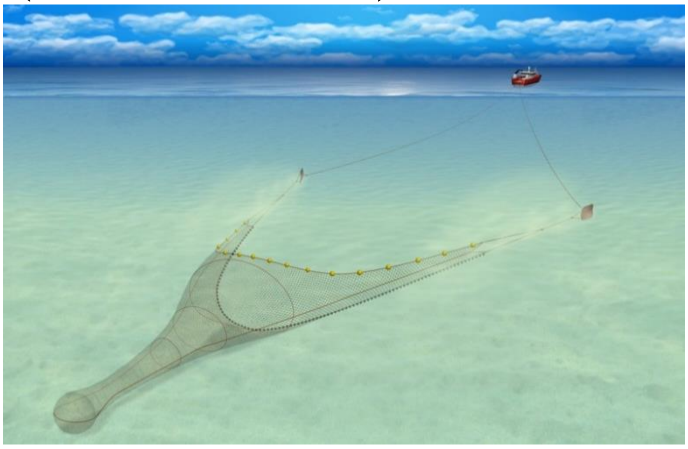

Fig 2.1: A visualisation of the most common otter trawl operation (Seafish Assetbank).

2.2. Twin trawl system (OTB, ISSCFG code: 03.1.2).

This trawl system is characterised by two trawl nets dragged side by side by the use of one set of otter boards (trawl doors) to open and spread the net horizontally (Fig. 2.2). A centre weight in the form of a (hydrodynamic) sledge, a depressor, a roller clump, a chain clump, or similar are used to give the trawl system correct balance and bottom contact of the groundgear.

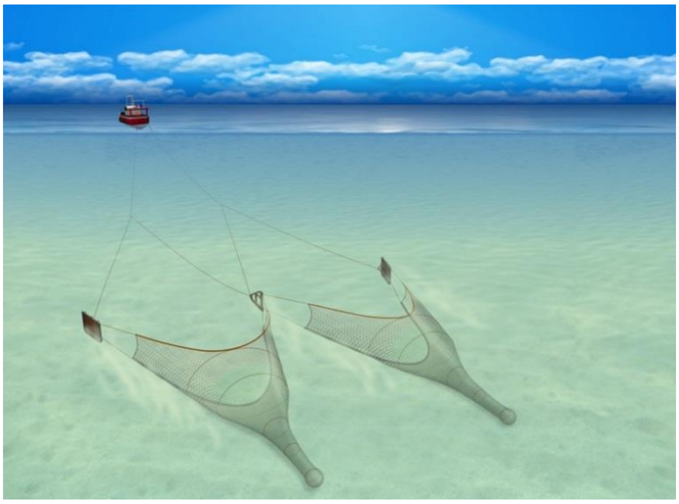

Fig 2.2.: A visualisation of an otter board twin trawl operation (Seafish Assetbank).

2.3. Multiple bottom otter trawl system (OTP, ISSCFG code: 03.14).

The multiple bottom otter trawl system is commonly used in many tropical prawn fisheries and in some Deep-water shrimp fisheries. This trawl system is characterized by more than two trawls towed side by side by a single boat. As many as eight trawls are towed in this trawl system.

2.3.1 Triple trawl system

This trawl system is characterised by three trawl nets dragged side by side with one set of otter boards (trawl doors) to open and spread the net horizontally (Fig. 2.3.1). Two centre weights in the form of (hydrodynamic) sledges, depressors, roller clumps, chain clumps, or similar, are used to give the trawl system correct balance and bottom contact with the groundgear.

In some large-scale operations (e.g. in Europe), a third or fourth towing warp is used, and the trawl system is equipped with a double set of centre weights.

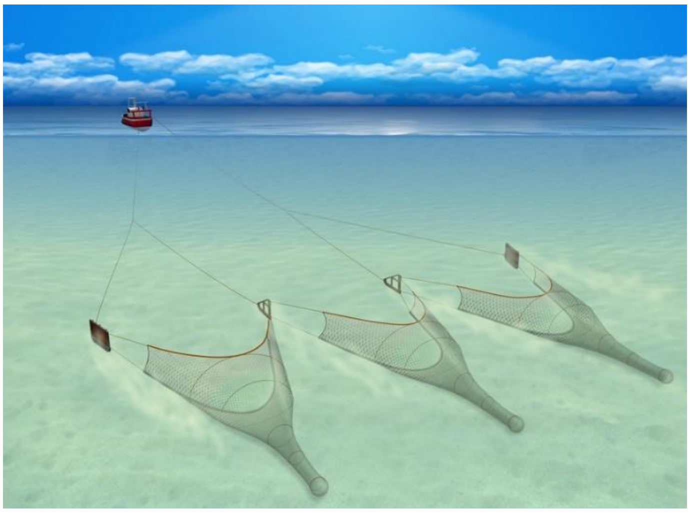

Fig 2.3.1: A visualisation of a triple bottom trawl in operation (Seafish Assetbank).

2.3.2. Quad trawl system

This trawl system is characterised by four trawl nets dragged side by side by the use of one set of otter boards (trawl doors) to open and spread the net horizontally (Fig. 2.3.2). One to three centre weights in the form of depressors, roller clumps, chain clumps or similar are used to give the trawl system correct balance and bottom contact with the groundgear.

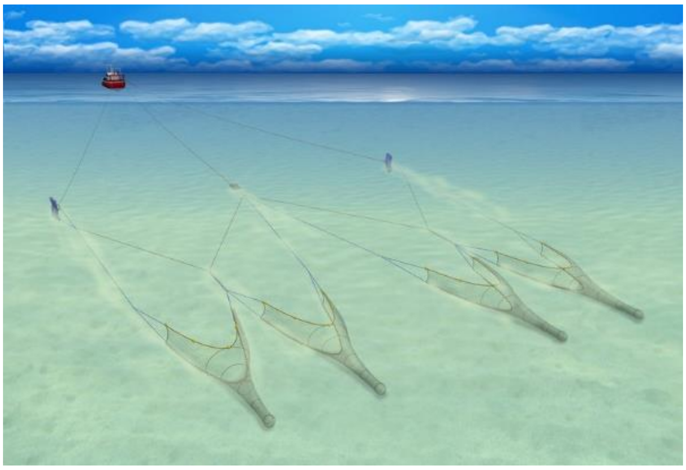

Fig 2.3.2: A visualisation of a quad bottom trawl in operation (Seafish Assetbank).

2.4. Bottom pair trawl system (PTB, ISSCFG code: 03.15).

This trawl system is operated by two vessels towing one bottom trawl without otter boards (Fig. 2.4). The cone-shaped belly can be made from two or four (and sometimes more) panels, and otherwise designed as bottom trawls used for single boat otter trawling. To ensure bottom contact of the sweep-lines ahead of the net, weights such as chain clumps are used.

Fig 2.4: A visualisation of a bottom pair trawl operation (Seafish Assetbank).

2.5. **Semipelagic trawl system** (TSP, ISSCFG code: 03.3).

The semipelagic trawl system is an ordinary bottom trawl or pelagic style trawl towed along the bottom with only parts of the trawl system having bottom contact for harvesting demersal fish. In some systems the otter boards are lifted several meters off the seabed with only the groundrope and sweeps (or part of the sweeps) touching the bottom (Fig. 2.5). There are also examples in semipelagic trawl systems where only the otter boards have bottom contact but not the trawl groundgear during the fishing operation.

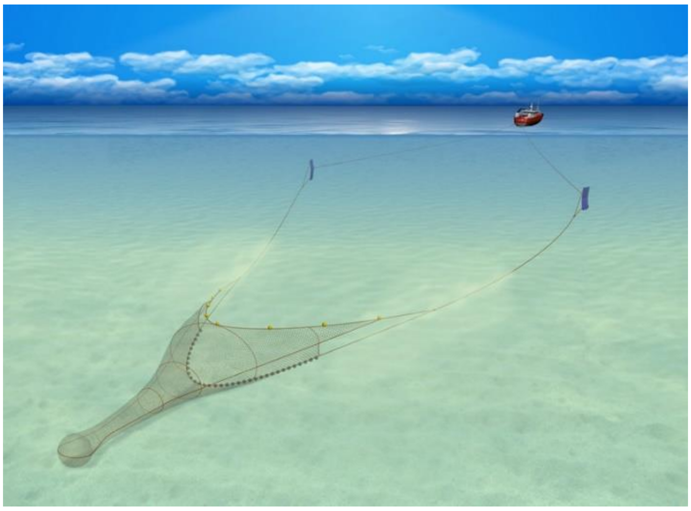

Fig 2.5: A visualisation of a semi-pelagic trawl in operation (Seafish Assetbank).

2.6. Components of a bottom trawl system

Bottom trawls are highly flexible systems (except for beam trawls), consisting of otter boards, sweep lines, upper, middle and lower bridles, a footrope (gear), the fishing line and headline (floatline), and a number of net sections (wings, top and bottom panel in the belly, extension piece in front of the codend), ending in a retaining compartment termed the ‘codend’. All parts of the trawl system play an important role in speading the net, and in herding the fish into the codend.

The balance of weights, tensions and drag between each part of a trawl system can each have important implications for a successful catch, fuel consumption, and wear and tear, etc. Any change in the rigging of components, weights or likewise will affect the entire system and the performance of the trawl system. It is obvious that the designs of bottom trawl systems vary from area to area and by the scale of the operation.

Bottom trawls are used for catching a wide range of species (finfish, crustaceans, molluscs, etc) and are operated on various types of seabed (mud, clay, sand, gravel, stone), thus their design and means of operation must be adapted from area to area. However, the same basic components can describe the bottom trawl system as illustrated in Fig. 2.6. Note that point 10 in Fig. 2.6 is called “footrope and ground gear” and differs from the definition of groundgear agreed upon by the topic group which will be further elaborated in Section 3.

The idea of using otter boards for horizontal spread of the trawl originated in Ireland around year 1870. Modern trawling with use of otter boards for horizontal spread was first time tested successfully in Scotland almost 15 years later[4]. The success of otter trawling spread very fast in Europe and became a common fishing method with the industrialization of the global fisheries since the early 1950s.

Otter bottom trawling is one of the most important fishing methods in the world contributing to ca. 25% of the global capture fisheries. This type of gear is operated with small and large vessels and the gear is used in inshore and deep-sea fisheries for the capture of a large variety of species. While most of the large-scale bottom trawl fisheries are operated from large vessels with many crew members, we also find examples on efficient trawl fisheries operated by one or two crew members with smaller vessels. The trawlers are powered by inboard engines, outboard engines and/or by wind.

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[4] Gabriel, O., Lange, K., Dahm, E. and Wendt, T. (eds), 2005. Von Brandt’s Fish Catching Methods of the World (4th ed). Blackwell publishing Ltd, Oxford, UK.

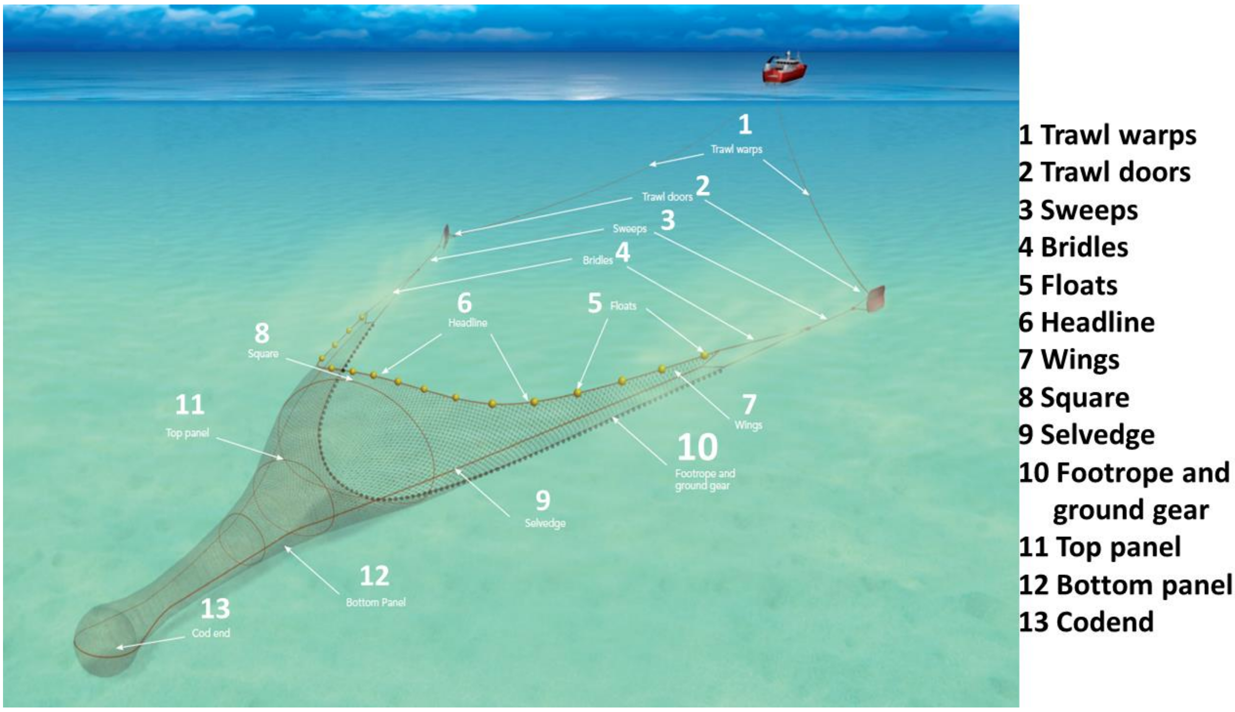

Fig 2.6: The basic components of an otter board bottom trawl system (Seafish Assetbank).

3. Definition and rigging of groundgear and commonly used names

The topic group defined “groundgear” as the bottom-tending components between wingends (Fig. 3). The topic group on “groundgear” will focus on both groundrope (i.e. also called footrope, which is the bottom tendering part between the wing ends) and the bottom-contacting cables connecting the trawl and the doors, including, but not limited to:

- Trawl doors (when dragged along the seabed).
- Sweeps and lower bridles and other cables attached.
- Centre weights (incl. depressors) and sleds of twin, triple or multi-rigs.
- Ground rope (footrope), fishing line and tickler chains.

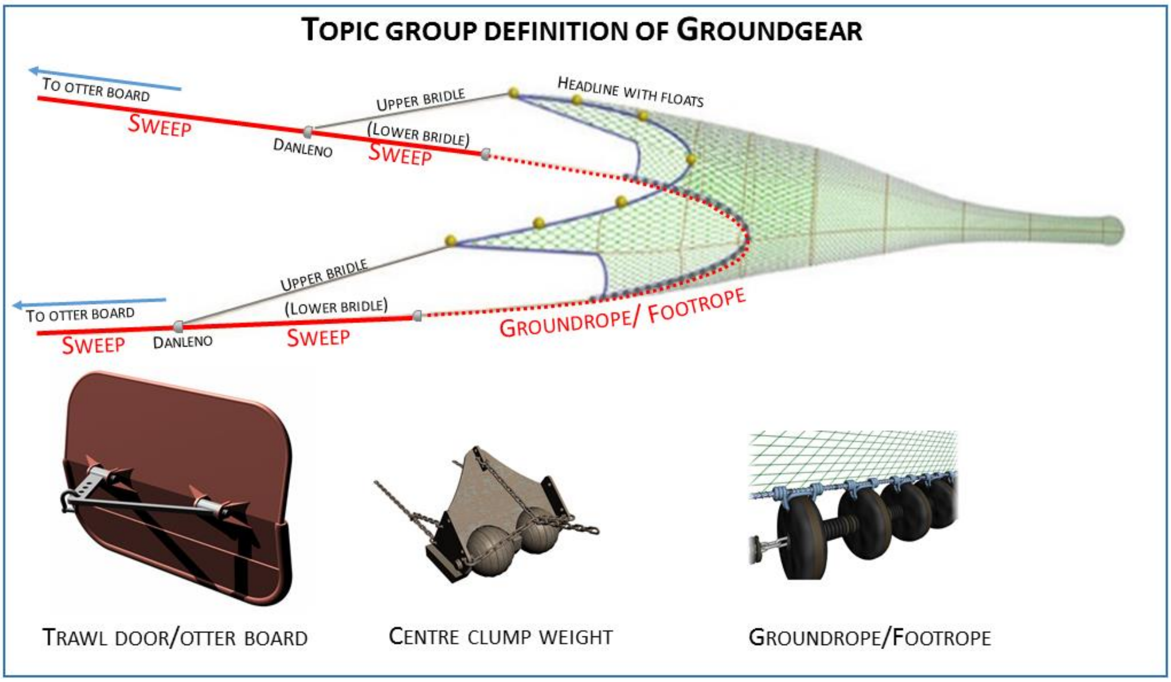

Fig :. The definition of the groundgear (in red), including trawl doors and centre clump weights, defined by the topic group during the FTFB WG meeting in Hirtshals, June 2018 (Seafish Assetbank).

3.1. Function of the groundgear:

The groundgear including otter boards, sweeps and lower bridles, has important functions in bottom trawls, i.e. to herd fish into the trawl mouth, maintain bottom contact and to protect the wings and lower belly from damage (Fig. 3.1.2). The groundrope is usually attached by toggles (rope, steel chain, quick links, carabiner hooks, etc.) to the fishing line of the trawl. The design, materials, sizes and weights of groundgears vary with vessel and gear size, type of fishery and seabed condition (mud, clay, sand, gravel, stones, smooth, rough).

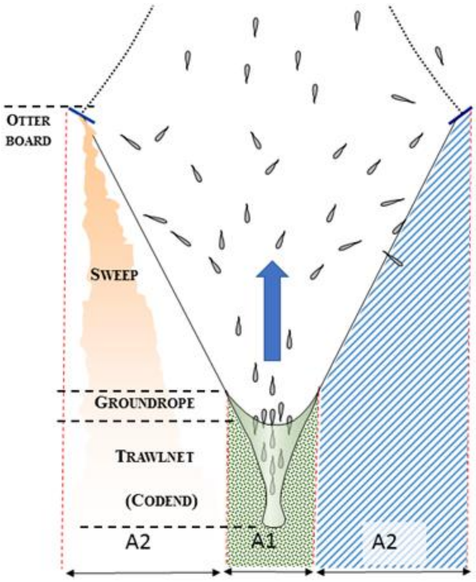

Fig 3.1.: A drawing of how fish are being herded into the path of a bottom trawl, where A1 represents the width covered by the groundrope and A2 represents the widths covered by the sweeps

3.2. Otter boards

Otter boards (trawl doors) are used in all trawl types, except for the pair trawl systems and beam trawls. Their main function is to maintain the correct horizontal spread of the trawl net (wings) during the trawling operation (towing). Their size, weight, shape, construction (aspect-ratio), angle of attack, etc. will vary with trawl size, seabed conditions, towing speed and target species. The size and layout of the boat being used especially affects the trawl door size and weight.

Otter boards for bottom trawling are usually built from steel, but in many of the global prawn/shrimp trawl fisheries the original simple design of the flat wooden doors with a steel framing and shoe are still being used. Due to their (flat) shape, they are known to create relatively high drag causing significant mud-clouds trails on a soft seabed. Most modern otter boards for finfish and deep-water shrimp fisheries are designed to optimize hydrodynamic forces and bottom contact for stable performance during the entire trawling operation. For instance, in large-scale triple-trawl configurations for shrimp fisheries, the otter boards may reach a size of 12 m^2 and weights of more than 5 tons each door. The drawings in Fig. 3.2 below show some examples of otter board designs currently used in bottom trawling. Only limited discussions will be made on otter boards in this report as this was the focus of a previous WGFTFB topic group "Tech-

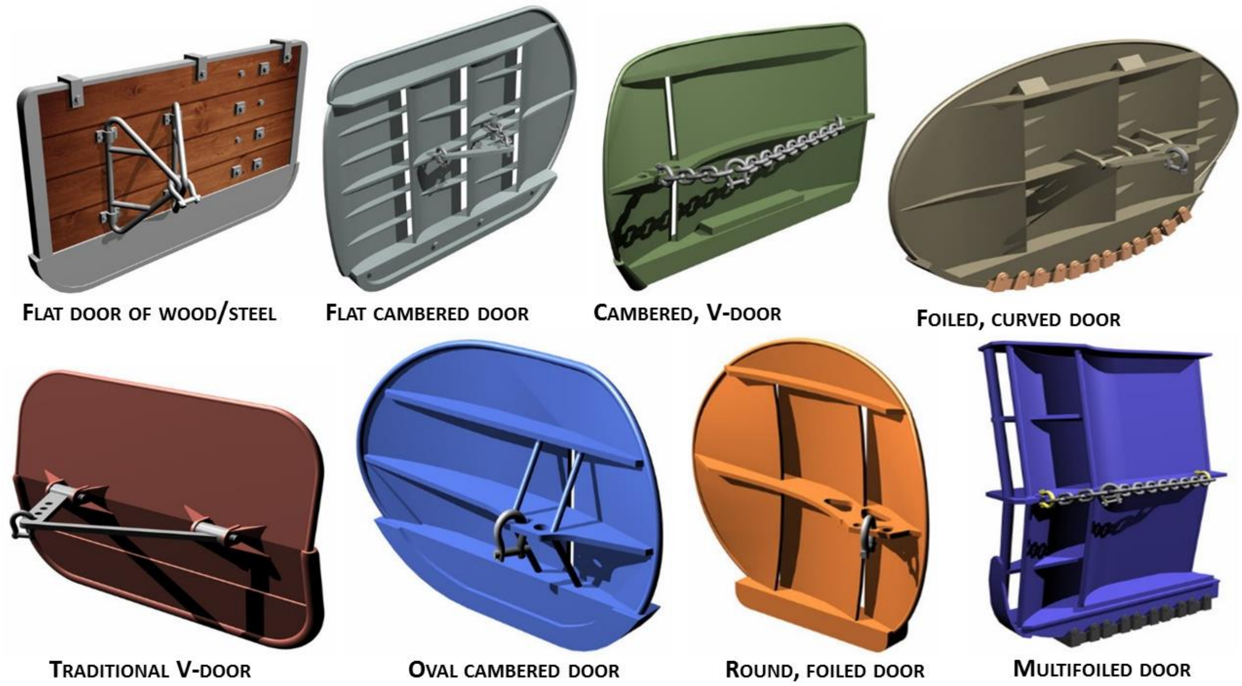

Fig 3.2: A selection of otter boards commonly used during bottom trawling (Seafish Assetbank).

3.3. Sweep lines

Sweeps connect between the otter boards and the trawl net (wings). In a pair trawl operation (see Fig. 2.7) there are usually chain-weights in the junction between the warps (towing wires/towing ropes) and the sweep lines, to enable this cable to touch the seabed in front of the net. The function of the sweep lines is to herd fish into the path of the trawl net thereby increasing the catch area during the tow. Usually the full length of the sweep is touching the seabed, but on rough, hard bottom or in cases to avoid such contact, bobbins or discs are added along the length of the sweep. To achieve the correct geometry in the trawl mouth and necessary force along the groundrope to secure bottom contact, there must be a balance between the aft part of the sweeps (sometimes termed the lower bridles) and the upper bridles. This balance is achieved by varying the length of the upper bridle (or the lower bridle) and the number of floats and the total lifting force along the headline.

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[5] ICES WGFTFB REPORT 2016.

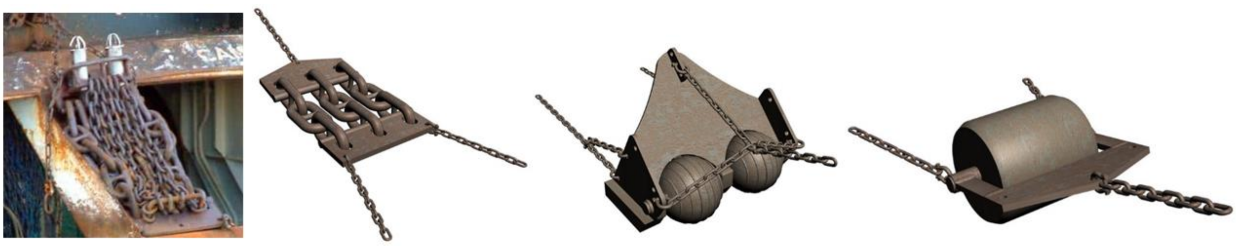
Steel is the dominant material being used for sweep lines, but combination ropes with a steel rope core covered by synthetic twines such as polypropylene are also used. “Cookie” sweeps, made of steel cable encased with 5 to 8 mm diameter discs are quite common in groundfish trawls in north-eastern USA. In some small-scale trawling operations, ropes made from natural fibres are used (Fig. 3.3). The correct choice of material, diameter and breaking strength is dependent on the scale of the operation, the amount of tension during fishing and haulback and the degree of abrasion expected on the seabed (i.e. the lifetime of the sweeps). Lengths and the diameter of sweep lines will therefore vary. For instance, in a tropical prawn trawl operation with multiple trawls, the sweep lines (and upper bridles) are seldom more than 3 m long and up to 12 mm in diameter. In some of the large-scale finfish operations, the sweeps (including the lower bridles) may be up to 200 m long and the steel wire may be up to 32 mm in diameter. The aft part of the sweep (i.e. the lower bridle) which connects to the footrope and fishing line of the net, are in some cases made from heavy chains to increase the contact of the groundrope with the seabed.

STEEL WIRE ROPES | COMBINATION ROPE WITH STEEL CORE | ROPES FROM NATURAL FIBRES | STEEL CHAINS

Fig 3.3: A selection of sweep materials commonly used during bottom trawling (images are copied from leaflets from various manufactures).

3.4. Centre weights

The purpose of the centre weights is to maintain correct seabed contact in twin or multiple trawl rigs. These weights are usually built as simple chain clumps or more sophisticated chain clumps, depressors or roller clumps. The size and weights vary from less than 100 kgs up to 10 tons and the width of the pressure points may be more than 1 m. Various clump weights are illustrated in Fig. 3.4.



CHAIN CLUMP WEIGHT | CHAIN CLUMP WEIGHT | DEPRESSOR CLUMP WEIGHT | ROLLER CLUMP WEIGHT

Fig 3.4: A selection of clump weights commonly used during bottom trawling (Seafish Assetbank).

3.5. Groundrope and its other names

The groundrope is the part of the groundgear directly attached to the fishing line of the trawlnet between the lower wingends (Fig 3.5). The groundrope is also termed the 'footrope'. Commonly used names of groundrope often reflect their design and where they are used, but the names of similar groundropes may vary from area to area. Typical names used are 'grasrope footrope', 'cookie/rubber leg footrope', 'bobbin groundgear' and 'rockhopper groundgear'.

The main functions of the groundrope is to protect the wings and lower panels of the trawlnet from damages during the operation and to enhance the catch efficiency of the trawl. The design of groundropes varies from very simple attachments by ropes of natural fibres to light chains, steel, rubber and plastic bobbins and discs.

In some areas, and especially on a rough and uneven seabed, the groundrope is made heavy to maintain optimized seabed contact. Such rigging may be undesirable when taking drag and fuel consumption into account. It is however complicated to find a design that balances proper protection of the net, maintaining fish capture efficiency with good and constant bottom contact, and fuel consumption. In some bottom trawl fisheries, the groundrope (and the sweeps) has been modified to reduce physical pressure and seabed impact by reducing the weights and/or the number of contact points of the whole groundgear with the seabed.

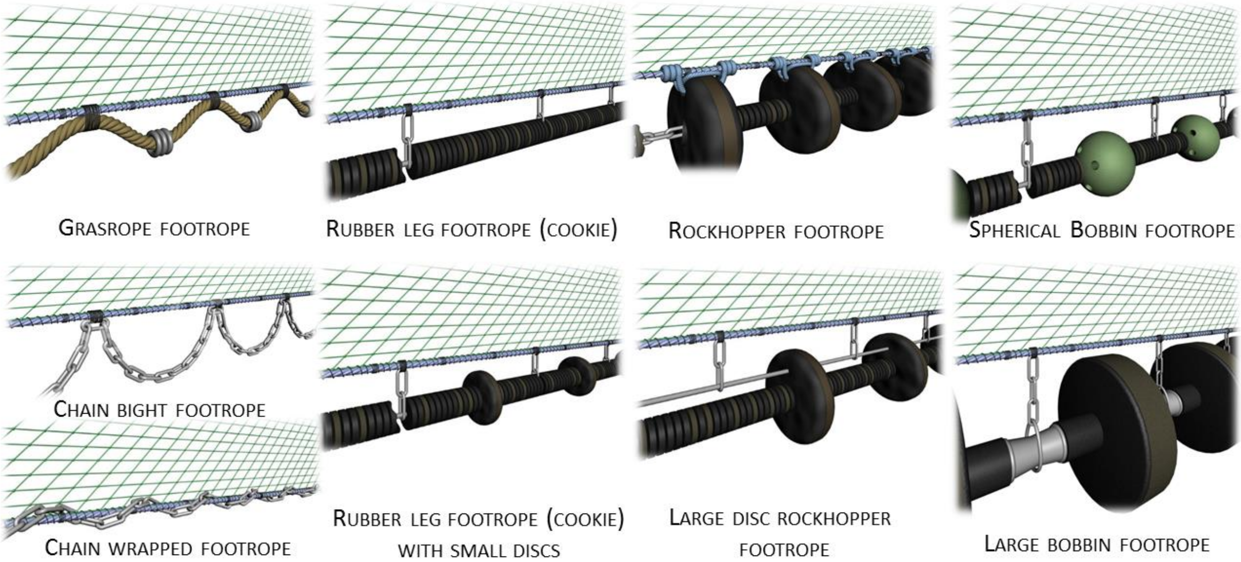


Fig 3.5: Examples of commonly used groundropes/footropes used for bottom trawling (Seafish Assetbank).

Groundropes can be made from strong netting panels ("skirt")[6] weighted in the lower part by combination rope and chain (or a mix of these). The groundrope skirt is primarily used in demersal seining. Another version tested was a "brush gear"[7] (street brush/street broom), but its practical application is unknown. Both systems close escape gaps for fish

[6] Gjøsund, S. et al. 2014. MultiSEPT - Development of multirig semi-pelagic trawling. http://hdl.handle.net/11250/2458173

[7] Pol, M. & Carr, H.A. 2000. Overview of gear developments and trends in the New England commercial fishing industry. Northeastern naturalist, 7(4): 329-336.

along the fishing line and they are much lighter than for instance rockhopper gears (see Section 7 for more details).

3.5.1: Components of the groundrope

Groundropes are built from cables of natural fibre ropes, steel wire ropes or chains, and sometimes a combination of them (Fig. 3.6). Along flat and smooth ground, the fishing line of the trawl can fly very close to the seabed. In that case a grasrope or a simple chain or cookie can be added to the fishing line for the protection of the net. On rougher grounds it is common to add bobbins or discs along the cable (steel wire rope or chain) spaced by fillers to protect the net from damage during towing. In designs where a butterfly rig with an upper (and middle) and lower bridle is used, the sweep line is connected to a Danleno bobbin or a triangle (or delta plate). Spherical and flat bobbins are able to roll along the bottom providing some slack along the centre steel wire/chain. This is contrary to rubber discs that are fixed to the fishing line by toggles directly through holes in the outer part of the disc or toggles fixed to a steel wire through similar types of holes. In groundropes with bobbins and rockhopper type discs, fillers with and without toggles are added to get the correct spacing.

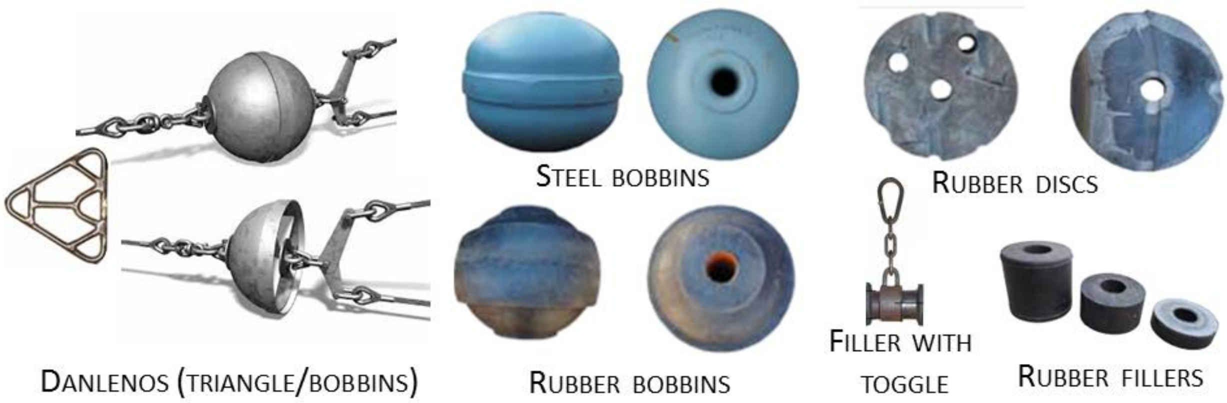


Fig 3.6: Examples of commonly used components on footropes/groundropes/gears for bottom trawling (images are copied from Galbraith and Rice 2004[8] and leaflets from various manufactures).

3.5.2: Weight of groundrope components

Steel ropes (wire), combination ropes, steel chains, rubber and steel fillers, rubber discs, rubber bobbins and steel bobbins have reduced weight in seawater compared to those in air. In seawater, solid steel components weigh approximately 87% of their weight in air, but air-filled steel bobbins weigh much less in seawater, i.e. approximately 15-35% of their weight in air. Large steel bobbins have more buoyancy than smaller ones. Rubber and plastic components like fillers and discs will weigh approximately 15% and rubber bobbins 20% of their weight in air.

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[8] Galbraith, R.D. and Rice, A. (after Strange, E.S.), 2004. An Introduction to Commercial Fishing Gear and Methods Used in Scotland. Scottish Fisheries Information Pamphlet No. 25 2004. ISSN: 0309 9105

Because these components of the groundrope have significant buoyancy, it is extremely important for the bottom trawl complex that the lift and weights are balanced to maintain the bottom contact. If the net is made from twines with density less than 1 (i.e. based on polyethylene or polypropylene) and the trawl has many hard-plastic air-filled floats, more weights are needed to counter the lift forces.

Section of a small shrimp trawl with looped chain groundrope and lead weights on the fishing line (RB Larsen 2019)

4. Operation of the bottom trawl

Many factors affect the groundgear contact with the seabed during the operation of bottom trawls. The sizes and weights of the various components contribute to the groundgear contact, but the impact on catch efficiency, energy consumption and unwanted effects on the seabed will also depend on several other factors during trawling. The area covered by the trawl system, i.e. the distance between the otter boards, is decided by the distance between the otter boards. In many small-scale trawl fisheries the distance between the trawl doors and wing ends can be less than 10 m, while large-scale otter trawling and pair-trawl systems may have door spread and distance between sweeps (at the start point) 200 m or more.

The balance between lift and weight is carefully adjusted in all bottom trawl systems, and the challenge of finding the correct balance is more complex with larger trawl systems operated at greater depths.

Hydrodynamic forces created by the towing speed and the currents along the ground will affect how forces from various parts of the groundgear act on the seabed. Increasing the towing speed and reducing the warp length will reduce the pressure of otter boards along the ground, but there is also a risk of creating lifted-off sweep and unstable wingspread and intermittent contact of the trawl system with the seabed. In most bottom trawl fisheries such effects will reduce the catch efficiency of the system.

4.1. Spread of the groundgear

The horizontal spread of bottom trawls varies among trawl systems (single boat trawling, pair trawling or beam trawling) and a number of parameters will affect this spread during the operation. The horizontal spreading force of otter boards is a result of the combination of the hydrodynamic lift and the frictional shear with the ground. Increasing the towing speed and lift, will reduce the friction shear and the acting downwards force (weight) of an otter board. While increasing the towing speed results in higher spreading forces of otter boards, the hydrodynamic drag of the trawl net and other components will also increase. In a trawl system for the capturing finfish, the angle of attack of long sweeps will be crucial for effective herding of fish (Fig. 4.1). If it becomes overly spread, some fish may escape out of the herding zone above or under the sweeps (A2).

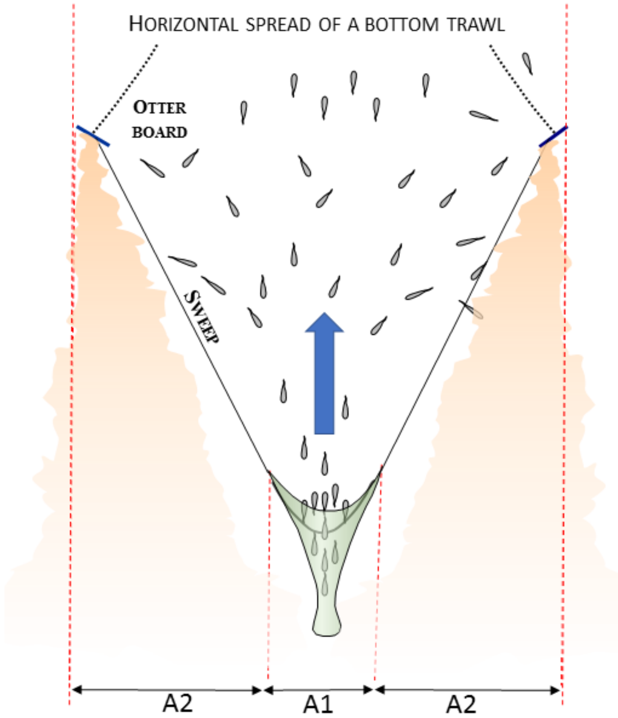

Fig. 4.1. The horizontal spread of a bottom otter trawl and an indication of herding zones (A2) and capture zone (A1).

For a single-boat trawl operation it is expected that particles stirred up by the otter boards (due to turbulence) along soft and sandy seabed, often called sand-clouds, will increase the herding efficiency and guide more fish into the capture zone (A1).

For shrimp trawls especially and some trawl fisheries of large aggregates of schooling fish (for example sprat, sand eel, Norway pout, etc.), the herding efficiency is believed to be minimal. The length of the sweeps, however, has to match the length of the bridles, which is important for the vertical opening of the trawl during the tow. In typical high-opening trawls for shrimps and some demersal fish, the sweep length has some effect on the spread of wings of the net, i.e. the longer the sweeps and bridles, the larger horizontal spread of the trawl.

4.2.Towing speed

The towing speed (i.e. speed over the ground) during bottom trawling varies with the type of fishery, target species and size of gears being used. Depending on species-specific behaviour, the towing speed in most finfish trawling usually varies between 2 and 5 knots (1-2.6 m/s). In many crustacean fisheries, the towing speed may range from 0.5 to 3.5 knots. For most finfish trawls the herding efficiency of the sweeps is crucial for optimized capture. Too high towing speed may result in fish passing under or over the sweeps (see area A1 in Fig. 4.1).

With the exception of beam trawls, variations in the towing speed will affect the geometry of a trawl system. An increasing towing speed will provide higher hydrodynamic forces to spread the door, resulting in increases in the horizontal spread of the wings, and decreases in the vertical opening of the trawl mouth.

All components of the groundgear (including the otter boards), will be affected by hydrodynamic forces and drag during the towing operation. The total drag of a mobile fishing gear will increase with towing speed. Given that engine power is not the restriction[9], the chosen towing speed is often a trade-off between how much area over ground the gear covers per unit time and the energy consumption. Simplified we assume that the hydrodynamic drag (D) of an object is a result of (projected) area (A) and velocity (v) and that towing drag increases exponentially by the square of the towing speed ($D = A * v^2$).

A general rule therefore is that increasing the towing speed leads to an exponential increase in the fuel consumption.

In Fig. 4.2 the forces on an otter board are illustrated and the calculation of the spread and the drag forces are explained.

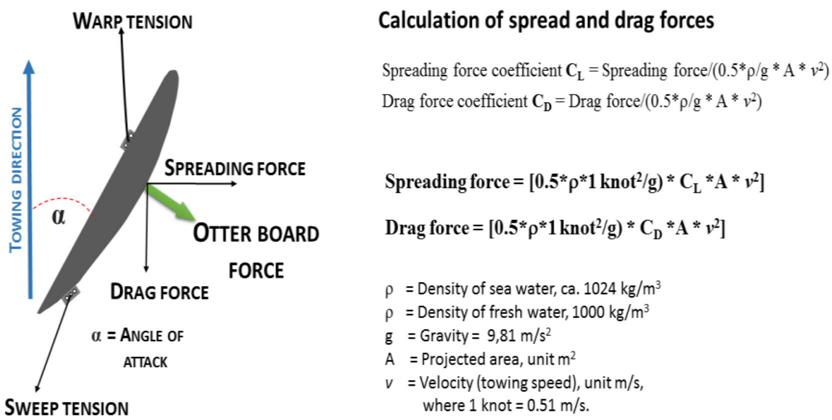

Fig. 4.2. Illustration of forces acting on an otter board.

Due to the area and weight, the otter boards are usually the components that contribute the most to the total drag of the groundgear. The shape of an otter board (see Section 3.2. and Fig 3.2) is important for its drag and spread (or lift) capacities. A curved otter board has a higher lift at a given angle compared to a traditional flat otter board and adding more foils increases the spreading forces. Some doors are slotted in order to reduce drag forces. The advantage of curved (and slotted) otter boards is that they can be operated at a lower angle of attack than flat doors, which means that a smaller and lighter door is needed compared to a flat door to achieve a given sweep and wing spread of the trawl system.

The spread (lift) forces created by the otter board may reduce its friction shear, pressure and footprint on the ground and for instance a rounded otter board will have a smaller contact point along its shoe than a rectangular otter board. The weight of a trawl door in water and its acting force on the bottom depends on its weight in the air and the material it is made from, in addition to towing speed and lift (spreading) forces. In seawater, the weight of a steel door is reduced by ca. 13%, while wood, aluminium and other materials are much lighter in water.

[9] Wind-powered (sail) trawlers are used in some areas.

Because the otter boards are so important for the performance of the bottom trawl system regarding ground contact, herding and capture efficiency, fuel consumption and the effect on bottom fauna, trawl door producers work continuously to improve their designs. The goal is thus to find the angle of attack (Fig. 4.2) which achieves the optimum relation between spread (C_L) and drag forces (C_D). Operating instructions are based on accurate measurements at sea and in laboratories such as in for instance flume tanks, where the C_L/C_D relationship (i.e. the efficiency) is measured when varying towing speeds and angles of attack are used. A flat rectangular otter board has its maximum efficiency at a. angle of attack of 40-45^o, while curved multi-foil otter boards would be more efficient at an angle of attack of 30-35^o.

4.3. Design of trawl

Bottom trawls are designed to maximize the capture of certain target species. Most of the trawl nets being used are typically two-panel designs, where the upper and lower net section is more or less similar in length, width, mesh size and twine thickness. In high-opening bottom trawls it is common to insert side-panels and an extra length of upper bridle to achieve the necessary vertical opening at the mouth (Fig. 4.3).

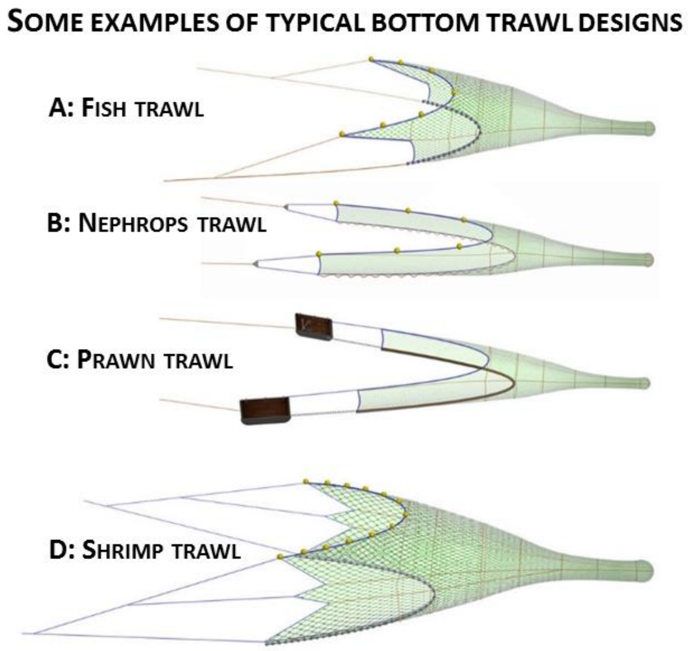

Fig. 4.3. Examples of typical bottom trawl designs. All designs shown here are two-panel and low opening constructions, except the design D (shrimp trawl), which has inserted side panels to achieve larger vertical opening (Seafish Assetbank).

4.3.1. Finfish trawls

In finfish trawls with long sweeps and large distances between the otter boards, the capture of fish depends on the behaviour of the fish and their swimming capacity to achieve optimal herding efficiency. If the target fish are typically bottom dwelling fish, a trawl net with a relatively small wingend spread and a low headline opening in addition to adequate bottom contact is enough to guide fish into the aft part of the net, i.e. the codend.

The proportion of drag from various components of the gear depends of a number of variables. As a general rule we assume that the net-sections of a fish trawl contributes to ca. 55%, the otter boards to ca. 25% and the rest of the groundgear to ca. 15% of the total drag. During a fishing operation, more than 90% of the fuel consumption can be required to tow the trawl along the seabed[10]. If twin or multiple trawl systems are used with one set of otter boards, the groundgear may contribute less to the total drag. In a pair trawl

[10] Sea Fish Industry Authority, IFREMER and DIFTA, 1993. Otterboard performance and behavior. Project nr. TE 1 124.

operation (with no otter boards or clump weights at the start of the sweeps, the groundgear will represent much less of the total drag.

4.3.2. Nephrops trawls

These low opening trawls are built from smaller mesh than those used in finfish trawls and as a rule are two-panel constructions (see Fig 4.3.B). The fishery uses a single or twin-trawl operation with otter boards and relatively long sweeps (40-70 m). As the sweep herding efficiency is low on crustaceans in general, the benefit of long sweeps is for the herding of bycatch species (finfish). The wing length and footrope design of Nephrops trawls is critical for the efficiency of this gear because Nephrops stay close to the seabed or they inhabit burrows in the sand or mud. The fishing line of a Nephrops trawl must be kept close to the seabed and groundropes typically used are of the type grasrope or chain bight/wrapped chain (Fig 3.5). The towing speed in this fishery is usually around 2.5 knots and the main component of the drag from the groundgear is related to the otter boards (together with the centre weight clump when twin trawls are used). In some European Nephrops trawls the groundgear is estimated to contribute ca. 40% of the total drag.

4.3.3. Prawn trawls

Prawn trawls are designed as low opening two-panel nets with a groundrope ensuring that the fishing line is continuously close to the seabed. The groundrope is preferably made as a grasrope or chain bight/wrapped chain and most of the prawn trawl operations are done along smooth mud/sand seabed. The trawl net is built as a low-opening construction and the mesh size is small for effective retention of prawns.

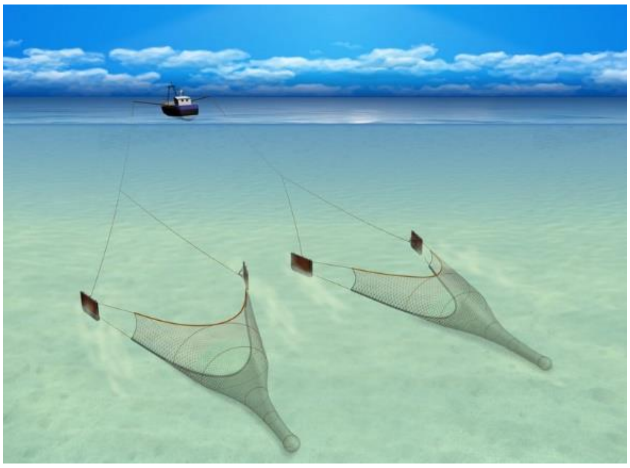

Fig. 4.3.1. An example of a twin trawl rigging operated as single trawl system from each boom (Seafish Assetbank).

The prawn trawl may be operated as a single trawl with relatively long sweeps and bridles connected to the otter boards, but short bridles and sweeps (3-4 m long) are more commonly used (see Fig 4.3.C and Fig. 4.3.1).

Typically, for prawn trawls with short bridles and sweeps, the otter boards applied are of the original (wood) flat, rectangular designs. It is assumed that the short distance to the wings and the relatively high drag with resulting turbulence behind these doors creates a favourable herding efficiency on prawns. In most of the global tropical prawn trawl fisheries vessels tow a double trawl, triple trawl or quad trawl rigs. Furthermore, most of these vessels use outrigger booms and in quad riggings a set of trawls including a pair of otter boards are towed from each boom (see Fig. 4.3.1.). The towing speed may vary with the size of the vessel and engine power, but normally these trawls are towed at 3-5 knots.

4.3.4. Otter trawls for shrimp and industrial fish

In bottom trawls used for deepwater shrimps and small fish (industrial fish) the preferred design is high opening trawls operated with long upper bridles (Fig. 4.3.D). These trawls may have a vertical opening (height from bottom to the centre of the headline) in the order of 10-20 m. Because these trawls typically use small-mesh netting, they usually have a large twine area, therefore a relatively high proportion of the total drag (60-75%) and fuel consumption is derived from the trawl-net. A small increase in towing speed will decrease the headline height significantly, and vice versa by reducing the towing speed.

In general, if the mesh size is reduced or the twine diameter is increased in a sheet of netting, drag increases. The relation between twine diameter (d) and mesh size (l_m) is termed solidity (S) and can be expressed as $S = 4*d/l_m$. The angle of attack of sections like wings and square, tapering ratio of a funnel and Reynolds number, will also affect the drag of the trawl net.

The groundgear of these trawls covers most of the types shown in Fig. 3.5, but good bottom contact is usually preferred for efficient capture. Along seabed of mud and sand, the fishing line can be towed closed to the seabed. For the protection of the underwings and underpanels (belly sections), a grasrope, a chain, a cookie or a rubber leg groundrope is sufficient. Along harder and rougher ground, the fishing line is lifted adequately off the seabed and the footropes used are mainly of the bobbin and rockhopper type.

In some of the deepwater shrimp fisheries in the northern hemisphere, it is common to tow large otter trawl systems as a twin or a triple trawl configuration. The weight and drag of otter boards, one or two centre clump weights and two or three bobbin/rockhopper footropes is significant. However, because a large part of these trawl nets are built from small meshes, as a result, most of the drag and fuel consumption comes from the trawl net.

Bottom otter trawls designed for the capture of industrial fish such as sand eels, Norway pout, sprat and other similar species, are usually equipped with much lighter groundropes than large shrimp trawls. In some cases, it is necessary to tow the trawl net close to the seabed with minimum bottom contact, i.e. to skim the seabed. There are also examples of successful semi-pelagic operation of such trawl systems. Most of the drag (60-80%) of such trawls comes from the twine area due to small meshes used throughout the trawl net.

4.4. Bridle and sweep configuration

Fig. 4.4 shows some examples of bridle and sweep riggings commonly used in bottom trawling.

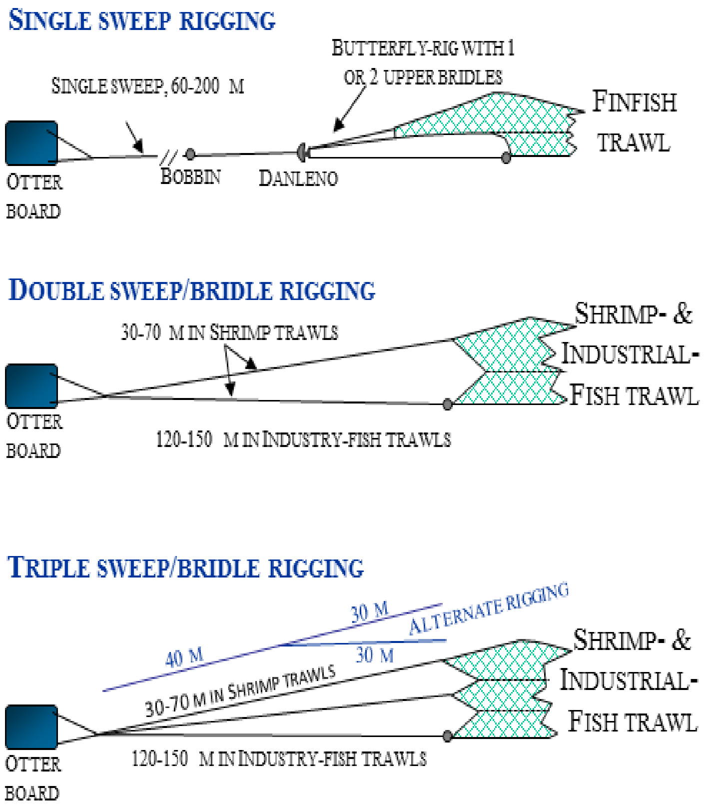

Fig. 4.4. Alternate bridle and sweep configurations.

4.4.1. Otter trawl system

It is common to add a bobbin in the centre of long single sweeps to reduce abrasion and avoiding snagging. For high opening trawls used for catching finfish species or shrimps that can be found several metres off the bottom, the rig may be modified to include a middle bridle, with or without a Danleno, or twin or triple bridle rigs may directly connect to the otter boards and the net. Sweeps and bridles are made from combination ropes or steel ropes (wire).

When fishing along hard ground, parts or all of the wire/rope in contact with the bottom may be replaced by abrasion-resistant alloy chain (also used to increase weight and bottom contact).

4.4.2. Twin trawl system

The twin (and single otter) trawl system is used for targeting various species of finfish, flatfish, shrimps, Nephrops, etc. By dragging two nets side by side the effective swept area is increased as illustrated in Fig. 4.4.1. In many fisheries, twin trawl systems are known to be a more efficient way of capturing fish compared to single otter trawl systems.

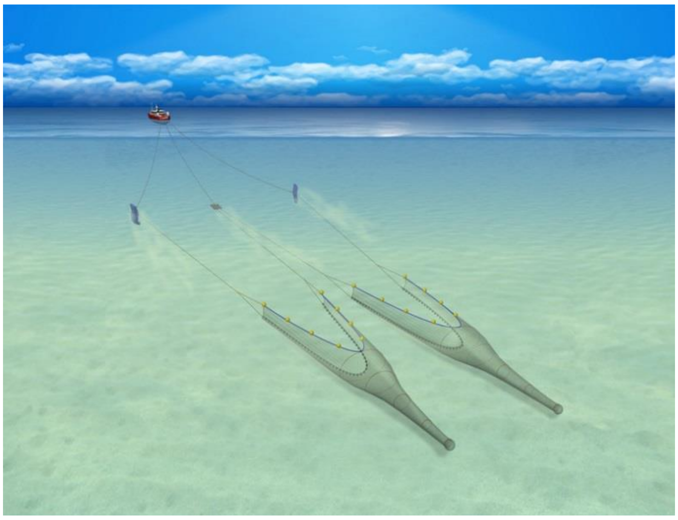

Fig. 4.4.1. A twin trawl system operated with three towing wraps and one centre clump weight (Seafish Assetbank)

One set of otter boards provide the horizontal spreading forces. Floats along the headline and the weight of the groundrope create the vertical forces and the opening height of the trawl mouth.

The twin trawl rig can be operated with a third towing warp to the centre clump (Fig. 4.4.1).

An alternate rig for a twin trawl system is to use two towing warps and a crowfoot system attached to each door-pair. In this setup the centre clump (or plate) weight to the inner parts of the crowfeet. This system is usually towed from the towing blocks at the stern of the vessel. (Fig. 4.4.2).

Another possibility is to tow the two trawls from outrigger booms (Fig. 4.4.3). In this setup each trawl is connected to one pair of otter boards by a separate crowfoot. The trawl system is usually towed from the outrigger booms.

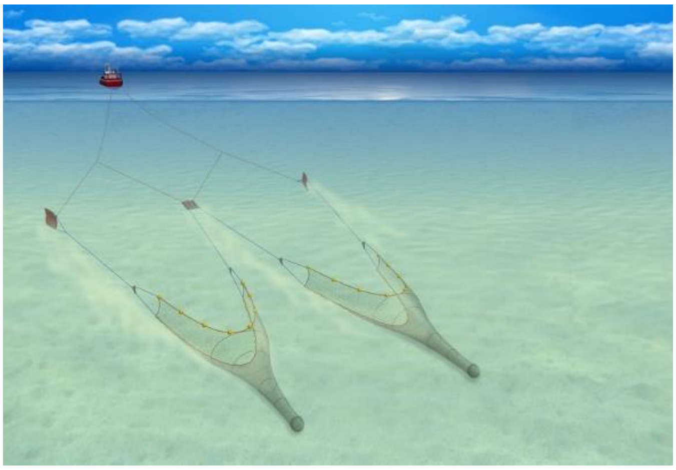

Fig. 4.4.2. A twin trawl system operated with towing from towing blocks at the stern (Seafish Assetbank)

A typical design of a large prawn trawler with outrigger booms for operating twin or quad trawl systems (RB Larsen 1992).

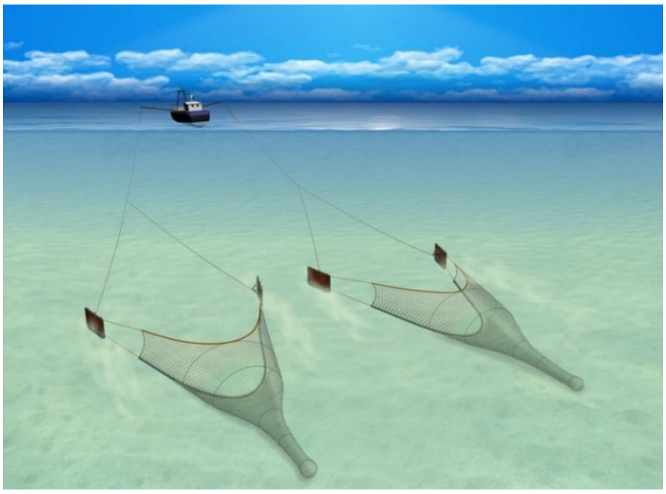

Fig. 4.4.3. A twin trawl system operated with towing from outrigger booms (Seafish Assetbank)

4.4.3. Pair trawl system

The trawl net and its construction in a pair trawl system (Fig. 4.2.3) is similar to bottom trawls operated with otter boards. The clear difference is in the overall size and weight of the net as well as the length of the footrope and sweeps.

The trawl is usually equipped with a rockhopper footrope. To achieve proper ground contact, heavy steel wires and/or chains are used as sweeps (i.e. between the warp and Danleno). In some cases, chain clump weights are added at the junction between the warps and sweeps.

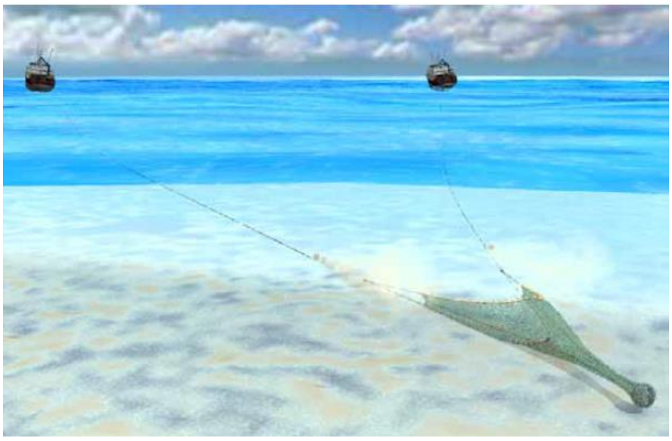

Fig. 4.4.4. Operating a pair trawl system (Seafish Assetbank).

5. Experimental designs for reduced seabed impact

The world total fish capture was 90.1 million (metric) tons in 2016, of which marine catch contributed to 79.3 million tons. Landings from marine capture peaked at 86.1 million tons in 1995. Since then, the average annual marine capture levelled out at around 80 million tons, while inland capture has grown slightly over the last few years to 11.6 million tons in 2016[11].

Bottom trawling has been an important method for the capture fisheries. For the efficient and large-scale capture of many finfish species, shrimps and prawns there exist few or no alternative fishing methods. It is therefore evident that many of the large-scale fisheries around the world will rely on effective bottom trawling in the foreseeable future.

However, this fishing method is currently debated for many reasons, i.e. uncertainties about the effects on bottom fauna, bycatch and selectivity issues, and high fuel consumption. As bottom trawling is one of the most energy demanding fishing methods, high fuel consumption contributes a relatively large proportion to greenhouse gas emissions. Global attention and concerns surrounding climate change, the lack of sustainable and responsible fishing practices and the rapid depletion of biodiversity will certainly influence how future bottom trawls are designed and operated.

The UN Sustainable Development Goal 14 *Life below water* points at several areas where improvements are needed. One of them is the removal of "destructive fishing methods"[12], a wording very often associated with bottom trawling. Bottom trawling is restricted or banned in many areas of the world. There are different reasons for excluding bottom trawling from the list of acceptable fishing methods such as protecting marine habitats (marine protected areas), avoiding gear collisions with passive fishing gears (gillnets, traps, lines, and similar), the disturbance of artisanal fisheries or avoiding bycatch, etc.

Bottom trawling that targets various species of shrimp has become one of the most controversial trawl fisheries globally. The total annual landings from the shrimp trawls is close to 3.5 million tons. They are therefore economically important fisheries, but they are widely disputed and a source to many conflicts, particularly in tropical regions. One of the reasons for this is the high discard rate in tropical shrimp and prawn trawling, i.e. this is estimated to represent 27% (or 1.8 million tons) of total discards of global marine fisheries[13]. In Chapter 8 we have added the abstracts of some reports and papers evaluating the possible effects on the seabed and the marine life as a result of bottom trawling.

5.1 Experimental designs

New groundgear designs have been developed in order to reduce bottom contact and the impact of various parts of the groundgear on the seabed and benthic fauna. Fishermen

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[11] The State of World Fisheries and Aquaculture 2018. FAO, Rome 2018. ISBN 978-92-5-130562-1.

[12] UN sustainable goal 14 Life below water (i.e. sub-goal 14.4).

[13] Kelleher, K., 2005. Discards in the world's marine fisheries. An update. *FAO Fisheries Technical Paper. No. 470.* Rome, FAO. 2005. 131p.

may be especially interested in improving the efficiency of fishing operations, both in the catch as well as the fuel. However, acknowledgement by fishermen for the harmful effects of bottom trawling on marine habitats has grown in particular. Examples of new methods to reduce the impacts of bottom trawling include:

- The use of high-aspect otter boards towed at a lower angle of attack in stead of using ordinary bottom trawl doors
- The replacement of ordinary otter boards by designs used in pelagic trawling (i.e. towing the otter boards off the ground)
- Lifting part of the sweep lines off the seabed
- Reducing contact points of the sweeps (by bobbins or discs)
- The use of groundropes (gears) that have a reduced weight and/or fewer contact points

The side effect of reducing bottom contact during trawling may include reduced catch efficiency for target species. In practical terms, the benefit of using new designs in bottom trawling will therefore be a trade-off between conservation and economic returns of the fishery. The physical and biological effects of bottom trawling on various benthic habitats and fish communities has been studied and the most severe of these effects has been found to be on hard-ground habitats dominated by large sessile fauna[14].

A study on Norwegian fisheries showed that bottom trawling is by far the most energy demanding fishing technique. The study also revealed that low fuel prices do not motivate the development of energy efficient technology in the long run[15]. Nevertheless, innovative designs of groundgear components are tested in many global fisheries. The justification is often driven by worries raised from the discussions on negative footprints from bottom trawling, questions over sustainable and responsible fishing practices and fuel consumption. For example, the use of sweeplines with few contact points and otter boards off the seabed was tested and implemented successful in Alaska (USA, Pacific North) many years ago (see Section 7; literature review). Similar techniques have been tested in Nordic large-scale bottom twin-trawl fisheries, but with less success.

The following sections discusses five different designs tested in bottom trawl fisheries to illustrate how groundropes can be modified to reduce seabed impact and their drag (and fuel consumption), to improve catch efficiency on target species, and to reduce bycatch on non-target species:

5.1.1: Aligned footgear (Canada, North-west Atlantic)
5.1.2: Drop chain footgear (Canada, North-west Atlantic)
5.1.3: Semicircular spreading gear (Norway, Northeast Atlantic)
5.1.4: Wheeled Groundgear (USA, Northwest Atlantic)
5.1.5: Shearing plate gear (Norway, Northeast Atlantic)

[14] Valdemarsen, J.W., Jørgensen, T. and Engås, A. 2007. Options to mitigate bottom habitat impact of dragged gears. FAO Technical paper 506. ISBN 978-92-5-105876-3.

[15] Schau, E., Ellingsen, H., Endal, A. and Aa. Aanondsen, S., 2009. Energy consumption in Norwegian fisheries. Journal of Cleaner Production. 17. 325-334. 10.1016/j.jclepro.2008.08.015.

5.1.1: Aligned footgear

The aligned footgear has been developed by the Fisheries and Marine Institute, Newfoundland, Canada. An aligned footgear is an innovative trawl technology that reduces seabed contact while targeting northern shrimp (*Pandalus borealis*) off the east coast of Canada. The innovative footgear, referred to as the "aligned footgear" (Fig. 5.1.1), was evaluated in a flume tank to estimate contact area with the seabed and then tested at sea for engineering performance and catch efficiency. Results demonstrated that the aligned footgear trawl produced a substantial reduction (i.e., 61%) in the predicted contact area with the seabed compared with the identical trawl equipped with traditional rockhopper footgear.

A total of 20 paired tows (n = 40 tows) were subsequently conducted at sea to evaluate fishing performance. The aligned footgear trawl caught significantly more northern shrimp (+23%), capelin (*Mallotus villosus*) (+71%), and Greenland halibut (*Reinhardtius hippoglossoides*) (+99%)
compared with the traditional rockhopper bottom trawl.

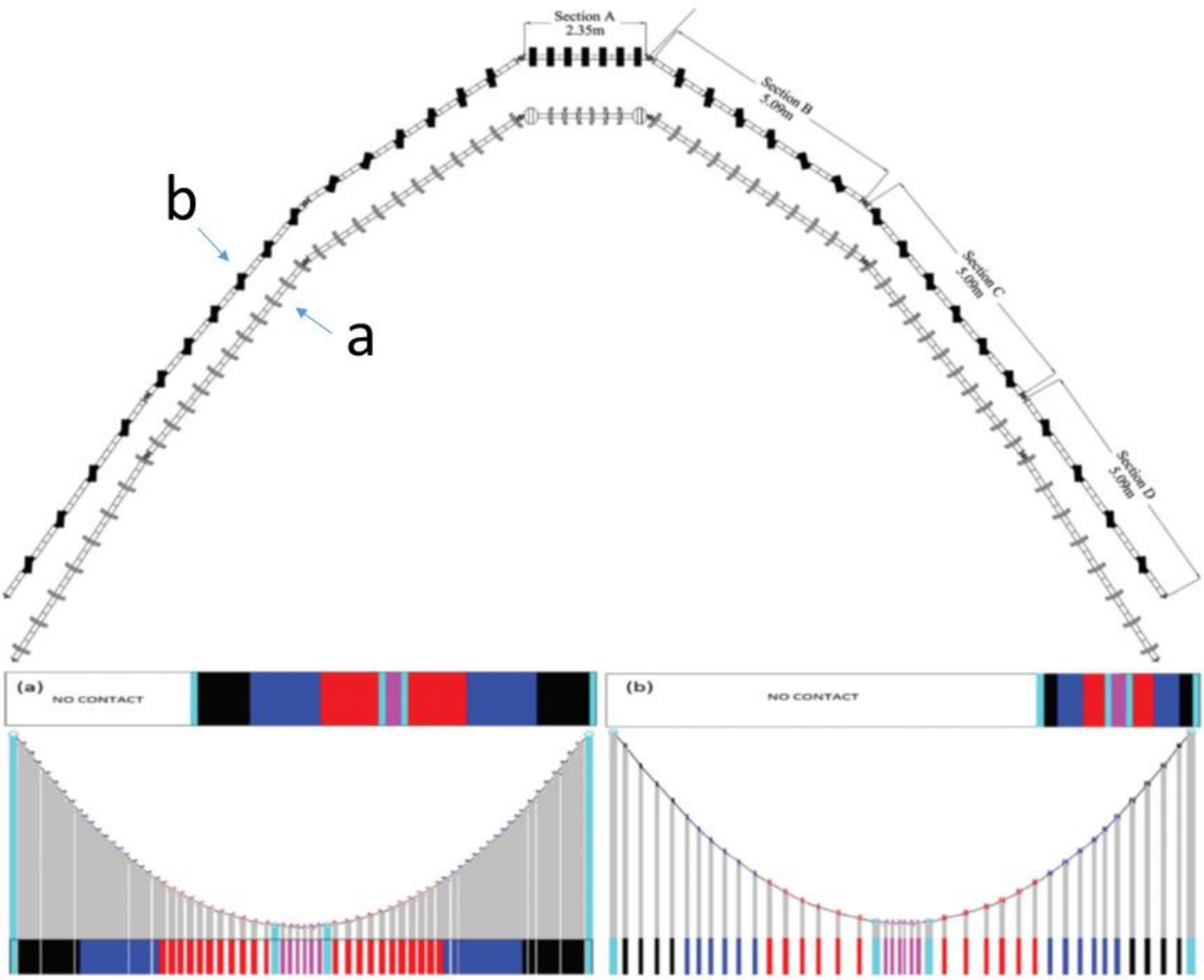


Fig. 5.1.1.: The design of a conventional rockhopper gear (a) and the new aligned footgear and (b). The lower part of the figure show differences in seabed contact between a and b.

Reference: P.D. Winger, J.G. Munden, T.X. Nguyen, S.M. Grant, and G. Legge, 2018. Can. J. Fish. Aquat. Sci. 75: 201–210 (2018). dx.doi.org/10.1139/cjfas-2016-0461.

5.1.2: Drop chain footgear

This study compared the effectiveness of a reduced seabed impact footgear (Fig. 5.1.2.c) versus a traditional rockhopper footgear (Fig 5.1.2.b) on identical bottom trawls targeting northern shrimp (*Pandalus borealis*) in Newfoundland and Labrador, Canada. The experimental trawl used in this study was designed to be low seabed impact through the reduction of contact area of the footgear by replacing traditional heavy rockhopper footgear with only a few drop chains which hare lightly in contact with the seabed (i.e., drop chain footgear).

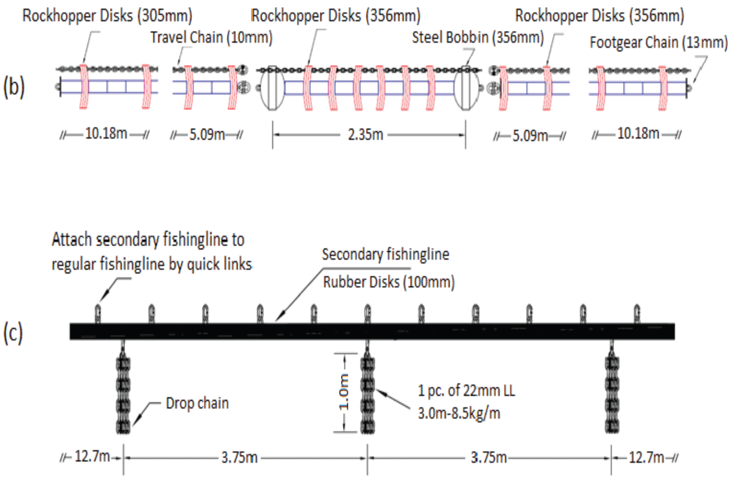


Fig. 5.1.2a. Upper part (b) show a rockhopper gear and lower part (c) a exprimental design with dropchains.

Two variations of the experimental drop chain footgear (9-drop chain and 5-drop chain) were designed and evaluated in a flume tank to estimate contact area with the seabed. The setup was then briefly tested at sea for engineering performance and catch efficiency. Results from the flume tank tests were encouraging, demonstrating that the traditional and experimental trawls were similar in performance, but the experimental drop chain footgears produced substantial reductions in the predicted contact area with the seabed (Fig 5.1.2.b).

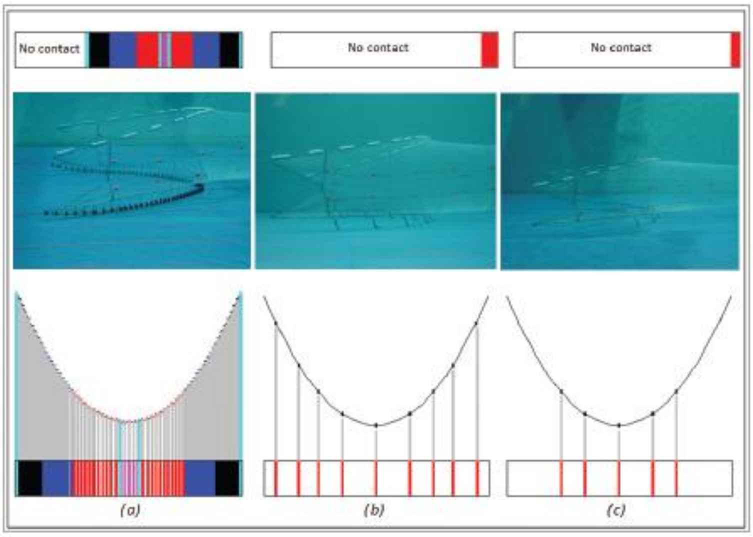


Fig. 5.1.2.b. Schematic of the estimated percentage of seabed contact for a traditional rockhopper footgear (a), experimental 9-drop chain footgear (b), and experimental 5-drop chain footgear (c).

Comparative commercial fishing trials were then subsequently made with a total of five pairs of tows (10 tows) for the 9-drop chain and six pairs of tows (12 tows) for the 5-drop chain. Though only briefly tested at sea, the results revealed that the drop chain footgears were promising in both engineering and catch performance. Underwater video observations demonstrated that the drop chain trawling system, with greatly reduced bottom contact on the seabed, could help reduce potential disturbance to the marine ecosystems, in particular minimizing encounters with snow crab (*Chionoecetes opilio*).

Reference: Nguyen, T. X.; Walsh, P.; Winger, P. D.; Favaro, B.; Legge, G.; Moret, K.; Grant, S. 2015. Assessin the effectiveness of drop chain footgear at reducing bottom contact in the Newfoundland and Labrador shrimp trawl fishery. The Journal of Ocean Technology, VOL. 10, NO. 2, 2015. Pp. 61-77.

5.1.3: Semicircular spreading gear

The semicircular spreading gear (SCSG) was developed by SINTEF in Norway. Results from full- scale tests showed that the spreading (distance between wingends) was approximately 7 % higher with the SCSG than with the ordinary rockhopper gear of same length and for the same door spreading. The SCSG had good bottom contact and passed bottom obstacles (e.g. stones) easily. The size distribution of fish caught with the SCSG was similar compared to that caught with the rockhopper gear, but apparently more cod (over 65 cm) and more haddock (of all sizes) was caught by the SCSG. However, the number of hauls performed with the SCSG and with the rockhopper was too small to draw a clear conclusion on catch efficiency.

The SCSG is easy to rig and handle on deck and it does not require precise adjustments. It has few control points and low weight compared to for example rockhopper groundgears. The results indicate that its fishing efficiency is comparable or better than the rockhopper gear for the given bottom conditions (Fig. 3.10).

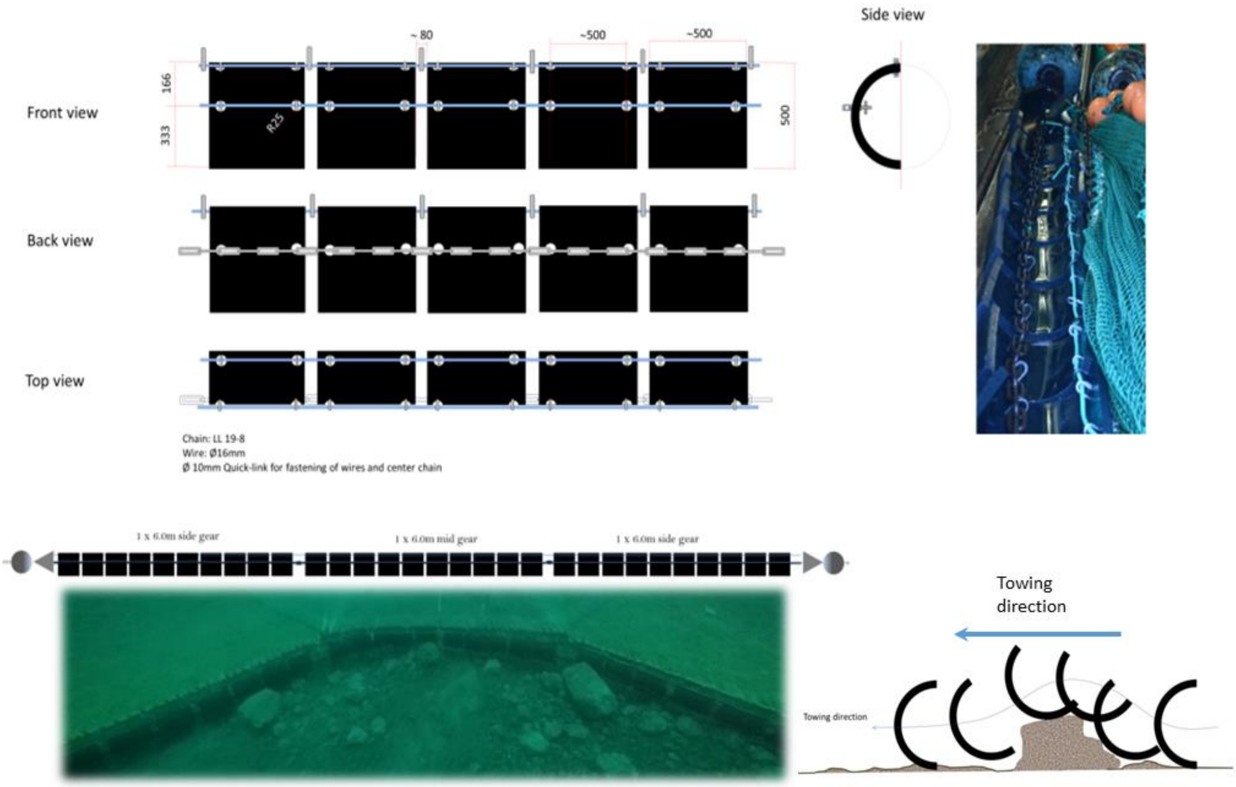
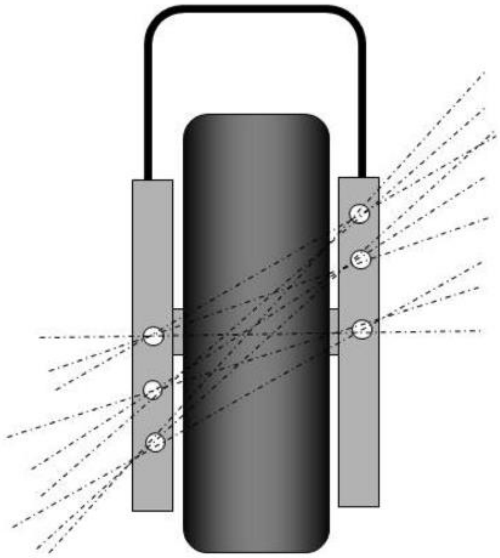


Fig 5.1.3: The construction of the semicircular spreading gear and performance during operation.

Reference: Grimaldo, E., Sistiaga, M., Larsen, R. B., Tatone, I., Olsen, F., 2013. MultiSEPT - Full cale tests of the semicircular spreading gear (SCSG). SINTEF Report No. A24271, 23 pp. 63.

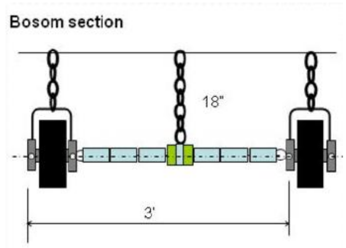
5.1.4: Wheeled groundgear

The debate and discussion on the effect of bottom trawling on the seabed has become a hot issue in the last ten years. Regardless of the severity of the impact and the effect of bottom trawling, means to reduce seabed effect is viewed positively by all concerned about the seabed and those making a living from the sea. Often, gear with less seabed effect also reduces drag and fuel costs.

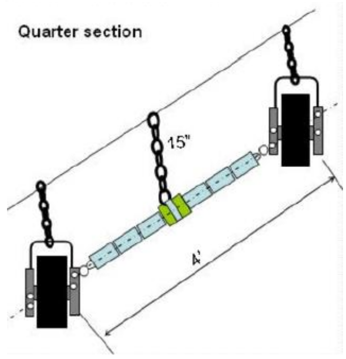


Design concept

The wheel design followed the principal of 1940s' German design as described in Gabriel et al. (2005) (Fig. 5.1.4). The design principle was that the attaching points on each side of the wheel could be adjusted depending on the position of the wheel along the footgear (wing, quarter or bosom), so that the wheel axle would always perpendicular to the towing direction. This was considered essential for proper rolling of the wheel.



The full-scale wheels were 30.5 cm in diameter and 10 cm thick rubber discs. The assembled footgear was attached to a silver hake trawl through toggle chains. The chains were 45.7 cm on the bosom, 38.1 cm in the quarter and 30.5 cm on the wing (Figure 2.7). The wheels were 91.5 cm apart in the bosom, 122.0 cm in the quarter, and 152,5 cm on the wing. The design of each wheel was similar regardless of their potential position. The lines show possible attaching points and resulting angles related to the position on the footgear. The only differences between the wheels are the position and the number of the holes drilled. A total of nineteen wheels were fabricated for the trawl



Results

The wheeled groundgear was easily handled with existing deck equipment and usual number of crew. There were no noticeable differences on the power required to tow the trawl with wheeled groundgear. Only four hauls were made with the system. Catch consisted silver hake, herring and *Pandalus* shrimps, but the amount of catch was not significant to evaluate its catch performance.

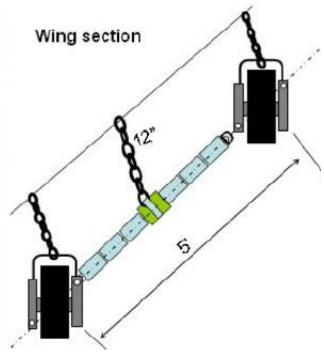


Fig 5.1.4: The wheeled ground gear. Upper drawing show the wheel and various attaching points and the actual rigging fot the bossom, quarters and wing sections.

Reference: He, P. and V. Balzano. (2010). Design and Test of a Wheeled Groundgear to Reduce Seabed Impact of Trawling. Final report submitted to the Northeast Consortium. University of Massachusetts Dartmouth - SMAST, New Bedford, MA. SMAST-CE-REP-2010-002. 11 pp.

5.1.5: Shearing plate gear

This new groundrope concept was developed by the Institute of Marine Research and SINTEF in Norway. The new gear concept consists of rectangular plates of rubber or plastic that are mounted in such a way that their surfaces are vertical and in line with the fishing line (Fig 3.11).

Earlier types of groundrope used in Norway have been based on bobbins, wheels or discs that have been threaded on a line or chain, which has been oriented parallel to the fishing line. The new plate gear has something in common with the “skirt” (i.e. a thick large mesh net ca. 50 cm in depth) used on the Norwegian style demersal seine. In the course of developing this “plate groundgear”, it was also found that a combination of plates along the wings of the trawl and Rockhopper discs mounted as mid-gear has the potential to be a successful concept.

During 2004 the new gear was observed by a video camera from a towed underwater vehicle and measured using Scanmar instruments. These trials confirmed earlier model experience that when they are installed as side-gear, plates have improved spreading ability and that they pass well over rocky ground. It was also documented that the way in which the gear was rigged was critical for good contact with the bottom. The gear could be rigged in such a way that the plates could either lift or dive. The angle of the plates could then be used to control bottom contact. An incline-meter on the plates and a Scanmar sensor that indicates the distance to the bottom both turned out to be useful instruments for monitoring bottom contact of the plate gear during towing.

Fig 3.11: The shearing plate gear attached to the fishing line (chain) of a trawl showing port side with square rubber plates and a section of ordinary rockhopper gear behind, i.e. the middle section of the groundrope.

Reference: Valdemarsen, J.W. and Hansen, K., 2004. IMR/ SINTEF report 4-2004. A new ground gear for bottom trawls, incorporating spreading features.

6. Effect of groundgear on catch efficiency, selectivity and fuel consumption

In this section we add factsheets of some of the latest modifications of some groundgears and the ways of operating bottom trawls that affect the groundgear bottom contact and its footprint, i.e. catchability, fuel consumption, bottom impact and bycatch reduction (selectivity).

Table 2 is based on fact sheets added by members of the ICES-FAO WG FTFB groundgear topic group. It shows a selection (only) of work done worldwide to improve bottom trawling in the direction of more responsible fishing practices that minimise their negative impact. The table shows:

- Reference number to factsheets,
- Factsheet codes (RHK= rockhopper, SCS= semicircle spreading gear, BOB=bobbins, ROL=roller gear, CHA=chain, COK=cookie, LED=lead rope).
- FAO gear code (reference: ISSCFG, 2013),
- Trawl system (single, twin, triple, quad, pair trawl, semipelagic trawl),
- Numbers of sweeps and the material they are built from,
- Seabed (bottom) type for operation,
- Commercial trawl (C) or experimental trawl (E) or survey trawl (S) systems,
- Location for operation/trials,
- Target species for the fishery,
- Catch increase (yes/no),
- Reduction of fuel consumption (yes/no),
- Seabed impact reduction (yes/no) and
- Bycatch reduction (yes/no).

Table 2. A summary of factsheets on type of bottom trawls, groundrope type, sweep number and material, sea bed type, commercial (C), experimental (E) or survey (S) gear, location, target species, catch increase, fuel reduction, seabed/bottom impact and bycatch reduction during bottom trawling. (A copy of the Table is added in Appendix V).

Ref.	Factsheet code	FAO gear code	System	Groundgear type	Sweep No.	Sweep Material	Seabed type	C/E/S	Location	Target species	Catch increase	Fuel use reduction	Seabed impact	Bycatch reduction
1	RKH 01	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	C	Barents Sea, Norway	COD	No			
1	SCS 01	OTB 03.12	Single	SCSG	2	Steel rope (wire)	Rocky-sand	E	Barents Sea, Norway	COD	Yes[a]	Yes[a]	Yes	
2	RKH 02	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	C	Barents Sea, Norway	COD,HAD,POK	No	-	-	No
3	RKH 03	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	E	Barents Sea, Norway	HAD	Yes[b]	-	-	
4	RKH 04	OTB 03.12	Single	Rockhopper + steel bobbins + chain clump	2	Steel rope (wire)	Rocky-sand-mud	E	Barents Sea, Norway	COD	No	Yes	Yes	
4	RKH 04	OTB 03.12	Single	Rockhopper + steel bobbins + chain clump	2	Steel rope (wire)	Rocky-sand-mud	E	Barents Sea, Norway	COD	No	Yes	Yes	
5	RKH 05	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand-mud	S	Barents Sea, Norway	COD,HAD				
5	BOB 01	OTB 03.12	Single	Bobbins	2	Steel rope (wire)	Rocky-sand-mud	S	Barents Sea, Norway	COD,HAD				
6	ROL 01	OTB 03.12	Single	Bobbin roller & rubber disk	2	Rubber encased wire	Rocky-sand	S	Newfoundland, Canada	COD,PLE,YEL				
7	RKH 06	OTB 03.12	Single	Rockhopper & raised fishing line	2	Steel rope (wire)	Sandy	E	North Sea	COD,HAD, POK, WHG,LEM,PLE				Yes[a]
8	RKH 07/COK 01	OTB 03.12	Single	Rockhopper & large footrope	2	Combination rope	Rocky-sand	C	West Coast (USA)	Demersal species			Yes[a]	
8	RKH 07/COK 01	OTB 03.12	Single	Rockhopper & small footrope	2	Combination rope	Rocky-sand	C	West Coast (USA)	Demersal species			-	
9	CHA 01	OTB 03.12	Single	Looped Chain	2	Combination rope	Sandy	C	Thailand	NPP,YEU			Yes	
10	CHA 02	PTB 03.15	Pair-trawl	Looped Chain	2	Steel rope (wire)	Mud-sandy	C	Vietnam	SQC,IAX, *(+demersal fish)*			Yes	
11	CHA 03	OTB 03.12	Pair-trawl	Combination Chain and Lead (pb)	2	Combination rope & PP	Mud-sandy	C	Vietnam	Loligo spp, Sepia spp and demersal fish		Yes		
12	LED 01	OTB 03.12	Single	Lead (Pb)	2	Lead rope	Mud-sandy	C	Philippines	Scad, herring, Mackeral, Sardine, Squid		Yes		
13	CHA 04	OTB 03.12	Single	Chain	2	PP (Polypropylene)	Mud-sandy	C	Cambodia	Parapenaeopsis spp. and Trachypenaeus spp.		Yes		
14	CHA 05	OTB 03.12	Single	Chain	2	PP (Polypropylene)	Sandy	C	Malaysia	Shrimp		Yes		
15	COK 02	OTB 03.12	Single	Rubber (Cookie)	2	PVA (polyvinyl alcohol)	Mud-sandy	C	Malaysia	Demeral fish		Yes		
16	CHA 06	OTB 03.12	Single	Dropchain Ø8-10 mm	2	Steel rope (wire)	Mud-sandy	C	New South Wales, Australia	Prawns (Peneaids)				-
16	CHA 07	OTB 03.12	Single	Dropchain Ø6 mm	2	Steel rope (wire)	Mud-sandy	E	New South Wales, Australia	Prawns (Peneaids)		Yes	Yes	Yes[a]
16	CHA 08	OTB 03.12	Single	Soft-brush chain	2	Steel rope (wire)	Mud-sandy	E	New South Wales, Australia	Prawns (Peneaids)			Yes	-
17	CHA 09	OTB 03.12	Single	Cookie + chain	2	Steel rope (wire)	Rocky-sand-mud	E	Oregon, California (USA)	PRA (Pandalus jordani)	No		Yes[a]	Yes
18	CHA 10	OTB 03.12	Single	Drop chain	2	Steel rope (wire)	Rocky-sand-mud	E	Oregon, California (USA)	PRA (Pandalus jordani)	No		Yes	Yes
19	CHA 11	OTT 03.13	Twin	Looped chain	4	Steel rope (wire)	Rocky-sand-mud	C	Irish Sea, west of Ireland, ...	NEP				
20	CHA 12	PTB 03.15	Quad	Looped chain	8	Steel rope (wire)	Rocky-sand-mud	C	Irish Sea, west of Ireland,	NEP				
21	COK 03	OTB 03.12	Single	Cookie	2	Steel rope (wire)	Rocky-sand-mud	C	Irish Sea, west of Ireland,	NEP, FLATFISH				
22	CHA 13	OTB 03.12	Single	Looped chain	2	Combination rope	Mud-sandy	C	Mediterranean, Italy	HKE, MUX, CEP	Yes			
23	CHA 14	OTB 03.12	Single	Comb. rope + Looped chain	2	Combination rope	Mud-sandy	C	Mediterranean, Italy	HKE, MUX, CEP, NEP	Yes	-		
23	CHA 15	OTB 03.12	Twin	Comb. rope + Looped chain	2	Combination rope	Mud-sandy	C	Mediterranean, Italy	HKE, MUX, CEP, NEP	Yes	Yes		
24	LED 01	OTB 03.12	Single	Comb. rope + Lead (Pb)	2	Combination rope	Mud-sandy	C	Mediterranean, Italy	HKE, MUX, CEP, NEP	No			
25	RHK 08	OTB 03.12	Single	Rockhopper + chain	2	Steel rope (wire)	Mud-sandy	E	Irish Sea, west of Ireland	COD, WHG, HAD, flatfish, monkfish, skate, ray	Yes			
26	RHK 09	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	E	Barents Sea, Norway	COD, HAD				
27	CHA 16	OTB 03.12	Single	Looped chain + PA with LED	2	Steel rope (wire)	Mud-sandy	C	Mediterranean, Turkey	PRA, red mullet, lizard fish, pandora				
28	RHK 10	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	E	Barents Sea, Norway	COD, HAD	No			Yes

(a)Assumed/not quantified [b] *For a limited range of sizes*

6.1. Factsheet code RKH 01 & SCS 01 (Table 6.1., ref. 1)

Rockhopper (RH) and semicricle spreading gear (SCSG) for cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*)

Gear setup with RH and SCSG groundropes

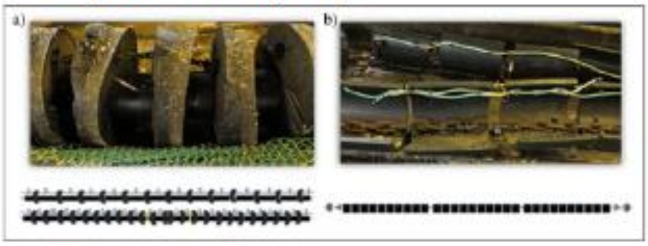
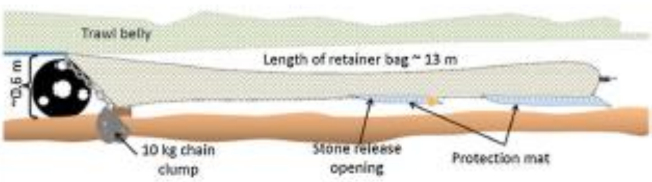
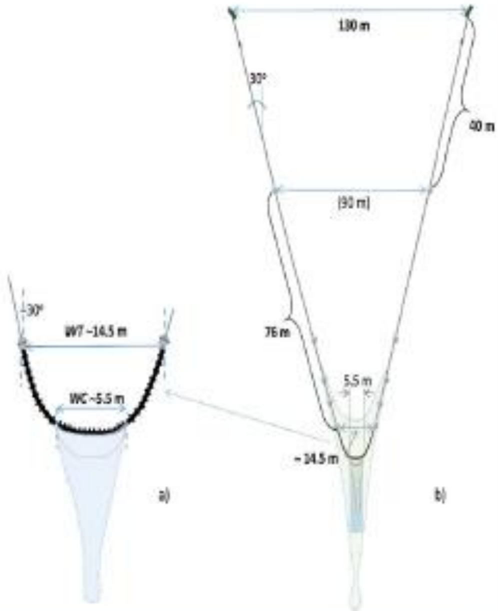


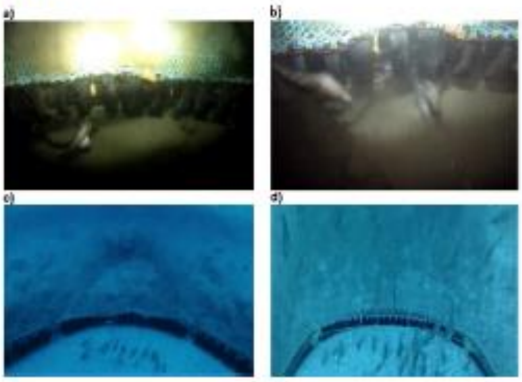
Fig. 2. Photo and sketch of the rockhopper gear (a) and the new semicircular spreading gear (SCSG) (b).





Experiments were performed with R(V "Helmer Hanssen" Along fishing ground of the Barents Sea (North East Atlantic)

Images below show fish reaction to a RH (a) and SCSG (b) groundgear.



Vessel size:	64 m
Engine BHp:	4080
Single or twin-trawls:	single
Towing speed:	2.0 ms^{-1}
Target species:	Cod and haddock

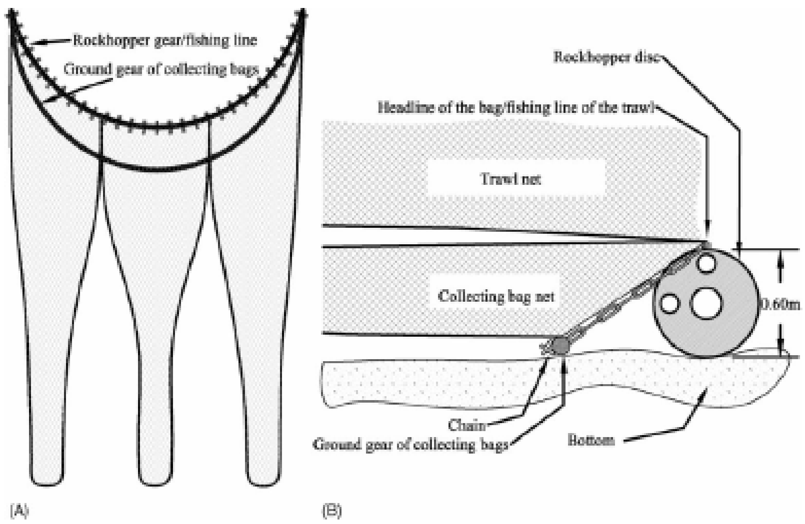
Bridle lengths:	28m
Sweep length:	116m
Bridle/Sweep material:	upper bridle – 18 mm wire, lower bridle – 19 mm chain sweeps – 32 mm wire
Otter board type:	Semi-pelagic Injector XF9
Otter board area and weight:	7.5 m2 (2850 kg)
Other:	450kg weight placed at the middle of the sweeplines. to maintain bottom contact of the groundrope.

https://www.sciencedirect.com/science/article/pii/S0165783616303368

UiT The Arctic University of Norway

6.2. Factsheet code RKH 02 (Table 6.1., ref. 2)

Escapement of gadeoid fish beneath a commercial fish trawl



This study investigated the escapement og cod, haddock and saithe under a commercially rigged bottom trawl with a rockhopper ground gear with Ø60 cm discs in the Barents Sea.

Three small meshed collecting bags (A) was attached behind the groundgear (B).

Vessel size:	60-70 m
Engine BHp:	3500-5000
Single or twin-trawls:	single
Towing speed:	2.0 ms^{-1}
Target species:	cod, haddock, saithe

Bridle lengths:	na
Sweep length:	na
Bridle/Sweep material:	Steel rope (wire)
Otter board type:	Bottom type
Otter board area and weight:	8 m^2 (3200 kg)

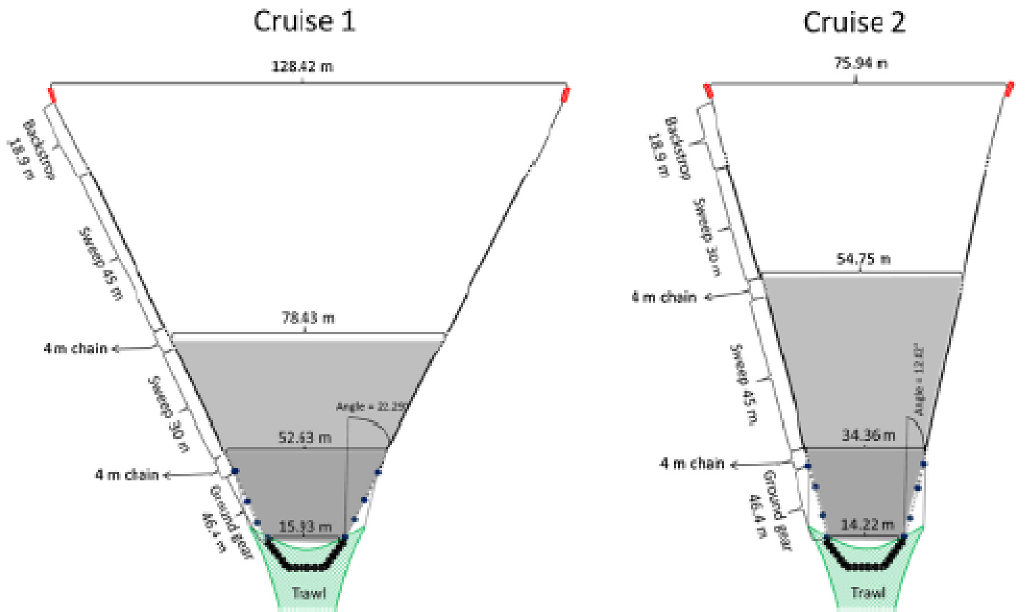
Ingólfsson, Ó. A., Jørgensen, T., 2006. Escapement of gadoid fish beneath a commercial bottom trawl: Relevance to the overall trawl selectivity. Fisheries Research, 79(3), 303-312. doi: http://dx.doi.org/10.1016/j.fishres.2005.12.017

Institute of Marine Research, Bergen
P. O. Box 1870 Nordnes
5817 Bergen

INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET

6.3. Factsheet code RKH 03 (Table 6.1., ref. 3)

The effect of sweep bottom contact on the catch efficiency of haddock (*Melanogrammus aeglefinus*)



Average geometry of the trawls during cruise 1 and cruise 2. The light grey area shows the area swept while using setup 2 whereas the dark grey area shows the area swept when using setup 1.

This paper illustrates the importance of length, angle and bottom contact of the sweep that connects the trawl and the otterboard for haddock (*Melanogrammus aeglefinus*) in Barents Sea. We compared the fishing efficiency of two different trawl setups over two cruises. During cruise 1, the sweep angle was 22.3° and the difference in sweep length with actual bottom contact was 30 m. During cruise 2, the average sweep angle was 12.0°, and the difference in length with actual bottom contact was 45 m.

The differences between the two setups were significant for a limited range of length classes in both cruises, indicating that effect of the sweep bottom contact for this species is length dependent. The results also demonstrate that lack of control over the position of the doors in the water column when fishing semi-pelagic may cause loss of contact of the sweep with the seabed, reducing fishing efficiency for haddock.

Vessel size:	64 m
Engine BHp:	4080
Single or twin-trawls:	single
Towing speed:	2.0 ms^{-1}
Target species:	Haddock

Bridle lengths:	28m
Sweep length:	116m
Bridle/Sweep material:	upper bridle – 18 mm wire, lower bridle – 19 mm chain sweeps – 32 mm wire
Otter board type:	Semi-pelagic Injector XF9
Otter board area and weight:	7.5 m2 (2850 kg)
Other:	450kg weight placed at the 76 and 91 m in front of the footrope.

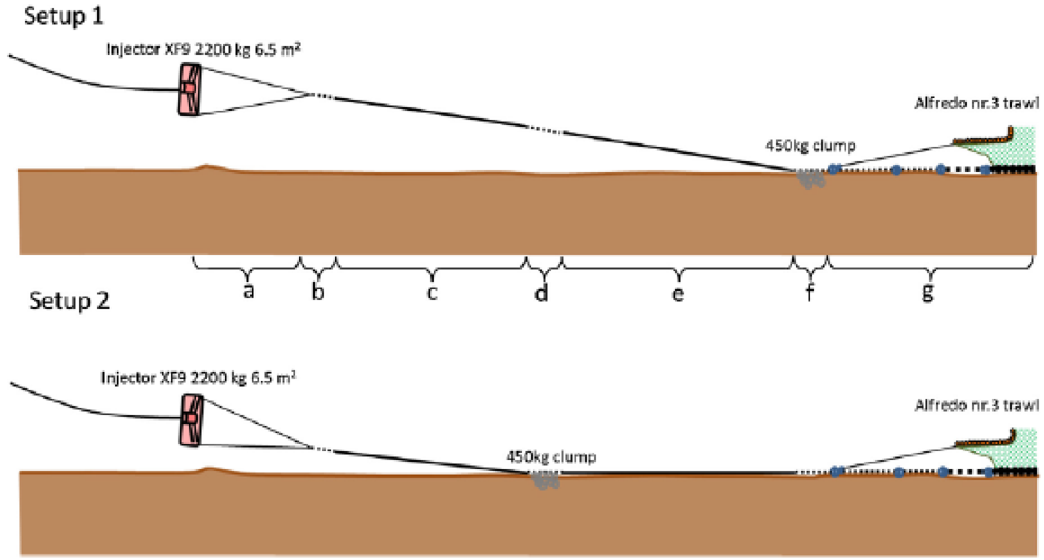
https://www.sciencedirect.com/science/article/pii/S0165783616300856

SINTEF

SINTEF Ocean,
N-7465 Trondheim

6.4. Factsheet code RKH 04 (Table 6.1., ref. 4)

Effect of lifting the sweeps on bottom trawling catch efficiency: Astudy based on the Northeast arctic cod (*Gadus morhua*) trawl fishery



Schematic view of the gear used during the sea trials. (a) 15.9 m backstrop, (b) 3 m backstrop extension, (c) 30 m of 30 mm sweep, (d) 4 m of 19 mm chain (attaching position for the clumps), (e) 45 m of 30 mm sweeps, (f) 4 m of 19 mm chain (attaching position for the clumps), (g) 45 m of ground gear composed of 19 mm chain (32 mm chain closest to the rockhopper), and the rockhopper.

Fuel consumption and environmental concerns have led bottom trawlers fishing for cod (*Gadus morhua*) in the Barents Sea to use semi-pelagic doors. In this study we compared the catch efficiency of two different setups where the sweep length with bottom contact was different. This setup also enabled us to estimate the herding efficiency of the sweeps on the seabed. We estimated that the setup with the lifted sweeps captured on average 33% fewer cod than the setup that kept the sweeps at the seabed. The loss of catch for cod was length independent and significant for a length span between 41 and104 cm. When sweeps were lifted above the seabed, herding was negatively impacted and fish were lost; in contrast, when on the seabed, the sweeps were able to herd (on average) 45% of the cod into the catch zone of the gear. Lifting the trawl doors from the seabed is touted as a positive development for this fishery. However, our results show that lifting the doors and consequently the sweeps can lead to substantial catch losses. Finally, the study highlights the importance of carefully evaluating the positive and negative potential consequences of introducing changes in a fishing gear.

Vessel size:	64 m
Engine BHp:	4080
Single or twin-trawls:	single
Towing speed:	2.0 ms^{-1}
Target species:	Cod

Bridle lengths:	28m
Sweep length:	116m
Bridle/Sweep material:	upper bridle – 18 mm wire, lower bridle – 19 mm chain sweeps – 32 mm wire
Otter board type:	Semi-pelagic Injector XF9
Otter board area and weight:	7.5 m2 (2850 kg)
Other:	450kg weight placed at the 46 and 90 m in front of the footrope (rockhopper).

https://www.sciencedirect.com/science/article/pii/S0165783615000363

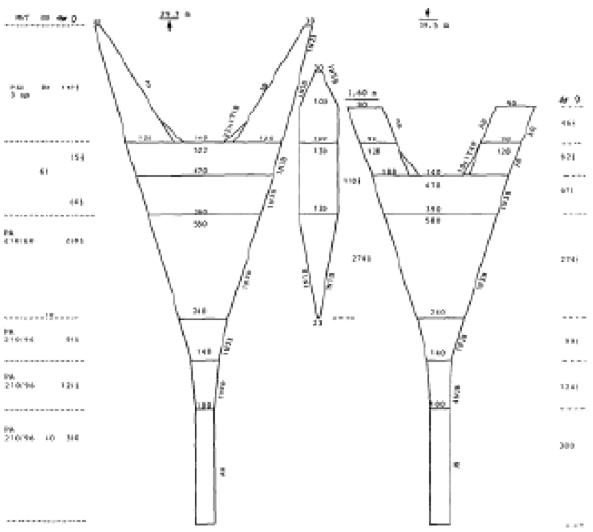
SINTEF

SINTEF Ocean, N-7465 Trondheim

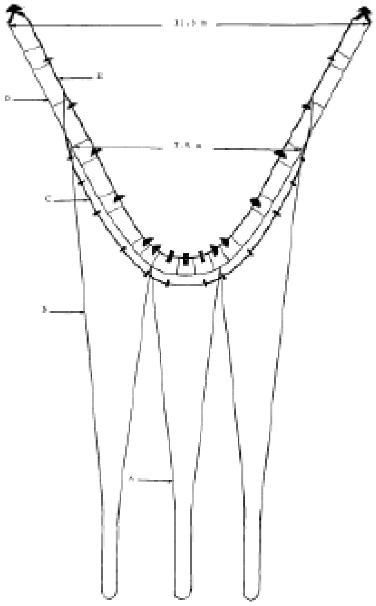
UiT The Arctic University of Norway, N-9037 Tromsø

6.5. Factsheet code RKH 05 and BOB 01 (Table 6.1., ref. 5)

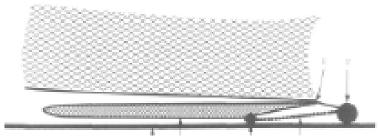
Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results



The Campelen 1800# survey trawl



Bags beind the groundrope of the 1800# survey trawl



The Institute of Marine Research, Bergen, has carried out combined bottom-trawl and acoustic surveys for cod and haddock in the Barents Sea and the Svalbard area since 1981. The results have demonstrated clearly that the current trawl and acoustic survey methods considerably underestimate the young age groups of cod, partly because of low gear efficiency for the smaller fish.

This paper describes the results of experiments with small bags to collect fish that escape under the trawl. Catches of several different species were obtained in the small bags. Comparison between trawl and bag catches reveals a length-dependent escape of cod and haddock under the trawl; i.e., small fish are severely underrepresented in the trawl catches. The escape also has a considerable effect on the species composition, because cod, more than haddock, tend to dive under the fishing line.

To improve the efficiency of the sampling trawl, a rock-hopper ground gear was introduced. Comparison of the trawl fitted with standard bobbins gear and with rock-hopper gear showed that escape under the standard equipment was of similar magnitude as that in the bag experiment

Vessel size:	60-70 m
Engine BHp:	3400-5400
Single or twin-trawls:	single
Towing speed:	2.0 ms^{-1}
Target species:	cod, haddock, flatfish

Bridle lengths:	40m
Sweep length:	40 m
Bridle/Sweep material:	upper sweep – 18 mm wire, lower sweep – 24 mm wire,
Otter board type:	bottom
Otter board area and weight:	6.5 m2 (2250 kg)
Other:	

Reference: J. Cons. int. Explor. Mer, 45: 269-276. 1989

Institute of Marine Research, Bergen
P. O. Box 1870 Nordnes
5817 Bergen

INSTITUTE OF MARINE RESEARCH
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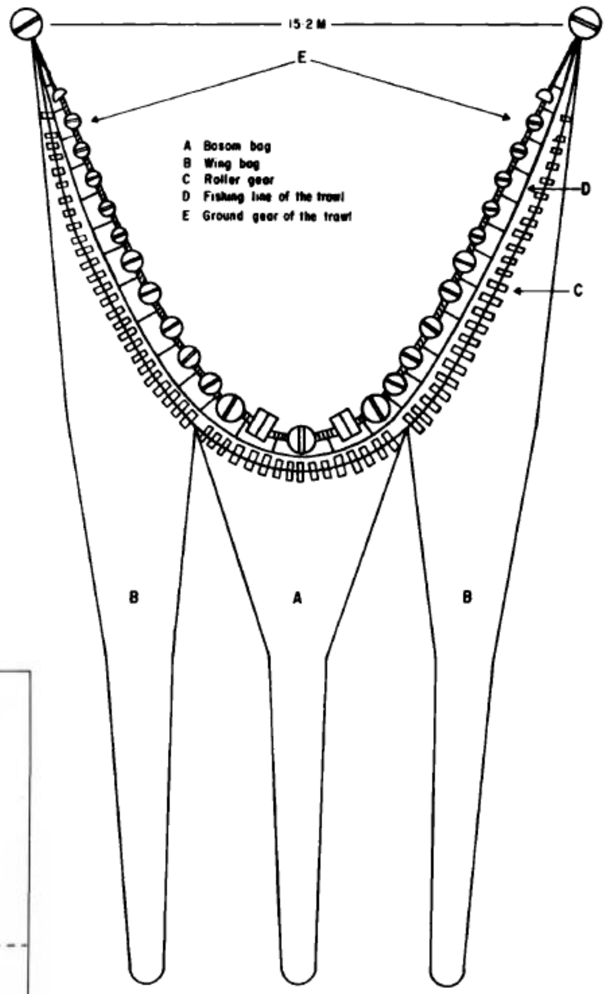
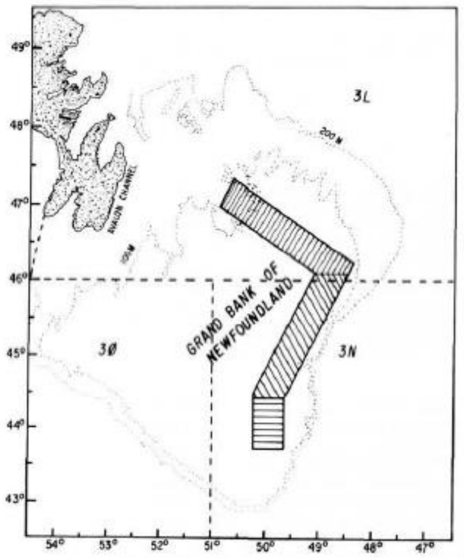
6.6. Factsheet code ROL 01 & BOB 02 (Table 6.1., ref. 6)

Size-Dependent Selection at the Footgear of a Groundfish Survey Trawl

Three trawl bags were attached underneath the footgear of a multispecies groundfish survey trawl to estimate escapement of Atlantic cod *(Gadus morhua.* American plaice (*Hippoghssoides platessoides),* yellowtail flounder (*Pleuronectes ferrugineus)* and thorny skate (*Raja radiata).*

Data from 26 fishing hauls on the Grand Bank, off the coast of Newfoundland, were used in the study. Net efficiency of the survey trawl reached 50% for the two flounder species greater than *24* cm and for Atlantic cod exceeding 35 cm, but efficiency never exceeded 42% for any si/e of thorny skate. Catchability coefficients ranged from 0.24 to 0.44.





A: Bosom bag, B: Wing bag, C: Roller gear,
D: Fishing line of the trawl, E: Groundgear of the trawl

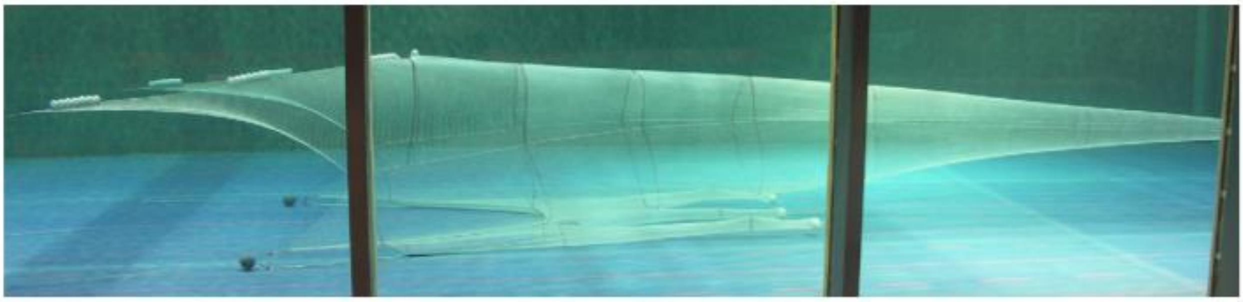
Bridle lengths:	54m
Sweep length:	54m
Bridle/Sweep material:	Steel rope (wire)
Otter board type:	Bottom polyval.
Otter board area and weight:	1250 kg
Other:	
Small bag groundrope made from Ø20 cm cookie	

http://dx.doi.org/10.1577/1548-8675(1992)012<0625:SDSATF>2.3.CO;2

6.7. Factsheet code RHK 06 (Table 6.1., ref. 7)

Selective haddock (*Melanogrammus aeglefinus*) trawling: Avoiding cod (*Gadus morhua*) bycatch

The critical condition of the North Sea cod stocks has resulted in restrictions on not only cod, but also haddock and other species that are caught together with cod. Thus full exploitation of the haddock stock is unachievable unless cod can be excluded from the haddock catch. We designed a selective trawl based on the behavioral differences between haddock and cod as they enter a trawl, i.e., cod stay close to the seabed whereas haddock rise above it. The trawl's fishing line is raised ~60 cm above the seabed to allow cod to escape beneath the trawl while haddock are retained. To collect the escapees, three sampling bags were attached beneath the raised fishing line. The selective haddock trawl reduced the total catch of cod by 55% during the day and 82% at night, and 99% of the marketable haddock was caught during the day and 89% at night. Cod escape rates were highly length dependent: smaller cod escaped the trawl in greater numbers than did larger individuals. Whiting, saithe, lemon sole, and plaice were included in the analysis.



	Depth (m)	Door-spread (m)	Headline height (m)	Speed (knt)	Wind (m/s)
Average	94.77 ± 10.1	123.5 ± 6.28	8.04 ± 0.2	3.16 ± 0.1	5.21 ± 3.0
Min–max	77–111	104–139	7.1–9.0	3.0–3.3	1.0–12.0

Bridle lengths: 55m
Sweep length: 163m
Bridle/Sweep material: Steel rope (wire)
Otter board type: Bottom V-door
Otter board area and weight: 2850 kg
Other:
Raised fishing line made from 13 mm chain (3.8 kg/m)

Vessel size: 28 m
Engine BHp: 910
Single or twin-trawls: single
Towing speed: 1.5 ms^{-1}
Target species: Cod, haddock, pollack, whiting, Lemon sole, plaice

Reference: Fisheries Research, 101(1–2), 20-26. doi: http://dx.doi.org/10.1016/j.fishres.2009.09.001

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National Institute of Aquatic Resources

6.8. Factsheet code RKH 07 & COK 01 (Table 6.1., ref. 8)

West Coast groundfish bottom trawl fishery:

In the U.S. West Coast groundfish bottom trawl fishery, there are two types of footropes that can be used (Large footrope and small footrope). For fishers trawling north of 40º10'N latitude and shoreward of 183 m bottom depth, they are required to use a footrope diameter no larger than 20.3 cm ("small footrope" requirement, defined below). The "small footrope" requirement is to deter fishers from trawling over high-relief substrates where rockfishes (*Sebastes* spp.) with restrictive harvest limits typically occur, as trawling over these grounds would damage the small footrope. For fishery trawling seaward of ~275 m over the continental shelf break and upper slope, they can use either the "small footrope" or "large footrope". Most fishers fishing seaward of ~275 m use the "large footrope" (defined below).

Regulation definition of the large and small footrope for the West Coast groundfish bottom trawl fishery.

"**Large footrope** trawl gear means a bottom trawl gear with a footrope diameter larger than 8 inches (20 cm,) and no larger than 19 inches (48 cm) including any rollers, bobbins, or other material encircling or tied along the length of the footrope."

"**Small footrope** trawl gear means a bottom trawl gear with a footrope diameter of 8 inches (20 cm) or smaller, including any rollers, bobbins, or other material encircling or tied along the length of the footrope."

Below: Images of a "large footrope" on a low-rise selective flatfish trawl.

6.9. Factsheet code CHA 01 (Table 6.1., ref. 9)

Hybrid otter board trawl net - Thailand

Hybrid otter board trawl is new named for bottom trawl what investigate at Kor Kasemsiri Fishing Port, Klongyai District, Trat province. Hybrid otter board trawl is definition of trawl net what cover target catch by fish and shrimp.

Categories of trawlers installed with this hybrid bottom trawl net is Length Overall (LOA) less than 14 m and LOA is between 14-18 m. Trawlers are assembled with 2 fishing booms (starboard side and port side; outrigger), 3-4 m in length, purpose for expanding sweep area.

The image below show mesh size in the lower wings and the looped chain attached to the fishing line.

Vessel size:	14-18 m
Engine BHp:	19-345
Single or twin-trawls:	single
Towing speed:	1.0 ms^{-1}
Target species:	Squid, shrimp, fish

Bridle lengths:	50 m
Sweep length:	50 m
Bridle/Sweep material:	Combination rope
Otter board type:	Wood, flat rectangular

Otter board area and weight: ca. 1 m^2 and ca. 100 kg

Other: Towing warps are made from Ø14-28 mm PE or PP

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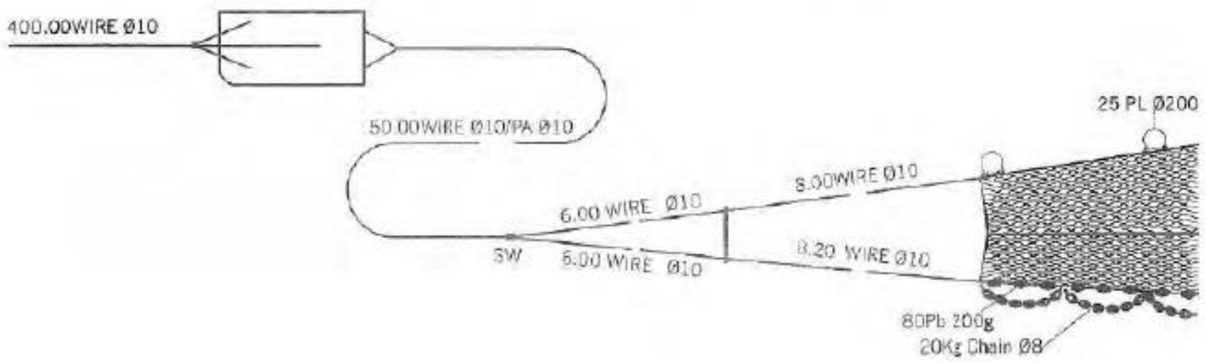
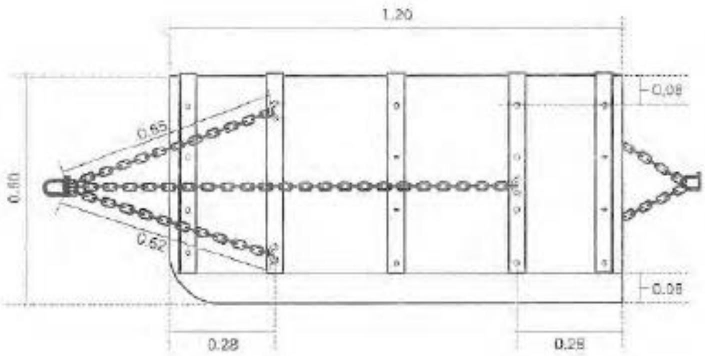
P.O. Box 97 Phrasamutchedi,
Samut Prakan 10209, Thailand
E-mail: td@seafdec.org
http://www.seafdecor.th

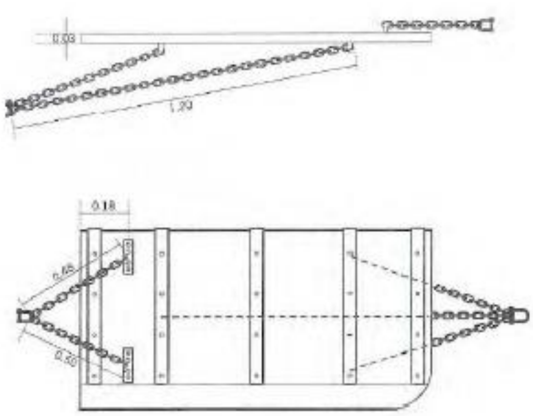
6.10. Factsheet code CHA 02 (Table 6.1., ref. 10)

Otter trawl system - Vietnam (Ly Hoa, Quang Bihn)

The data refers to a 2x220 mesh (by 125 mm) bottom trawl.
Headline length : 29.90 m and Fishng line length: 37.10 m







Vessel size:	20 m
Engine BHp:	135
Single or twin-trawls:	single
Towing speed:	1.0 ms^{-1}
Target species:	Demersal fish, squid, cuttlefish

Bridle lengths:	14 m/14.2 m
Sweep length:	50 m
Bridle/Sweep material:	Steel rope (Ø10 mm wire)
Otter board type:	Wooden, flat rectangular
Otter board size and weight:	0.7 m^{2}, 70-100 kg
Weights along the fishing line: 20 kg chain + 16 kg lead	

Other: The length of the towing warps are: 400 m and made from Ø10 mm steel rope (wire).

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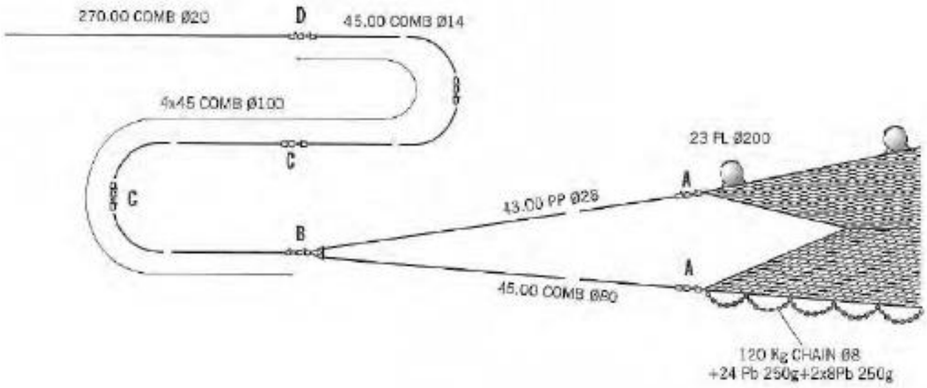
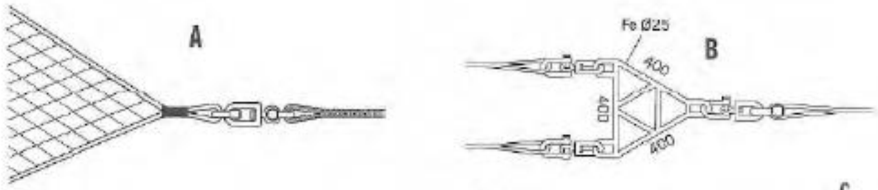
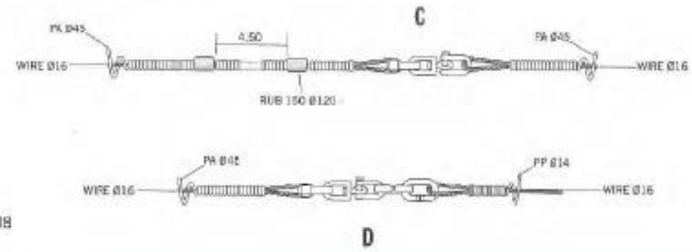
6.11. Factsheet code CHA 03 (Table 6.1., ref. 11)

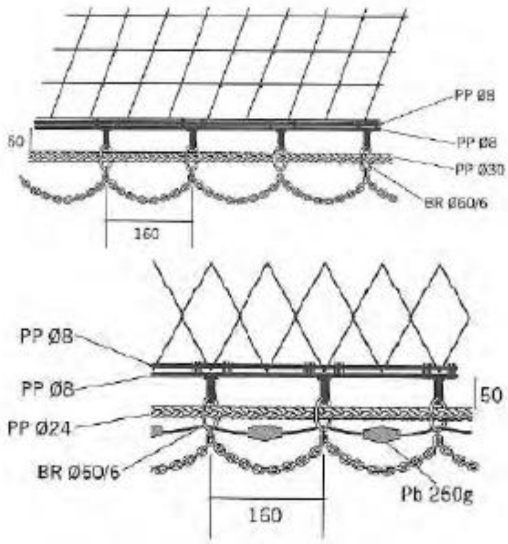
Pair trawl system - Vietnam (Chau Thanh, Kien Giang)

The data refers to a 2x268 mesh (by 200 mm) bottom trawl.
Headline length : 47.90 m and Fishng line length: 55.60 m









Vessel size:	20 m
Engine BHp:	190-345
Single or twin-trawls:	single
Towing speed:	1.0 ms^{-1}
Target species:	Demersal fish, squid, cuttlefish

Bridle lengths:	43 m
Sweep length:	45 m
Bridle/Sweep material:	PP/Combination rope
Otter board type:	No otter boards

Weights along the fishing line: 120 kg chain + 10 kg lead

Other: The length of the towing warps are: 270+45-45 m and made from combination ropes.

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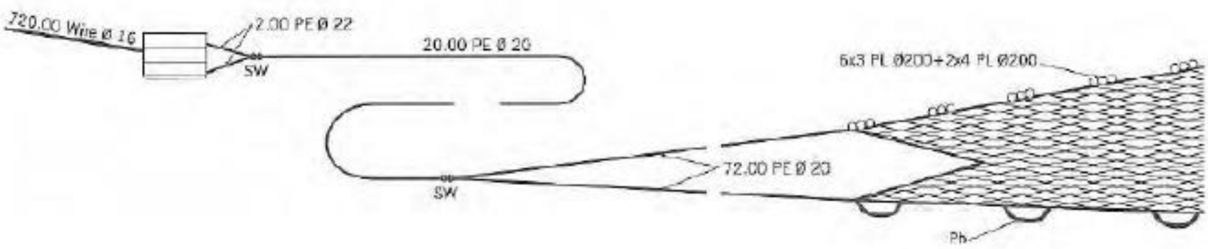
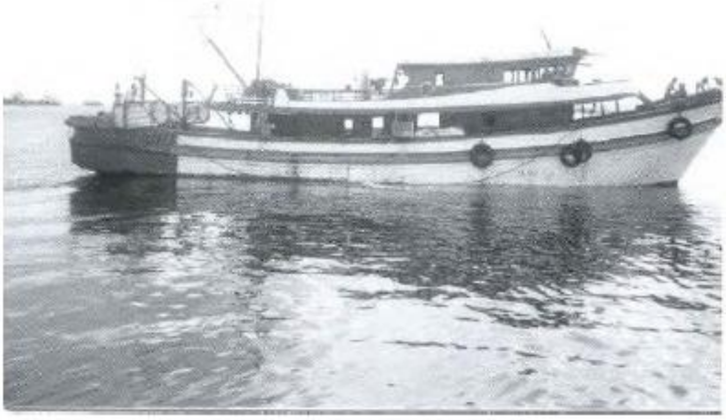
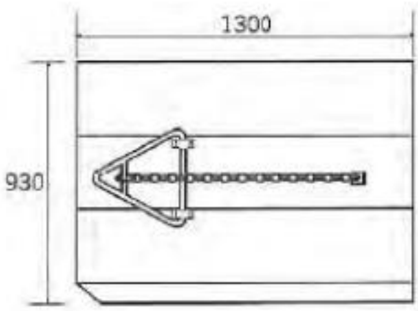
6.12. Factsheet code LED 01 (Table 6.1., ref. 12)

Otter trawl system - Philippines (Sto. Tomas)

The data refers to a 2x50 mesh (by 2200 mm) bottom trawl.
Headline length : 29.90 m and Fishng line length: 37.10 m







Vessel size:	15 m
Engine BHp:	350
Single or twin-trawls:	single
Towing speed:	1.5 ms^{-1}
Target species:	Scad, herring, mackerel, squid, sardine

Bridle lengths:	72 m (PE)
Sweep length:	20 m
Bridle/Sweep material:	Polyethylene (PE Ø20 mm)
Otter board type:	Flat rectangular
Otter board size and weight:	1.2 m^2.
Weights along the fishing line:	Looped, lead rope,

Other: The length of the towing warps are: 720 m and made from Ø16 mm steel rope (wire).

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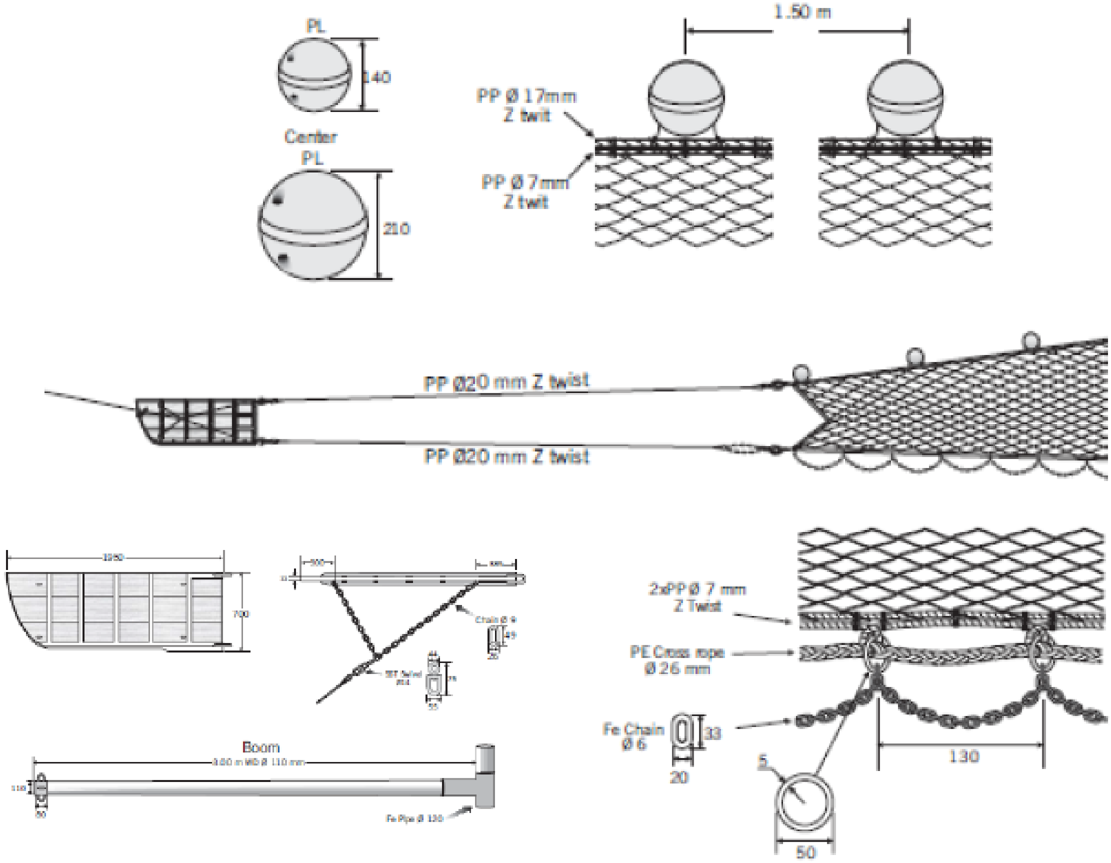
In co-opeation with Bureau of Fisheries and Aquatic Resources (BFAR) of the Philippines

6.13. Factsheet code CHA 04 (Table 6.1., ref. 13)

Otter trawl system - Cambodia (Koh Kong)

The data refers to a 2x240 mesh (by 23 mm) bottom trawl.
Headline length : 14.60 m and Fishing line length: 17.25 m



Vessel size:	14 m
Engine BHp:	115-120
Single or twin-trawls:	single
Towing speed:	1.5 ms^{-1}
Target species:	Various fish, squid,

Bridle lengths:	na
Sweep length:	na
Bridle/Sweep material:	Polypropylene (PP Ø20 mm)
Otter board type:	Flat rectangular
Otter board size and weight:	1.4 m^2
Weights along the fishing line:	Looped chain

Other: The otter boards are towed from 3.0 m long booms.

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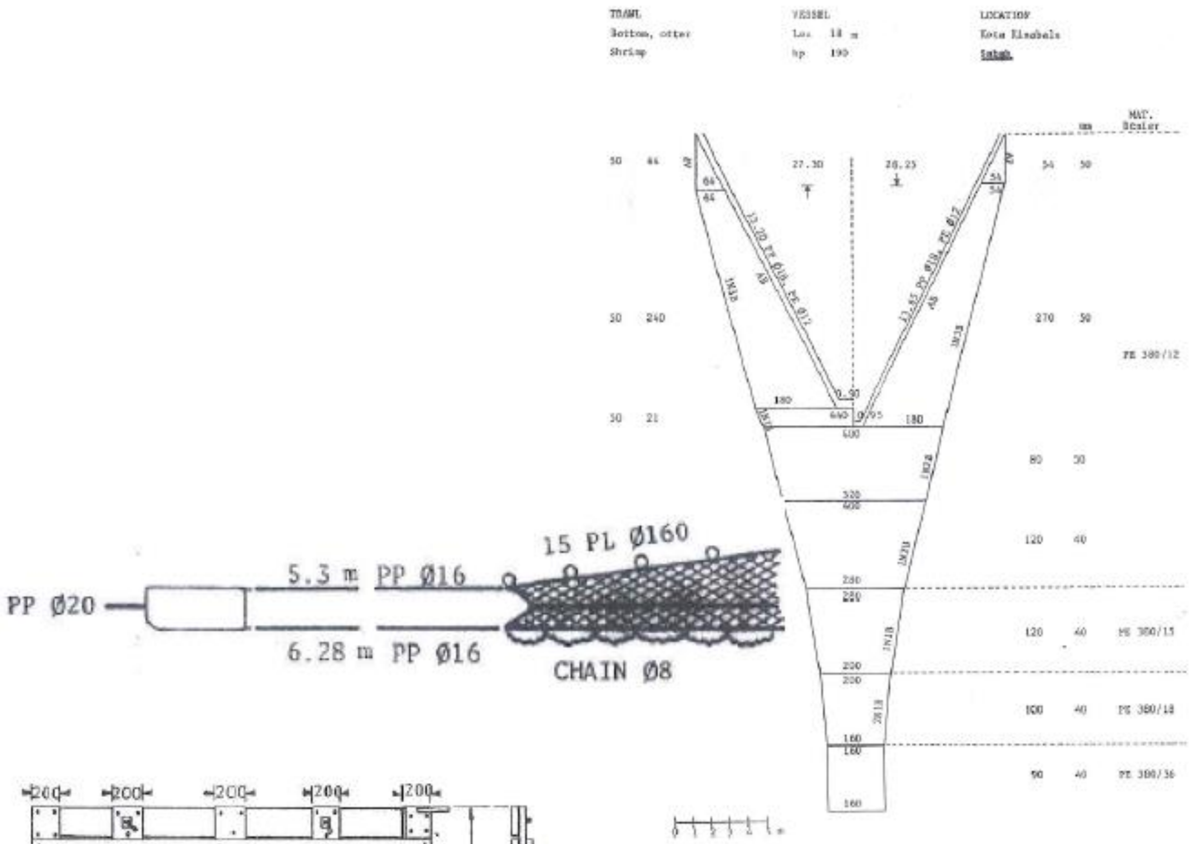
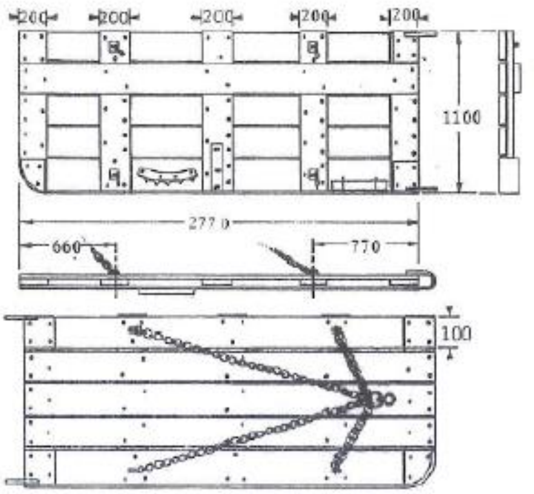
6.14. Factsheet code CHA 05 (Table 6.1., ref. 14)

Otter trawl system - Malaysia (Kota Kinabalu)

The data refers to a 2x400 mesh (by 50 mm) bottom trawl.
Headline length : 27.30 m and Fishing line length: 28.25 m





Vessel size:	18 m
Engine BHp:	190
Single or twin-trawls:	single
Towing speed:	1.0 ms^{-1}
Target species:	Shrimp

Bridle lengths:	5.3 m/6.28 m
Sweep length:	na
Bridle/Sweep material:	Polypropylene (PP Ø16 mm)
Otter board type:	Flat rectangular
Otter board size and weight:	3.1 m^2, na
Weights along the fishing line:	Looped chain
Other:	

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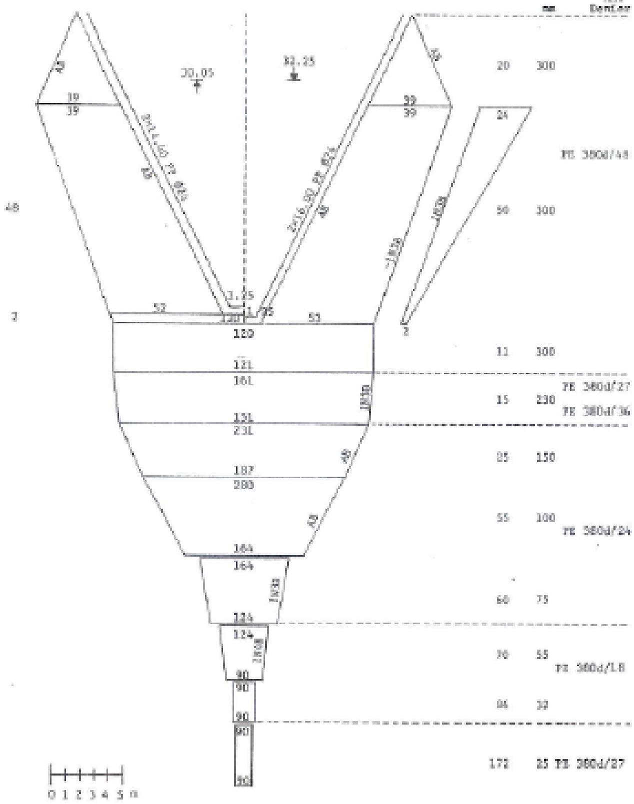
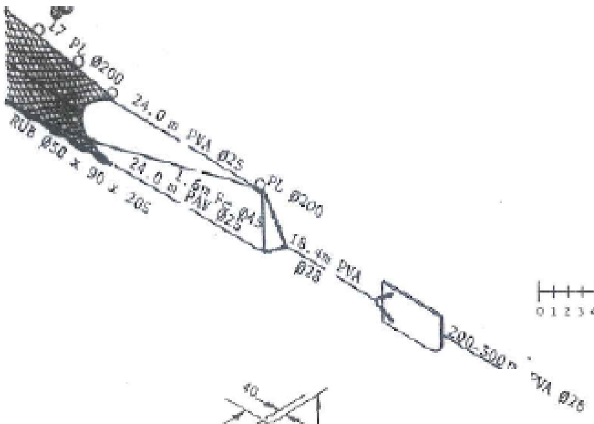
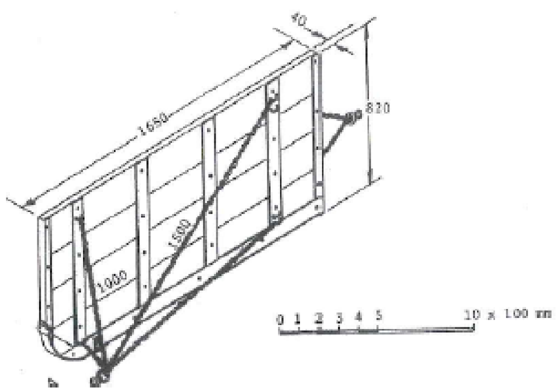
6.15. Factsheet code COK 02 (Table 6.1., ref. 15)

Otter trawl system - Malaysia (Pulau Pangkor)

The data refers to a 2x120 mesh (by 300 mm) bottom trawl.
Headline length : 30.05 m and Fishing line length: 32.25 m







Vessel size:	19 m
Engine BHp:	355
Single or twin-trawls:	single
Towing speed:	2.0 ms^{-1}
Target species:	Demersal fish

Bridle lengths:	24 m
Sweep length:	18.4 m
Bridle/Sweep material:	PVA (PP Ø25/Ø28 mm)
Otter board type:	Flat rectangular
Otter board size and weight:	1.4 m^2, na
Weights along the fishing line:	Cookie, na

Other: Towing warps made from PVA (polyvinyl alcohol), 200-300 m long, Ø28 mm.

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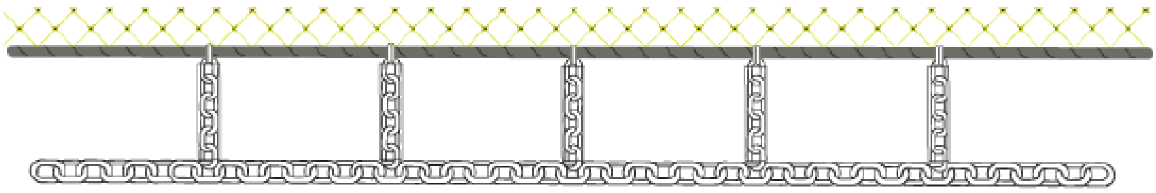
In co-opeation with Marine Fishery Resources Development and Management Department, Kuala Ternggano, Malaysia

6.16. Factsheet code CHA 06-07-08 (Table 6.1., ref. 16)

Drop chain groundgear, and School Prawn in NSW estuary fishery



Drop chains (6 mm Ø) are 135 mm long inside 32 mm Ø plastic tubing and are spaced at 550 mm

Ground chain (8–10 Ø)

Fishing line (12 mm Ø) combination

The estuary prawn trawl regulations stipulate a maximum fishing line of 15 m i.e. single trawl max 15 m or 2 x 7.5 m max for twin trawls

A typical New South Wales (NSW) estuary prawn trawler

The fishing takes place in estuaries and lagoons in NSW Australia

Vessel size: 8–11 m
Engine: up to 150 kW
Rig type: Single and twin-trawls
Towing speed: ~1.5 ms^{-1}
Target species: *Metapenaeus macleayi*

Bridle lengths: 3.14 m
Sweep length: 3.14 m
Bridle/Sweep material: wire
Otter board type: low-aspect demersal
Otter board area and weight: 30–80 kg
Other:

Website www.bim.ie/fisheries For further information email gear@bim.ie

6.17. Factsheet code CHA 09 (Table 6.1., ref. 17)

Pacific States Marine Fisheries Commission

Ocean Shrimp (*Pandalus jordani*) fishery

Here are two common groundgear configurations used in the ocean shrimp fishery. In 2018, regulations were implemented requiring fishers landing ocean shrimp in Oregon and Washington to use lighting devices (e.g., LEDs) near the trawl fishing line to reduce eulachon (*Thaleichthys pacificus*) bycatch.

Groundgear configuration #1:

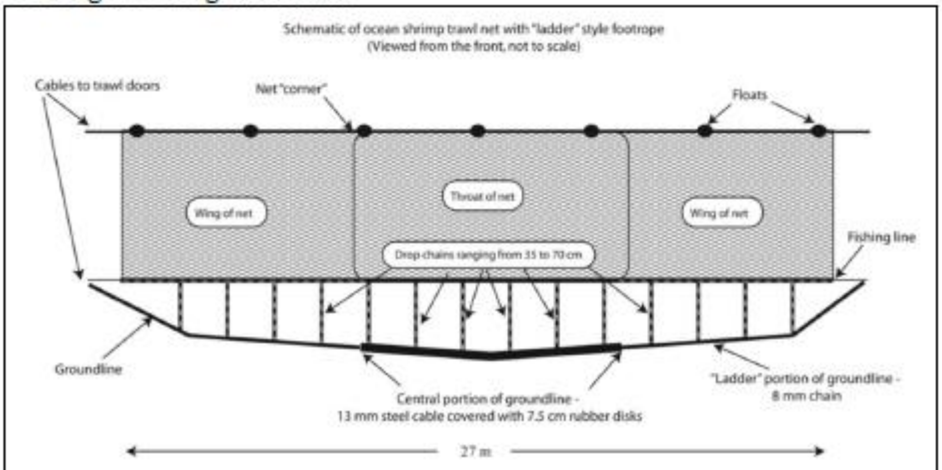


Fig. 2. Schematic drawing of an ocean shrimp trawl with a "ladder style" footrope (view looking into the net from the front).

Source: Hannah, R.W., Jones, S.A., Lomeli, M.J.M., Wakefield, W.W., 2011. Trawl net modifications to reduce the bycatch of eulachon (*Thaleichthys pacificus*) in the ocean shrimp (*Pandalus jordani*) fishery. Fisheries Research, 110: 277–282.

6.18. Factsheet code CHA 10 (Table 6.1., ref. 18)

Pacific States Marine Fisheries Commission

Ocean Shrimp (Pandalus jordani) fishery Groundgear configuration #2:

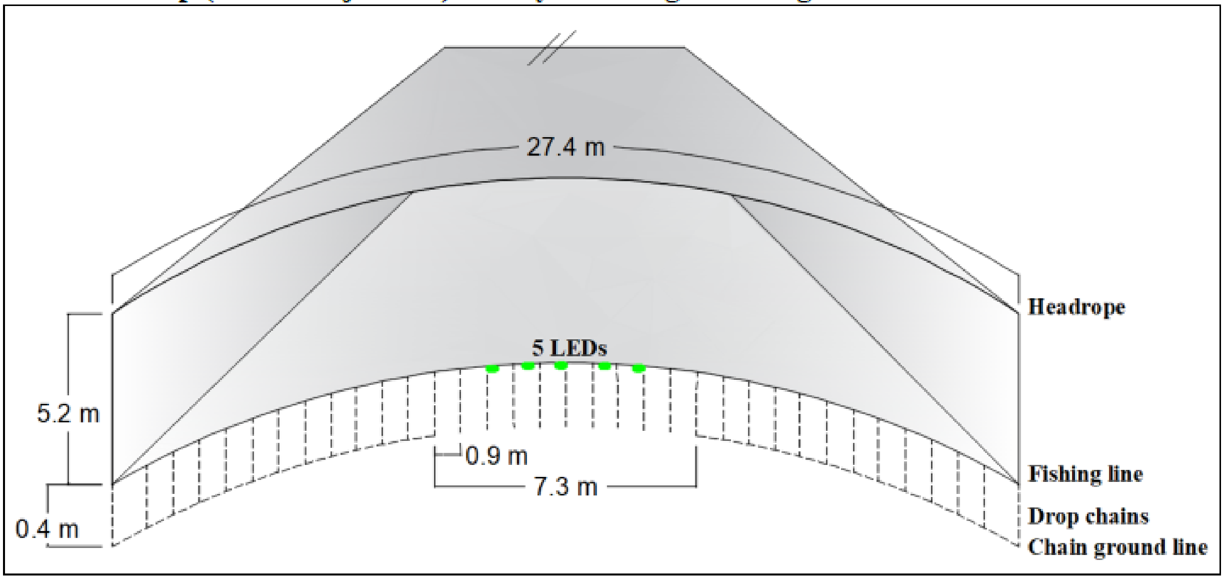


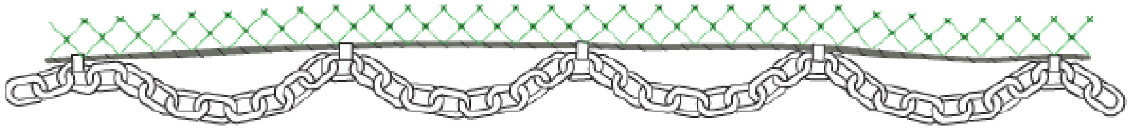
Figure 2. Schematic diagram of an ocean shrimp trawl and placement of LEDs along the trawl fishing line. Note: diagram not to scale.

- Wood and steel combination doors, 2.4 x 2.7 m (length x height), were used to spread each trawl. The trawl bridles were 19 mm steel cable and totaled 6.1 m in length and connected directly to the trawl doors. The headropes and fishing lines were 27.4 m in length (Fig. 2). Drop chains measuring 0.4 m in length attached the fishing line to the chain ground line at 0.9 m separations. The center 7.3 m section of the trawl groundgear consisted of only drop chains.

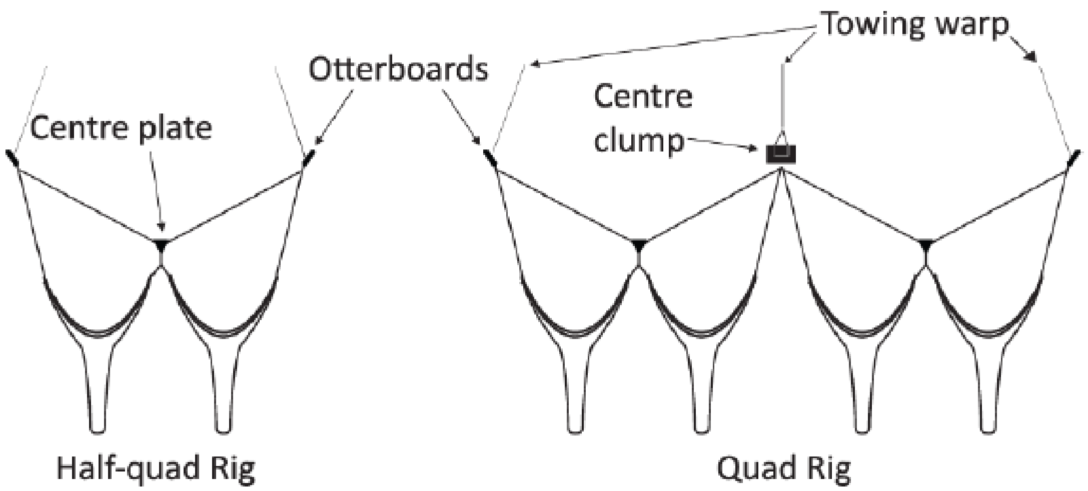
Source: Lomeli, M. J. M., Groth, S. D., Blume, M. T. O., Herrmann, B., and Wakefield, W. W. Submitted. The Efficacy of illumination to reduce bycatch of eulachon and groundfishes before trawl capture in the eastern North Pacific ocean shrimp fishery. Canadian Journal of Fisheries and Aquatic Sciences, *under review*.

6.19. Factsheet code CHA 11-12 (Table 6.1., ref. 19 and ref .20)

Looped chain groundgear, for Irish *Nephrops* trawl fishery



Looped chain groundgear length: 33–73 m (depending on vessel)
There are nine free chain links in each loop, chain type is to fishers specification
Chain is attached at ~0.30 m and is typically twice the length of the footrope



A typical Irish prawn trawler

Fishing grounds—ICES areas: 6a; 7a,b,c,f,g,h,j & k

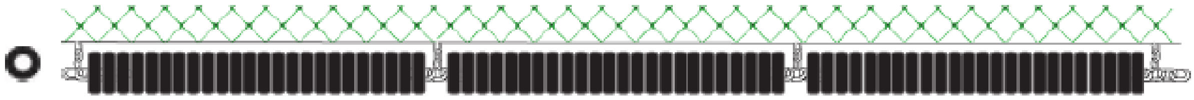
Vessel size: 10–25 m
Engine: 80–600 kw
Trawls rigs: single, half-quad, quad-rig
Towing speed: ~1–1.5 ms^{-1}
Target species: *Nephrops norvegicus*

Bridle lengths: up to 10 m
Sweep length:70 — 128 m
Split-sweep length:50 — 91 m
Centre-sweep length:20 — 37 m
Bridle/Sweep material: wire rope
Otter board type: low=aspect demersal
Otter board area and weight: 100–800 kg
Centre clump weight (quad rig): ~ 800kg

Website www.bim.ie/fisheries For further information email gear@bim.ie

6.21 Factsheet code COK 03 (Table 6.1., ref. 21)

Bobbin groundgear in the Irish whitefish and prawn fisheries



Disc groundgear is made from rubber discs (~50–80 mm Ø) threaded on chain

Groundgear is split into sections (to allow some flexibility to take curved shape)

This groundgear (up to 30 m) is typically on low opening trawls

This groundgear is typically fished on flat ground that might have occasional rough patches

A typical Irish trawling vessel

Fishing grounds—ICES areas: 6a & b; 7a,b,g & j

Vessel size: 15–23 m
Engine: 150–600 kW
Rig type: Single and twin-trawls
Towing speed: up to 3 ms^{-1}
Target species: *Nephrops norvegicus* and benthic species (e.g. flatfish, *Lophius sp.)*

Bridle lengths: 10 m
Sweep length: 62 m
Bridle/Sweep material: wire rope
Otter board type: low-aspect demersal
Otter board area and weight:
Other:

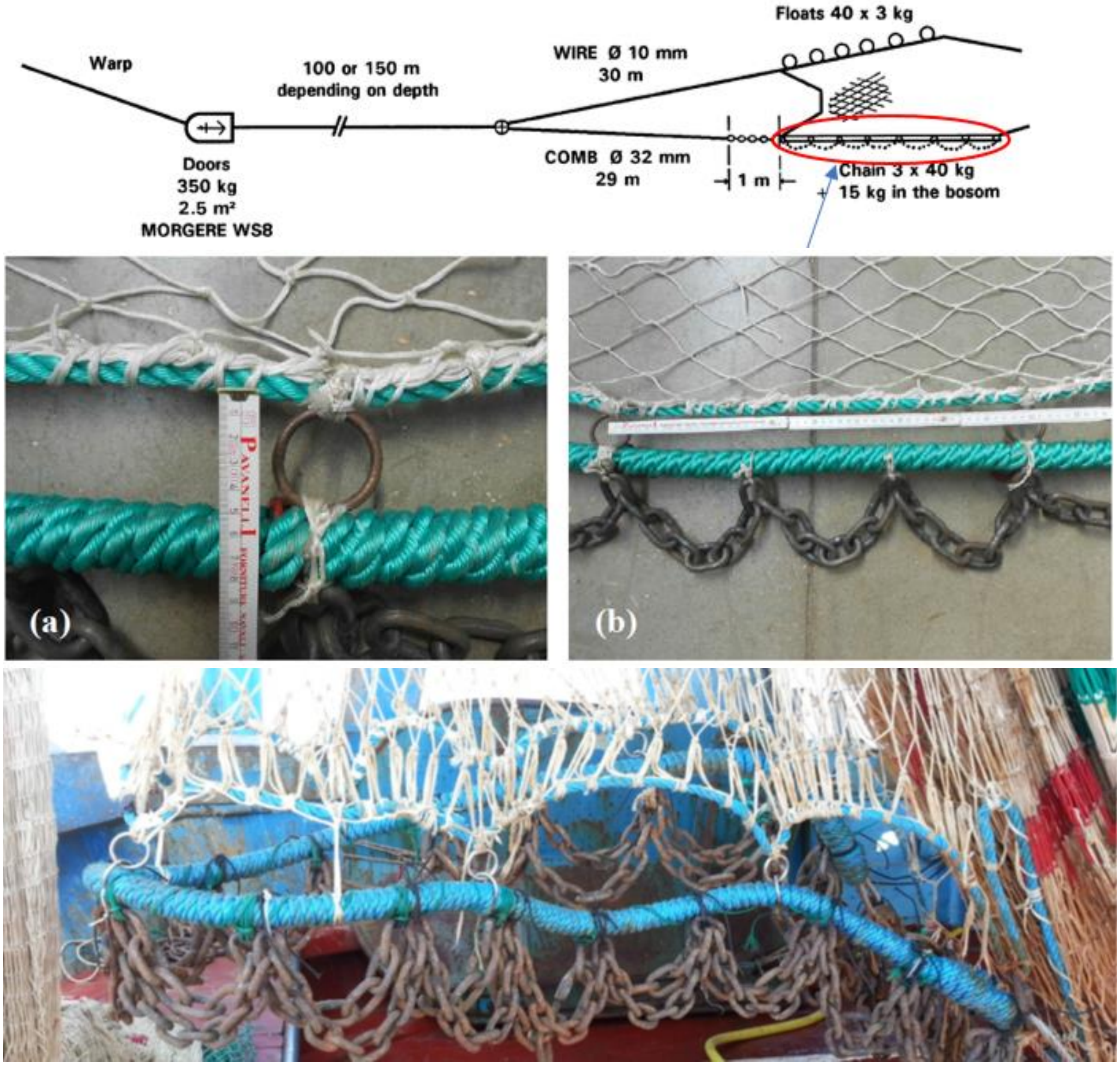
Website www.bim.ie/fisheries For further information email gear@bim.ie

6.22. Factsheet code CHA 13 (Table 6.1., ref. 22)

The GOC73 trawl (Mediterranian)

In 1993, the European Commission (Directorate of Fisheries) encouraged a joint survey programme for demersal-resource assessment in the Mediterranean. The Mediterranean international trawl survey (MEDITS) programme was started at the end of 1993. Its aims were: (i) to contribute to the characterization of bottom-fisheries resources in terms of population distribution (relative-abundance indices) and demographic structures (length distributions); and

(ii) to provide data for modelling the dynamics of the species studied. The programme originally involved the four Mediterranean countries of the European Union (Spain, France, Italy and Greece). Since 1996, it also includes Albania, Croatia and Slovenia. The GOC73 trawl (Fig 3.12) is used in the International Mediterranean Stock Assessment programme (MEDITS).



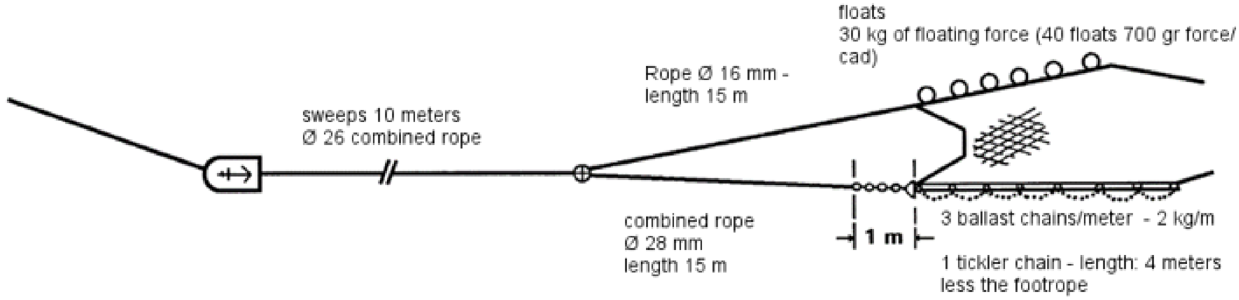
The GOC73 sampling trawl (used in the Mediterranian).

Reference: Fiorentini L, Dremière PY, Leonori I, Sala A, Palumbo V, 1999. Efficiency of the bottom trawl used for the Mediterranean International Trawl Survey (MEDITS). Aquatic Living Resources, 12(3): 187-205.

6.23. Factsheet code CHA 14-15 (Table 6.1., ref. 23 and ref. 24)

The OTB4 Americana trawl

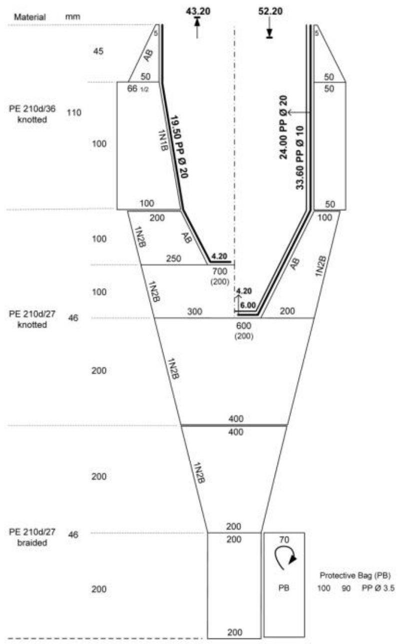
The OTB4 Americana is a polyethylene trawl usually rigged with sweeps and bridles (Fig. 3.13). The groundgear is often equipped with a fishing line and a tickler chain in order to catch mixed demersal species. In the middle Adriatic is common to use the twin rigging with a centre clump weight.

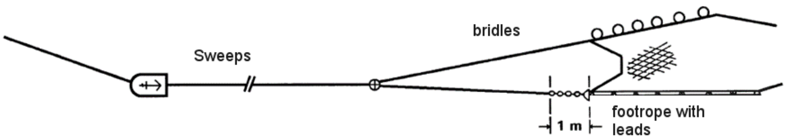


The Americana trawl ….

Reference: Sala A, Brčić J, Conides A, De Carlo F, Klaoudatos D, Grech D, Lucchetti A, Mayans A, Notti E, Paci N, Salom S, Sartor P, Sbrana M, Soler I, Spedicato MT, Virgili M, 2013. Technical specifications of Mediterranean trawl gears (myGears). Final project report, financed by the European Commission through the Framework service contract for Scientific Advice and other services for the implementation of the Common Fisheries Policy in the Mediterranean (Contract MARE/2009/05-Lot 1), 519 pp

6.24. Factsheet code LED 01 (Table 6.1., ref. 24)





<u>Rigging:</u>
Footrope: 75.2 m Ø 36 combined
Sweeps: length 165 meters, combined rope Ø 28 mm
Bridles: sup/inf: Ø16/50 mm; 40/40 m length; 1 m of extention chain; leads on footrope, 3.05 kg/m

<u>Vessel:</u>
LOA =
Power = 1200 hp
Trawl speed = 3.8 kn

<u>Otterboards:</u>
2,01 x 1,20 m type Morgere Polyfoil Type III;
Projected area = 2.26 m^2
Weight in air = 350 kg;
estimated angle of attack = 40°

Reference: Sala A, Brčić J, Conides A, De Carlo F, Klaoudatos D, Grech D, Lucchetti A, Mayans A, Notti E, Paci N, Salom S, Sartor P, Sbrana M, Soler I, Spedicato MT, Virgili M, 2013. Technical specifications of Mediterranean trawl gears (myGears). Final project report, financed by the European Commission through the Framework service contract for Scientific Advice and other services for the implementation of the Common Fisheries Policy in the Mediterranean (Contract MARE/2009/05-Lot 1), 519 pp.

6.25. Factsheet code RHK 08 (Table 6.1., ref. 25)

Reducing cod catch in a whitefish trawl with a raised fishing line

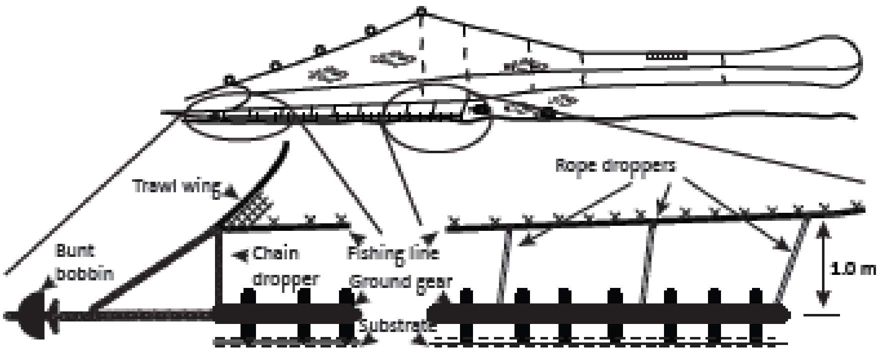
AREA, VESSEL

The twin-rig catch comparison trial took place in the Celtic Sea (ICES VIIg) on board a 25 m whitefish trawler during March 2017, when targeting whiting.

GEAR MODIFICATION

Two identical whitefish trawls (620 × 80 mm fishing circle) were used during the trial.
On the test gear the droppers between the fishing line and the ground gear were lengthened to 1 m.

On the standard gear the ground gear/ fishing line arrangement was unaltered.



Species	Standard gear (kg)	Raised fishing line (kg)	Difference (%)
Cod	798	488	-39
Whiting	2706	5069	87
Haddock	1975	2713	37
Flatfish	584	250	-57
Monkfish	202	57	-72
Skate and ray	124	25	-80

RESULTS

- Reduced catches of cod, flatfish, monkfish, and skate and ray
- Substantial increases in whiting and haddock catches
- Total catch value increased by 14%

FURTHER INFORMATION

https://tinyurl.com/y9qtq5m2

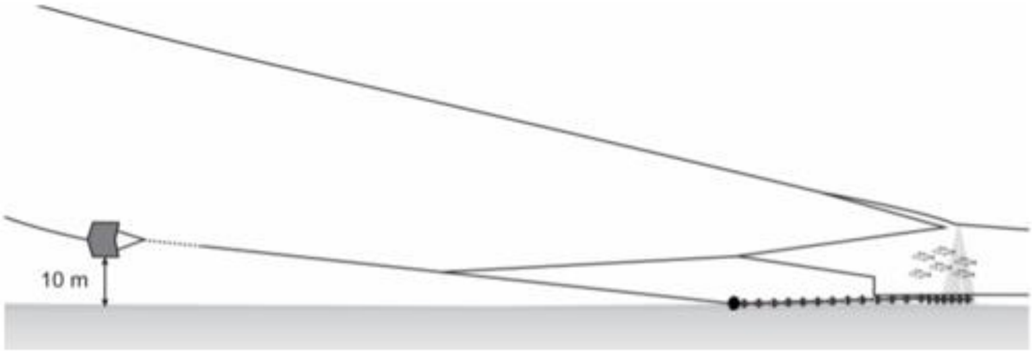
BIM Ireland's Seafood Development Agency

An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine

EUROPEAN UNION
This measure is part-financed by the European Maritime and Fisheries Fund

6.26. Factsheet code RHK 09 (Table 6.1., ref. 26)

Semi-pelagic trawling for cod (*Gadus morhua*)



Information on typical fishing grounds (ICES areas) and a photo of a typical vessel using this groundgear:

Used in ICES areas IIa and IIb on research vessels and a 67-m commercial off-shore factory trawler.

Vessel size:	67 m
Engine BHp:	5170
Single or twin-trawls:	single
Towing speed:	2.0 ms^{-1}
Target species:	cod

Bridle lengths:	70m
Sweep length:	55m (+11m chain)
Bridle/Sweep material:	upper bridle – 20 mm wire, lower bridle – 32 mm wire, sweeps – 32 mm wire
Otter board type:	semi-pelagic
Otter board area and weight:	9.5 m2 (4250 kg) and 10.5 m2 (4500)
Other:	300kg weight placed where the bridle and footgear connect.

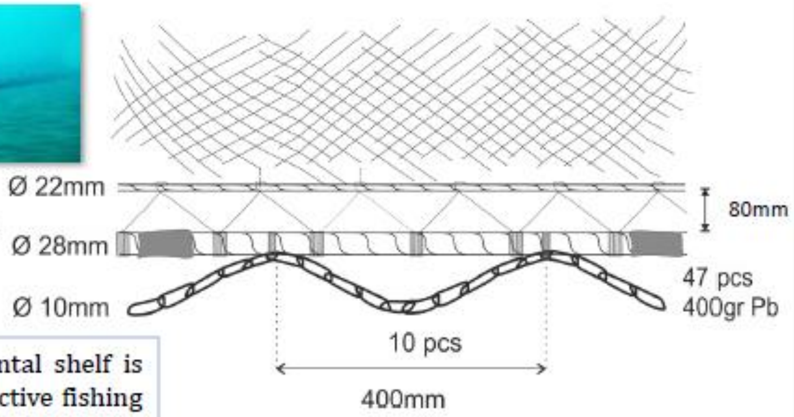
CRISP

http://crisp.imr.no/resources/Crisp-Annual-Report-2013.pdf

6.27. Factsheet code CHA 16 (Table 6.1., ref. 27)

Double Attached Lead Lines used in the Northeastern Mediterranean multi-species demersal trawl fishery

Double Attached is one of the most commonly used conventional ground gear which consists of two ropes attached to each other with a 3.5mm diameter polypropylene (PP) rigging twine. The overall ground gear is 39m long. The fishing line is 22mm diameter made of nylon material and the footrope is 28mm diameter made up of combination of lead and nylon with extra chain and lead on it. DA is rigged with 60 pieces of lead (1,15kg/m) and 8mm diameter mid-link chain (2,9kg/m). The gap between fishing line and the footrope is roughly 7-8cm in the air. Fishers use this one in order to reduce marine debris entering through the mouth and protect the trawl net while fishing on the rough grounds.



The Mersin Bay in which continental shelf is relatively large offers a very productive fishing grounds for bottom trawling which is most efficient fishing method to catch demersal fish and crustacean species.

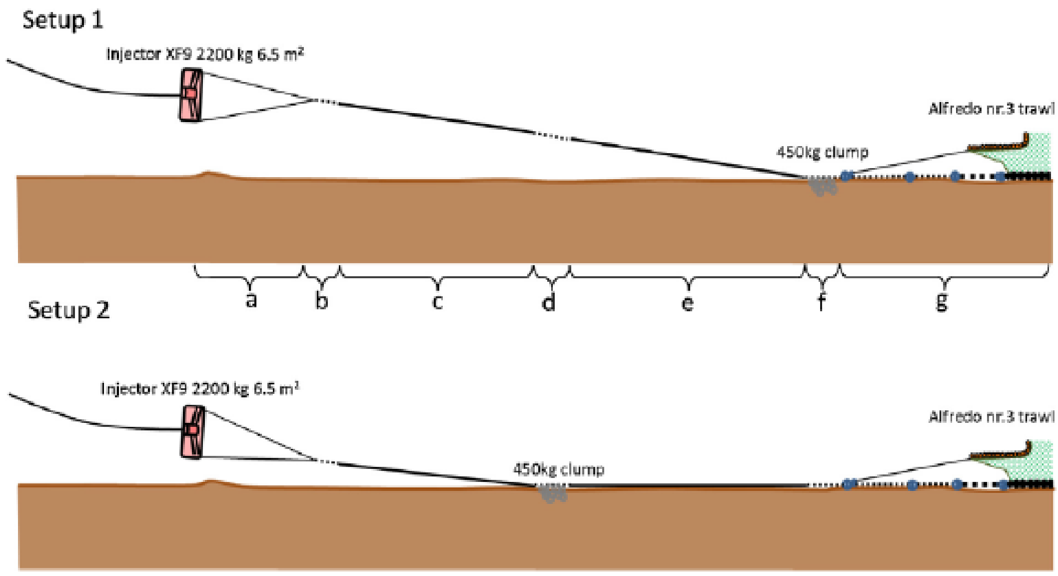
Vessel size (m): 17,33 ± 4,01
Engine size (HP): 403,7±107,5
Single or twin-trawls: Single
Towing speed (knot): 2,7±0,07
Target species: Red mullet, prawns, brushtooth lizardfish, common pandora

Bridle/Sweep material: Nylon+lead combination, (160-200m)
Otter board type: Flat rect. (100-120kg)

Project title: Fish Behaviour in Trawl Mouth and Effect of Lead Line Modifications on Species Selectivity – TABADKUM
This project is funded by TÜBİTAK – 1150647
Contact: emrefakioglu@gmail.com
TABADKUM

6.28. Factsheet code RHK 10 (Table 6.1., ref. 28)

Effect of lifting the sweeps on bottom trawling catch efficiency: Astudy based on the Northeast arctic cod (*Gadus morhua*) trawl fishery



Schematic view of the gear used during the sea trials. (a) 15.9 m backstrop, (b) 3 m backstrop extension, (c) 30 m of 30 mm sweep, (d) 4 m of 19 mm chain (attaching position for the clumps), (e) 45 m of 30 mm sweeps, (f) 4 m of 19 mm chain (attaching position for the clumps), (g) 45 m of ground gear composed of 19 mm chain (32 mm chain closest to the rockhopper), and the rockhopper.

Fuel consumption and environmental concerns have led bottom trawlers fishing for cod (*Gadus morhua*) in the Barents Sea to use semi-pelagic doors. In this study we compared the catch efficiency of two different setups where the sweep length with bottom contact was different. This setup also enabled us to estimate the herding efficiency of the sweeps on the seabed. We estimated that the setup with the lifted sweeps captured on average 33% fewer cod than the setup that kept the sweeps at the seabed. The loss of catch for cod was length independent and significant for a length span between 41 and104 cm. When sweeps were lifted above the seabed, herding was negatively impacted and fish were lost; in contrast, when on the seabed, the sweeps were able to herd (on average) 45% of the cod into the catch zone of the gear. Lifting the trawl doors from the seabed is touted as a positive development for this fishery. However, our results show that lifting the doors and consequently the sweeps can lead to substantial catch losses. Finally, the study highlights the importance of carefully evaluating the positive and negative potential consequences of introducing changes in a fishing gear.

Vessel size:	64 m
Engine BHp:	4080
Single or twin-trawls:	single
Towing speed:	2.0 ms^{-1}
Target species:	Cod

Bridle lengths:	28m
Sweep length:	116m
Bridle/Sweep material:	upper bridle – 18 mm wire, lower bridle – 19 mm chain sweeps – 32 mm wire
Otter board type:	Semi-pelagic Injector XF9
Otter board area and weight:	7.5 m2 (2850 kg)
Other:	450kg weight placed at the 46 and 90 m in front of the footrope (rockhopper).

https://www.sciencedirect.com/science/article/pii/S0165783615000363

SINTEF

SINTEF Ocean, N-7465 Trondheim

UiT The Arctic University of Norway, N-9037 Tromsø

7. Brief summaries on “groundgear” literature

In this section we add resumes of some reports describing studies and results from various types of bottom trawls. A list of references are given below and reflects work done in various parts of the area covered by ICES. The effect of trawling on the seabed and mitigation measures to reduce impact from bottom trawling is described in detail in a recent textbook[16].

Axelsen, B.E. and Johnsen, E., 2014. An evaluation of the bottom trawl surveys in the Benguela Current Large Marine Ecosystem. Fisheries Oceanography.

Brinkhof, J., Larsen, R. B., Herrmann, B., Grimaldo, E., 2017. Improving catch efficiency by changing ground gear design: Case study of Northeast Atlantic cod (*Gadus morhua*) in the Barents Sea bottom trawl fishery. Fisheries Research, 186, 269-282, http://dx.doi.org/10.1016/j.fishres.2016.10.008

Dahm, E., Wienbeck, H., 1992. Escapement of fish underneath the groundrope of a standard bottom trawl used for stock assessment purposes in the North Sea. ICES CM/B: 20

Endres, C., Jones, N., Rillahan, C., Bendiksen, T., Magalnaes, M., Roman, S. and He. P., 2014. Testing of Modified Groundgear to Reduce Capture of Yellowtail Flounder (*Limanda ferruginea*) and Sublegal Atlantic Cod (*Gadus morhua*) in the Georges Bank Multispecies Otter Trawl Fishery. Technical report, National Marine Fisheries Servcice, Office of Sustainable Fisheries, Bycatch Reduction Engineering Program (BREP 1), pp. 9-16.

Engås, A., Godø, O. R., 1989. Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. ICES Journal of Marine Science: Journal du Conseil, 45(3), 269-276. doi: 10.1093/icesjms/45.3.269 62

Gjøsund, S.H., Hansen, K., Sistiaga, M., Grimaldo, E., 2012. MultiSEPT – Initial model scale tests of traditional and alternative trawl ground-gears. SINTEF Report A23318, 34 pp.

Godø, O. R., Walsh, S. J., 1992. Escapement of fish during bottom trawl sampling — implications for resource assessment. Fisheries Research, 13(3), 281-292. doi: http://dx.doi.org/10.1016/0165-7836(92)90082-5

Grimaldo, E., Sistiaga, M., Larsen, R. B., Tatone, I., Olsen, F., 2013. MultiSEPT - Full scale tests of the semicircular spreading gear (SCSG). SINTEF Report No. A24271, 23 pp. 63

Hammond, C., Conquest, L.L., Rose, C. S., 2013. Using reflex action mortality predictors (RAMP) to evaluate if trawl gear modifications reduce the unobserved mortality of Tanner crab (*Chionoecetes bairdi*) and snow crab (*C. opilio*). *ICES J Mar Sci*; 70 (7): 1308-1318

Hannah, R. W., Jones, S. A., 2000. By-catch reduction in an ocean shrimp trawl from a simple modification to the trawl footrope. Journal of Northwest Atlantic Fishery Science, 27, 227-234.

[16] He, P., Winger, P.D., 2010. Effect of trawling on the seabed and mitigation measures to reduce impact, in: He, P., (Ed.). Behavior of marine fishes: capture processes and conservation challenges. Ames, Iowa: Wiley-Blackwell, pp. 295-314

Hannah, R. W., Jones, S. A., 2003. Measuring the height of the fishing line and its effect on shrimp catch and bycatch in an ocean shrimp (*Pandalus jordani*) trawl. Fisheries Research, 60(2), 427-438, http://dx.doi.org/10.1016/S0165-7836(02)00138-8

He, P., Rillahan, C. and Balzano, V., 2015. Reduced herding of flounders by floating bridles: application in Gulf of Maine Northern shrimp trawls to reduce bycatch. ICES Journal of Marine Science, 72 (5), 1514–1524. doi:10.1093/icesjms/fsu235.

Ingólfsson, Ó. A., Jørgensen, T., 2006. Escapement of gadoid fish beneath a commercial bottom trawl: Relevance to the overall trawl selectivity. Fisheries Research, 79(3), 303-312. doi: http://dx.doi.org/10.1016/j.fishres.2005.12.017

Krag, L. A., Holst, R., Madsen, N., Hansen, K., Frandsen, R. P., 2010. Selective haddock (*Melanogrammus aeglefinus*) trawling: Avoiding cod (*Gadus morhua*) bycatch. Fisheries Research, 101(1–2), 20-26. doi: http://dx.doi.org/10.1016/j.fishres.2009.09.001

Lomeli, M. J. M. W., Wakefield, W. and Herrmann, B. 2018. Illuminating the headrope of a Selective Flatfish Trawl: Effect on Catches of Groundfishes, Including Pacific Halibut. Marine and Coastal Fisheries. https://doi.org/10.1002/mcf2.10003.

Nguyen, T. X., Winger, P. D., Legge, G., Dawe, E. G., Mullowney, D. R., 2014. Underwater observations of the behaviour of snow crab (*Chionoecetes opilio*) encountering a shrimp trawl off northeast Newfoundland. Fisheries Research, *156*, 9-13, http://dx.doi.org/10.1016/j.fishres.2014.04.013

Pol, M. & Carr, H.A. 2000. Overview of gear developments and trends in the New England commercial fishing industry. Northeastern naturalist, 7(4): 329-336.

Rose, C S. 1999. Injury rates of red king crab, *Paralithodes camtschaticus*, passing under bottom-trawl footropes. Marine Fisheries Review 61.2, 72-76.

Rose, C. S., Gauvin, J. R., Hammond, C. F., 2010. Effective herding of flatfish by cables with minimal seafloor contact. Fishery Bulletin, 108(2), 136-145.

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R. B., Tatone, I., 2015. Effect of lifting the sweeps on bottom trawling catch efficiency: A study based on the Northeast arctic cod (*Gadus morhua*) trawl fishery. Fisheris Research, 167, 164-173. doi:10.1016/j.fishres.2015.01.015

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R. B., & Tatone, I., 2016. The effect of sweep bottom contact on the catch efficiency of haddock (*Melanogrammus aeglefinus*). Fisheries Research, *179*, 302-307, http://dx.doi.org/10.1016/j.fishres.2016.03.016

Walsh, S. J., 1992. Size-dependent selection at the footgear of a groundfish survey trawl. North American Journal of Fisheries Management, 12(3), 625-633. doi: 10.1577/1548-8675(1992)012<0625:SDSATF>2.3.CO;2

Weinberg, K. L., Munro, P. T., 1999. The effect of artificial light on escapement beneath a survey trawl. ICES Journal of Marine Science: Journal du Conseil, 56(3), 266-274. doi: 10.1006/jmsc.1999.0442

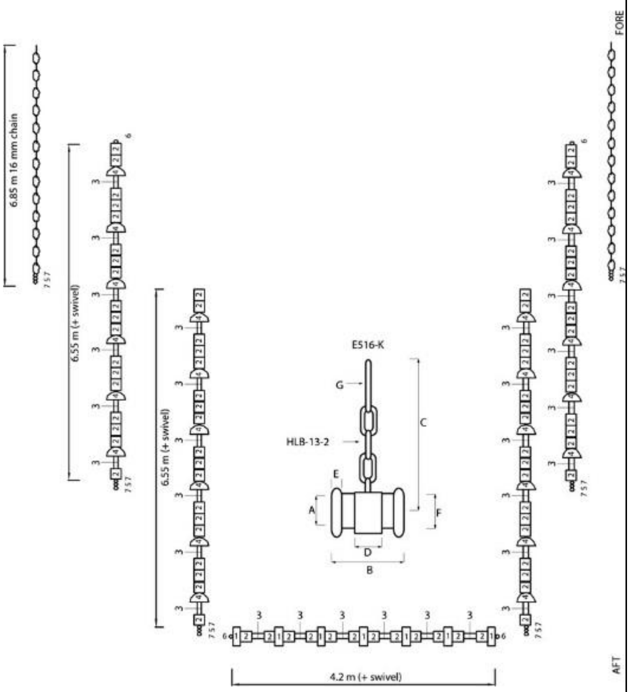
Reference: Axelsen, B.E. and Johnsen, E., 2014. An evaluation of the bottom trawl surveys in the Benguela Current Large Marine Ecosystem. Fisheries Oceanography.

Type/part of ground-gear: Bobbin roller gear for survey trawls

Short description:

Demersal fish, shrimp and cephalopod assemblages on the continental shelves and slopes off Angola, Namibia and the southern and western coasts of South Africa have been monitored in terms of fisheries-independent trawl surveys since the 1980s.

The time series have provided vital input to stock assessments and are widely used in studies of ecology and biodiversity. The objectives of this study were to evaluate the technical specifications of the vessels and trawls used, to examine effects of modifications on catching efficiency, and to assess implications of these modifications over time.



Schematic illustration of the bobbins roller gear of the new *Dr. Fridtjof Nansen*. 1: bobbin discs (Ø: 12″ = 305 mm); 2: spacer (Ø: 170 mm); 3: E516-K centre spacer (F) and chain (HLB-13-2) unit; 4: Danleno bunt bobbins (Ø: 305 mm); 5: swivel (19 mm); 6: chain (16 mm); 7: swivel-chain fixture. Dimensions of the E516-K spacer and chain unit: A: Ø = 65 mm; B: 200 mm; C: 360 mm; D: 60 mm; E: 19 mm; F: Ø = 83 mm (6.1 kg).

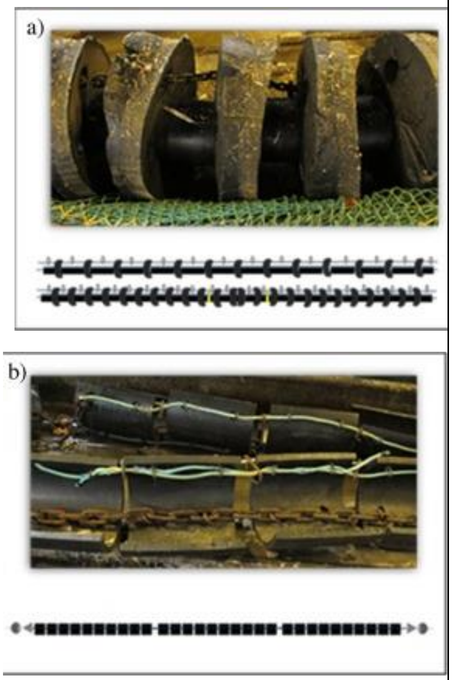
Results/Conclusions: We find that the demersal trawl data collected in South Africa are not comparable with those of Namibia and Angola, and that the time series of Angola and Namibia contain inherent differences in terms of catchability of bottom dwellers. The introduction of smaller bobbins gear on the RV *Dr. Fridtjof Nansen* in 1994 increased the catchability of bottom-dwelling species, and catch rates of monkfish and sole were higher in surveys with commercial vessels than the RV *Dr. Fridtjof Nansen*. We recommend that temporal trends are interpreted with caution and that time series for the three countries are viewed in isolation.

Reference: Brinkhof, J., Larsen, R. B., Herrmann, B., Grimaldo, E., 2017. Improving catch efficiency by changing ground gear design: Case study of Northeast Atlantic cod (*Gadus morhua*) in the Barents Sea bottom trawl fishery. Fisheries Research, 186, 269-282, http://dx.doi.org/10.1016/j.fishres.2016.10.008

Type/part of ground-gear: Rockhopper gear and semicircular spreading gear in commercial trawls

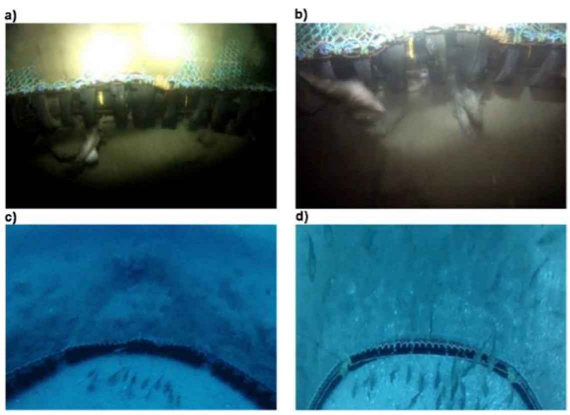
Short description:

The objective of this study was to quantify the escape of cod underneath the fishing line with a conventional rockhopper gear, and compare the results with a new ground-gear; semicircular spreading gear. It is believed that large amounts of fish escape underneath the fishing line and between the discs of the conventional rockhopper gear, causing reduced catch efficiency and high injury rate of the fish overrun. The semicircular spreading gear id believed to increase catching efficiency due to its design, as well as reduce seabed impact since it weighs 1/3 of the total weight of a standard rockhopper gear.



Conventional rockhopper gear (a) and the semicircular spreading gear (b).

Fish reactions diring night and day time in a RH and SCSG groundrope. Photo a show cod escaping beneath the footrope and photo b show cod colliding with rockhopper discs.
Photo c show cod behaviour in front of rockhopper gear during daytime and photo d show cod in front of the semicircle spreading gear durin daytime.

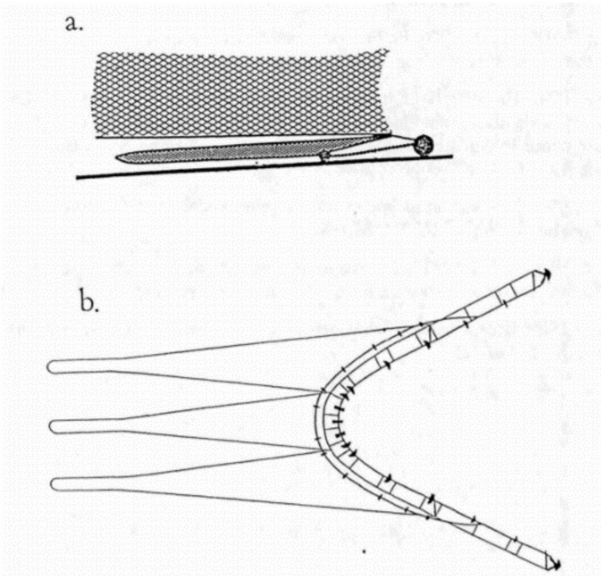


Results/Conclusions: A significant improvement in the catch efficiency was found for the SCSG relative to the rockhopper gear for cod between 56 and 105 cm, as significantly fewer cod escaped under the trawl equipped with the new ground gear. The results demonstrated that ground gear efficiency was length dependent for both ground gear types, as both showed increasing efficiency with increased fish length.

Reference: Dahm, E., Wienbeck, H., 1992. Escapement of fish underneath the groundrope of a standard bottom trawl used for stock assessment purposes in the North Sea. ICES CM/B: 20.

Type/part of ground-gear: Roller gears for survey trawls

Short description:
Recent research work has shown that large quantities offish and shellfish herded by the wings and bridles of survey trawls escape before entering the trawl by diving through the gaps provided by the roller gear. Their numbers and proportions can be assessed according to the method developed by Engås and Godø by attaching a set of so-called bagnets under the footrope and behind the roller gear consisting of two assymmetrical ones under the wings and one symmetrical under the bosom.



Few attention has been paid so far to the fact that this provides four separate sets of data showing the way the chased fishes chose. In the contribution presented it is tried to scrutinize available data sets piled up from German cruises in the North Sea for escape patterns of different species, to see if accumulations can be detected and to link this to known behaviour ofsingle species towards mowing objects.

Three main strategies were detected: 1 (stay and hide), 2 Gump as high as possible and escape) and 3 (stay ahead of the danger and look for an escape opportunity). The results of bagnet experiments and the distributions among the bagnets are influenced by constructional properties of the roller gear and the number of fish present.

Results/Conclusions: It is reasonable to assurne a significant effect of different types of roller gear only with fishes of the last type of reaction. But to which extent and where do fish of the reaction type III escape when an appropriate footgear lifts the fishing line upwards? When comparing the escape reactions of the same species towards the three trawl type mentioned this can be answered satisfactoryly. Cod shall serve as an example for this.

It is now already five years aga that during the Congress on Fish Behaviour in Relation to Fishing Gear (Bergen 1992) voices were heard claiming that commercial fishing gear is inappropriate for stock assessment sampling of a lot ofspecies and should be replaced by gear specially adapted to this purpose. Very few attempts to solve this problem by increasing the chasing properties of the bosom section of the footgear have been reported. Fishing gear teclmologists should be encouraged to do this in the future. The separate analysis of synchrononous trawl and bagnet catches offers one of the means to test the efficiency of such improvements.

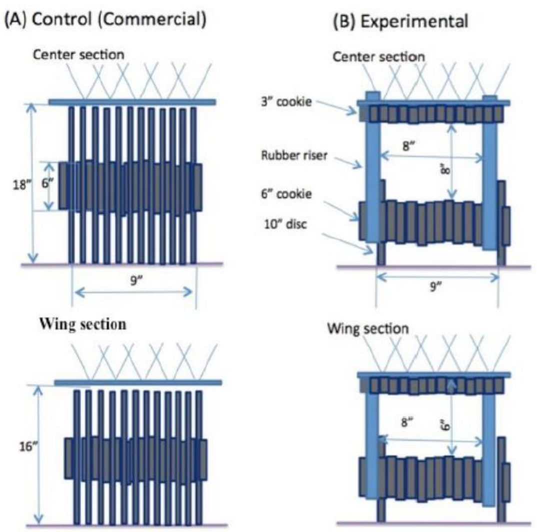
Reference: Endres, C., Jones, N., Rillahan, C., Bendiksen, T., Magalnaes, M., Roman, S. and He. P., 2014. Testing of Modified Groundgear to Reduce Capture of Yellowtail Flounder (*Limanda ferruginea*) and Sublegal Atlantic Cod (*Gadus morhua*) in the Georges Bank Multispecies Otter Trawl Fishery. Techn. report, National Marine Fisheries Servcice, Office of Sustainable Fisheries, Bycatch Reduction Engineering Program (BREP 1), pp. 9-16.

Type/part of ground-gear: Modified rockhopper gear with cookie

Short description: A modified groundgear with 8 inch by 8 inch “escape windows” in the center and 8 inch by 6 inch in the wings was tested with the aim to reduce the catch of yellowtail flounder and juvenile cod.

Fishing on Georges Bank faces great challenges due to low stock abundances for many species including Atlantic cod (*Gadus morhua*) and yellowtail flounder (*Limanda ferruginea*) that often inhabit the same area and caught together.

The discards represent a direct economic loss to the fishermen and waste of valuable resource since mortality can be high for these individuals. One method of reducing discards is to modify fishing gears so that they are more selective. This project evaluated the modification to the groundgear of a multispecies trawl and its effect on the retention of cod and yellowtail flounder.



Comparative fishing trials were conducted with F/V “Hera” on Georges Bank in June 2013. The modified groundgear showed a 67% reduction in yellowtail flounder catch and a 37% reduction in sublegal cod catch compared to a traditional rockhopper groundgear.

Fig. 1. Schematic drawing of the groundgear and escape window configurations. A is the commercial control groundgear and B is the modified experimental groundgear.

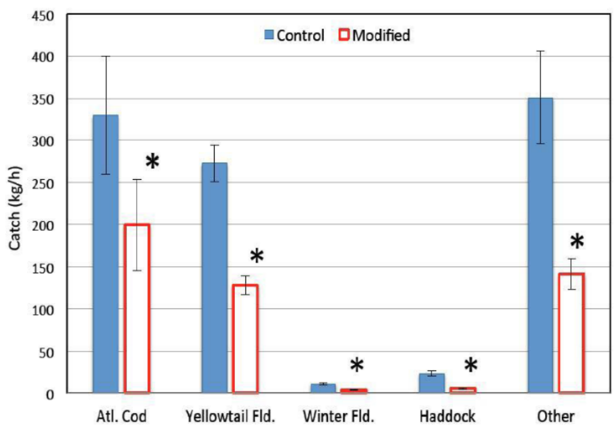


Fig. 2. The average catch rates of target and non-target species. (mean ± SEM). The ‘Other’ category include skates, spiny dogfish, lobster, halibut, butterfish, cunner, American plaice, sand dab, witch, and summer flounder, longhorn sculpin, monkfish, ocean pout, sea raven, and Pollock. *denotes significant difference.

Results/Conclusions: The modified gear reduced overall bycatch by 61% when compared to the control net. However, the reduction in legal-sized cod (39%) makes the modification commercially unviable at the current fishing regime. As fishing condition changes with the time and management measures, understanding of the effect of gear design on catch of different species and sizes is valuable for future implementation and further research.

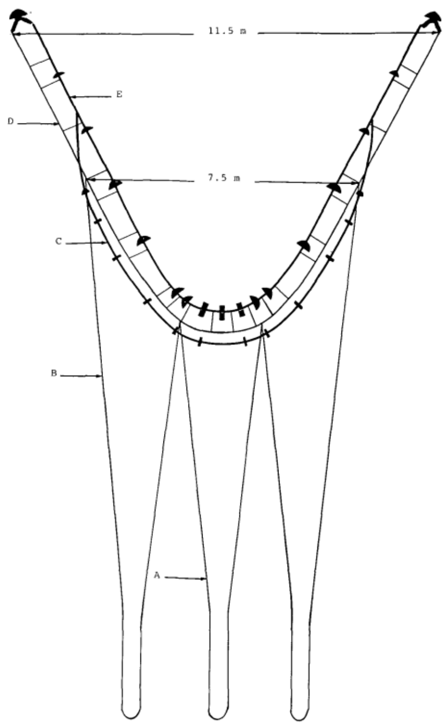
Reference: Engås, A., Godø, O. R., 1989. Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. ICES Journal of Marine Science: Journal du Conseil, 45(3), 269-276. doi: 10.1093/icesjms/45.3.269 62

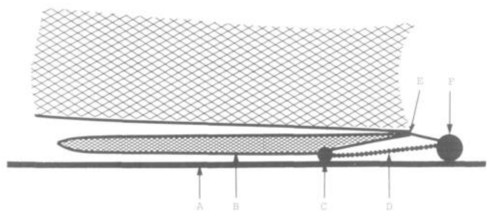
Type/part of ground-gear: Bobbins gear and rockhopper gear in survey trawls

Short description: The study compares the escape of fish underneath a survey trawl with a bobbins gear (which was standard at that time) and a trawl equipped with a rockhopper gear

The Institute of Marine Research, Bergen, has carried out combined bottom-trawl and acoustic surveys for cod and haddock in the Barents Sea and the Svalbard area since 1981. The results have demonstrated clearly that the current trawl and acoustic survey methods considerably underestimate the young age groups of cod, partly because of low gear efficiency for the smaller fish.

This paper describes the results of experiments with small bags to collect fish that escape under the trawl. Catches of several different species were obtained in the small bags. Comparison between trawl and bag catches reveals a length-dependent escape of cod and haddock under the trawl; i.e., small fish are severely underrepresented in the trawl catches. The escape also has a considerable effect on the species composition, because cod, more than haddock, tend to dive under the fishing line. To improve the efficiency of the sampling trawl, a rockhopper ground gear was introduced. Comparison of the trawl fitted with standard bobbins gear and with rockhopper gear showed that escape under the standard equipment was of similar magnitude as that in the bag experiment.





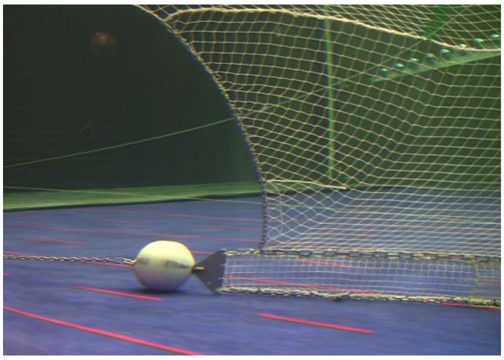
Results/Conclusions: It is thus indicated that the escape of cod and haddock under the trawl is an
important obstacle to representative sampling of Northeast Arctic cod and haddock throughout the year and in
their main area of distribution

Reference: Gjøsund, S.H., Hansen, K., Sistiaga, M., Grimaldo, E., 2012. MultiSEPT – Initial model scale tests of traditional and alternative trawl ground-gears. SINTEF Report A23318, 34 pp.

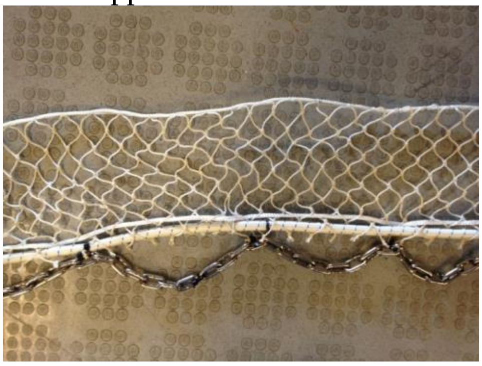
Type/part of ground-gear: Rockhopper gear, skirt and modified skirts, modified plate gears, semicircular spreading gear tested in a flume tank (model scale)

Short description: This report describes different ground gears tested in a model scale in a flume tank. The ground gears tested where traditional rockhopper gear, skirt and modified skirts, modified plate gears including the semicircular spreading gear. The tension on the lower sweeps, headline and fishing line was measured during the experiments.

Rockhopper



Skirt



Modified skirt with bungie

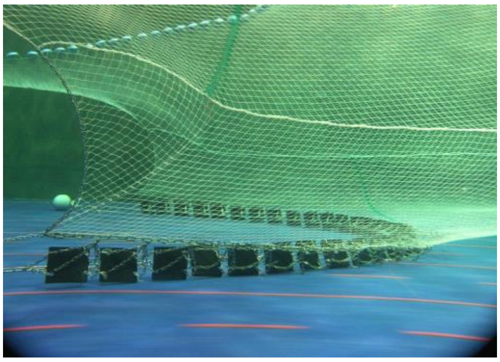
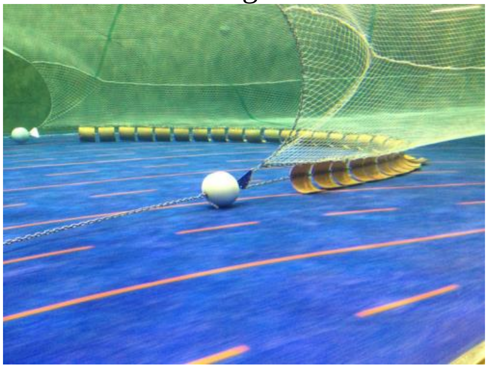


Plate gear

Modified plate gear



Semicircular spreading gear

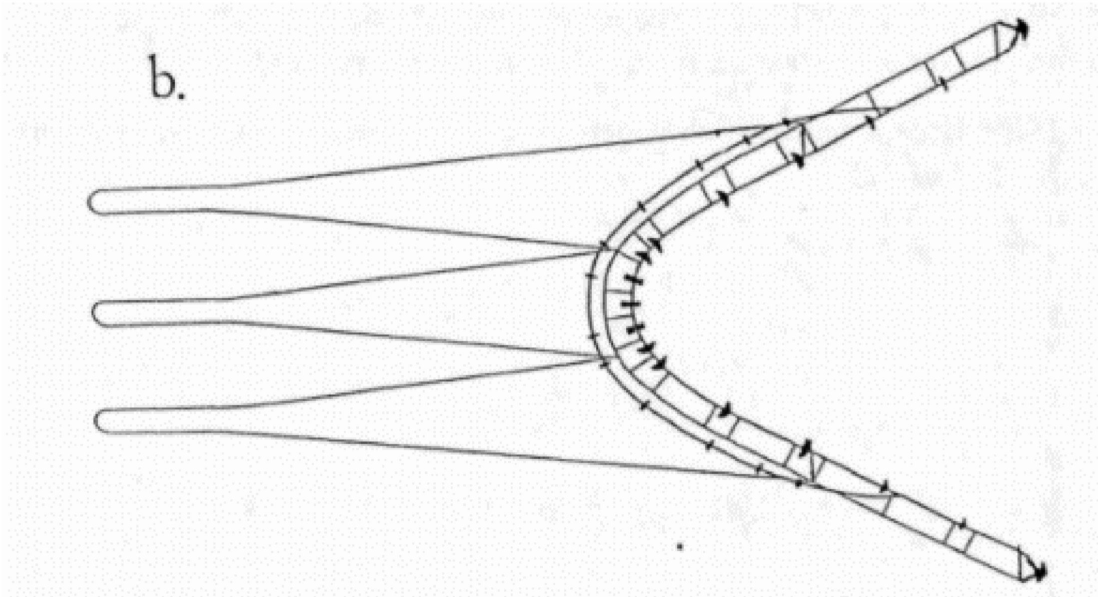
Results/Conclusions: The results demonstrated reduced towing resistance when applying skirts compared to a rockhopper gear. The semicircular spreading gear gave also promising results.

Reference: Godø, O. R., Walsh, S. J., 1992. Escapement of fish during bottom trawl sampling — implications for resource assessment. Fisheries Research, 13(3), 281-292. doi: http://dx.doi.org/10.1016/0165-7836(92)90082-5

Type/part of ground-gear: Bobbins rigged ground gear in survey trawls

Short description:
This study addresses the escapement of groundfish underneath survey trawls, and compares Norwegian and Canadian data on the size dependent escapement of cod and long-rough dab.

In recent years studies of escapement of groundfish species such as cod, haddock and flatfish underneath the net of survey trawls have indicated common problems in Norwegian and Canadian surveys. In this paper we compare Norwegian and Canadian data on size-dependent escapement of cod and long rough dab, species common to both areas of investigation. Although survey trawls and experimental designs differ between the two countries, the similarities in the results are striking. Trawl net efficiency estimates showed that bobbin-rigged trawls used by both countries contribute significantly to escapement, resulting in considerable variability in estimates of pre-recruits. This variability is discussed in terms of its implications for resource assessments.

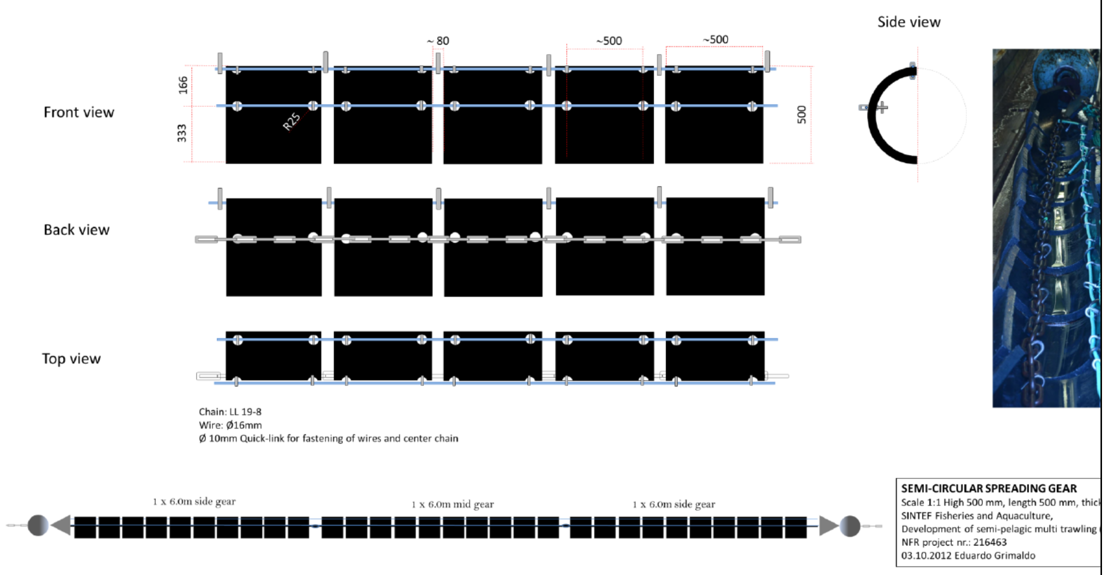


Results/Conclusions: The study demonstrated striking similarity between the data from the two countries. The results show a considerable length dependent escapement and addresses the potentne4ial implications for stock assessment.

Reference: Grimaldo, E., Sistiaga, M., Larsen, R. B., Tatone, I., Olsen, F., 2013. MultiSEPT - Full scale tests of the semicircular spreading gear (SCSG). SINTEF Report No. A24271, 23 pp. 63

Type/part of ground-gear: Semicircular spreading gear

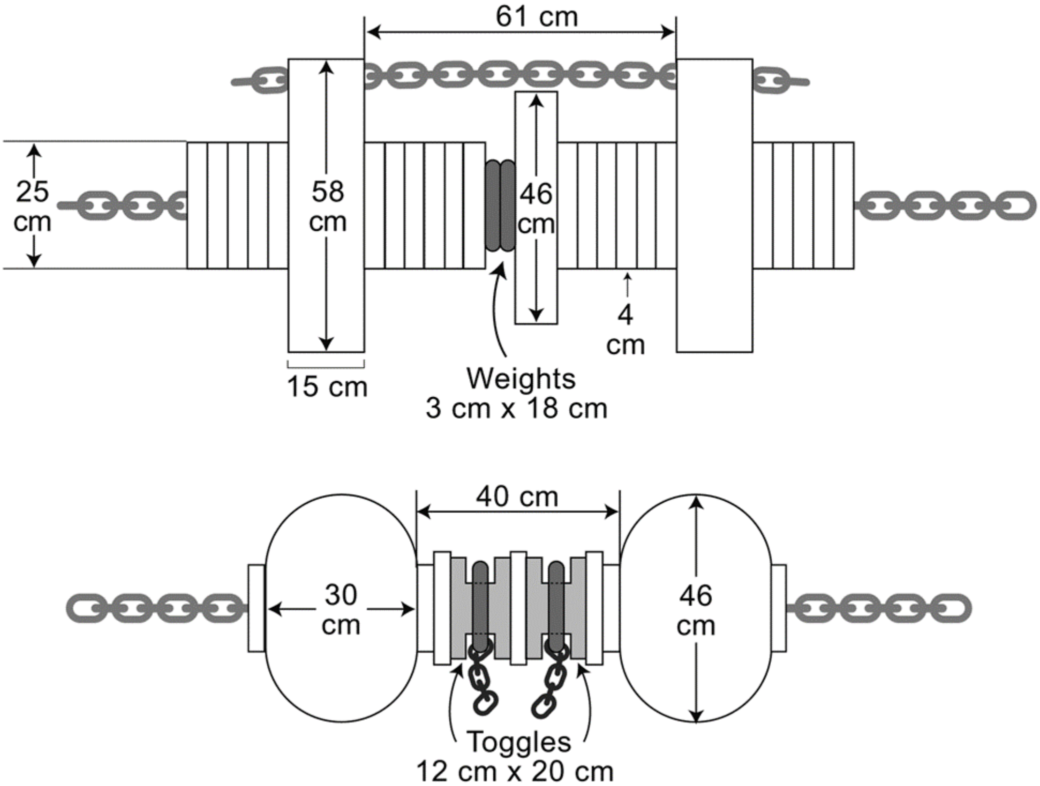
Short description: This report describes full-scale test with the semicircular spreading gear (SCSG). During the test the spreading and the bottom contact was monitored. The fishing efficiency was assessed by comparing the size distribution.



Results/Conclusions: The results showed that the spreading (distance between wing-ends) was approximately 7 % higher with the SCSG than with the rockhopper gear for the same door spreading. The SCSG had good bottom contact and passed bottom obstacles (e.g. stones) easily. The size distribution of fish caught with the SCSG was similar to that caught with the rockhopper, but apparently more cod (over 65 cm) and more haddock (of all sizes) was caught by this gear. However, the number of hauls performed with the SCSG and with the rockhopper was too small to draw a clear conclusion on catch efficiency.

The SCSG is a gear that is easy to rig and handle on deck, it does not require accurate adjustments, it has few control points, it has low weight and the results indicate that its performance at sea is comparable or better than the rockhopper gear for the given bottom conditions.

Reference: Hammond, C., Conquest, L.L., Rose, C. S., 2013. Using reflex action mortality predictors (RAMP) to evaluate if trawl gear modifications reduce the unobserved mortality of Tanner crab (*Chionoecetes bairdi*) and snow crab (*C. opilio*). *ICES J Mar Sci*; 70 (7): 1308-1318. doi: 10.1093/icesjms/fst085
Type/part of ground-gear: Bobbins gear and modified rockhopper gear combined with conventional sweeps and modified off-bottom sweeps
Short description: This study aimed to document and reduce the unobserved mortality of two crab species by modifying both the ground gear and the sweeps. The alternative ground gear, a rockhopper gear consisted of larger and narrower discs and was compared to a conventional bobbins gear. The modified sweeps contained discs which elevated the sweeps off the seabed, compared to conventional sweeps.



Modified rockhopper gear (upper), conventional bobbins gear (lower).

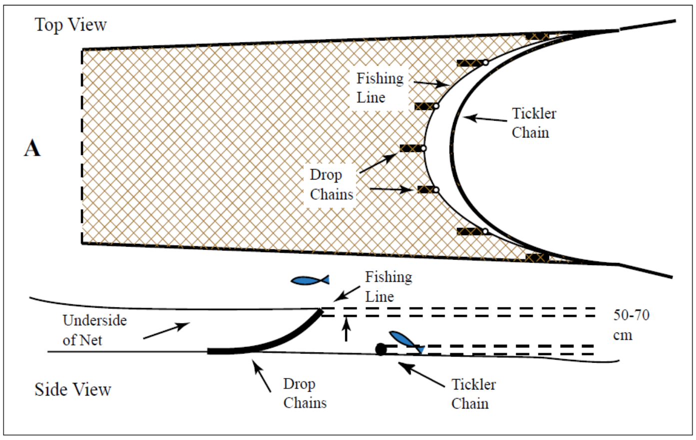
Results/Conclusions: The results presented in the study concluded that the alternative ground gear reduced mortality from 11.4 to 7.2% for Tanner crab and from 9.7 to 5.0% for snow crab. The elevated sweeps reduced mortality from 4.1 to 1.0% for Tanner crab and from 4.9 to 0.0% for snow crab.

Reference: Hannah, R. W., Jones, S. A., 2000. By-catch reduction in an ocean shrimp trawl from a simple modification to the trawl footrope. Journal of Northwest Atlantic Fishery Science, 27, 227-234.

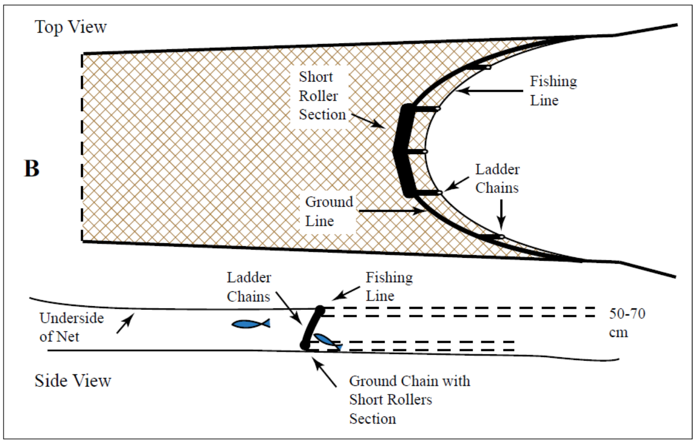
Type/part of ground-gear: Tickler chain, ladder chain/roller gear.

Short description: This study compares two footrope configurations with regard to bycatch in the shrimp trawl fishery for *Pandalus jordani*. The conventional tickler chain runs in front of the fishing line and was thus believed to cause increased catches of fish. Therefore, a new ground gear, i.e.; The ladder chain with a short roller gear in the center that was position under/slightly behind the fishing line was believed to reduce the catches of fish compared to the tickler chain footrope.

A: Configuration with tickler and drooped chain

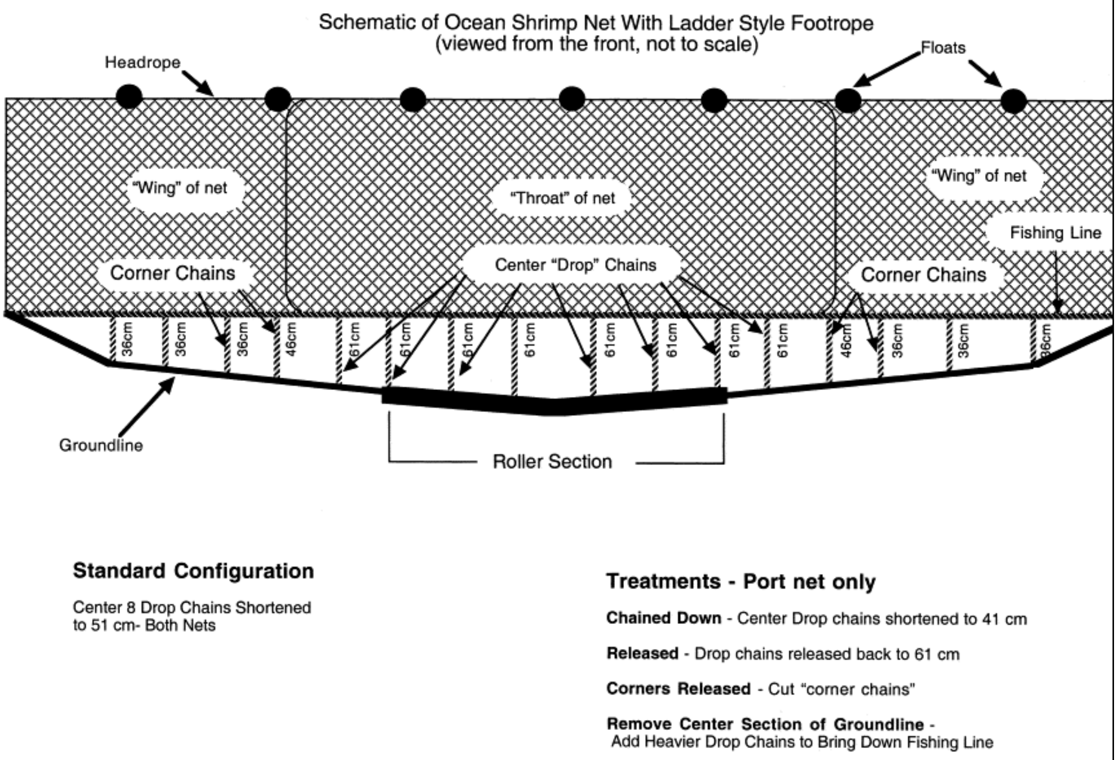


B: Configuration with ladder chain and centre roller gear



Results/Conclusions: The study reports that compared to the tickler chain the the ladder chain with the roller gear in the center caught 84% fewer slender sole (*Eopsetta exilis*), 49% fewer greenstriped rockfish (*Sebastes elongatus*) and 47% fewer juvenile rockfish (*Sebastes* spp.). Shrimp catch was increased by 6% in the ladder trawl (compared to the control gear).

Reference: Hannah, R. W., Jones, S. A., 2003. Measuring the height of the fishing line and its effect on shrimp catch and bycatch in an ocean shrimp (*Pandalus jordani*) trawl. Fisheries Research, 60(2), 427-438, http://dx.doi.org/10.1016/S0165-7836(02)00138-8
Type/part of ground-gear: Fishing line height and semi-pelagic trawling with a ladder chain footrope
Short description: This study investigated the relationship between the height of the fishing line above the seabed with regard to shrimp catch and bycatch in a semi-pelagic shrimp trawl fishery for *Pandalus jordani*.

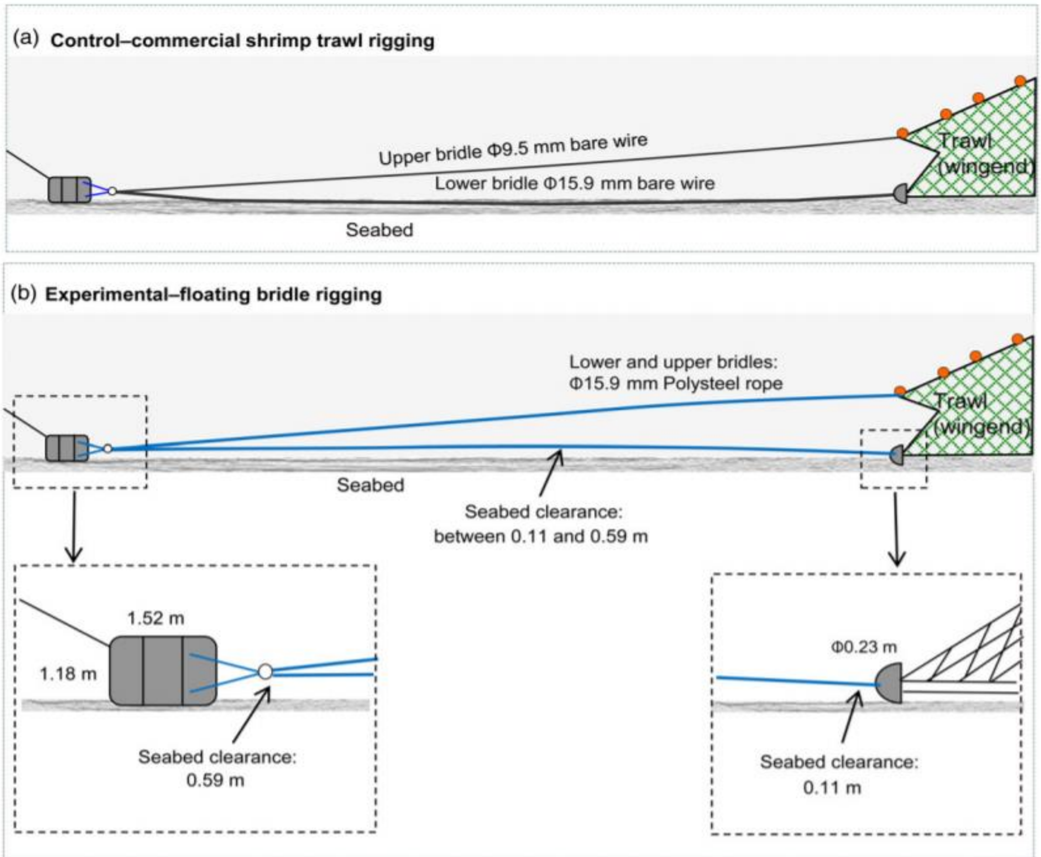


Results/Conclusions: Shrimp catch and the bycatch of flatfish and juvenile rockfish varied inversely with height of the fishing line, suggesting that the height of the fishing line can be adjusted to equalize the catch of shrimp, flatfish and juvenile rockfish.

Reference: He, P., Rillahan, C. and Balzano, V., 2015. Reduced herding of flounders by floating bridles: application in Gulf of Maine Northern shrimp trawls to reduce by-catch. ICES Journal of Marine Science, 72 (5), 1514–1524. doi:10.1093/icesjms/fsu235.

Type/part of ground-gear: Floating bridles (and sweeplines)

Article abstract: We hypothesized that a floating trawl bridle that does not contact the seabed would reduce the herding of fish, especially bottom dwelling flounders, and thus reduce bycatch of these fish in shrimp trawls. We further hypothesized that, due to the non-herding nature of northern shrimp (*Pandalus borealis*), the use of an off-bottom floating bridle would not reduce shrimp catch. These hypotheses were tested in the field by comparing a trawl with regular bottom-tendering wire bridles and the same trawl with floating synthetic bridles in the Gulf of Maine northern

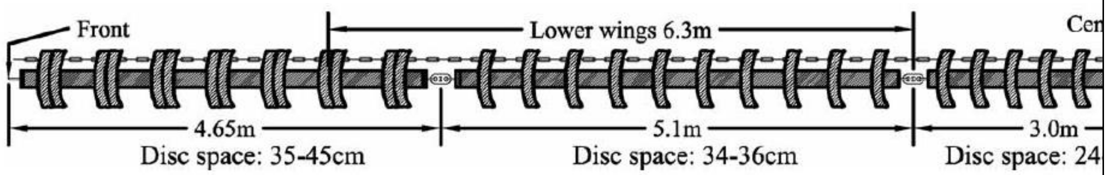


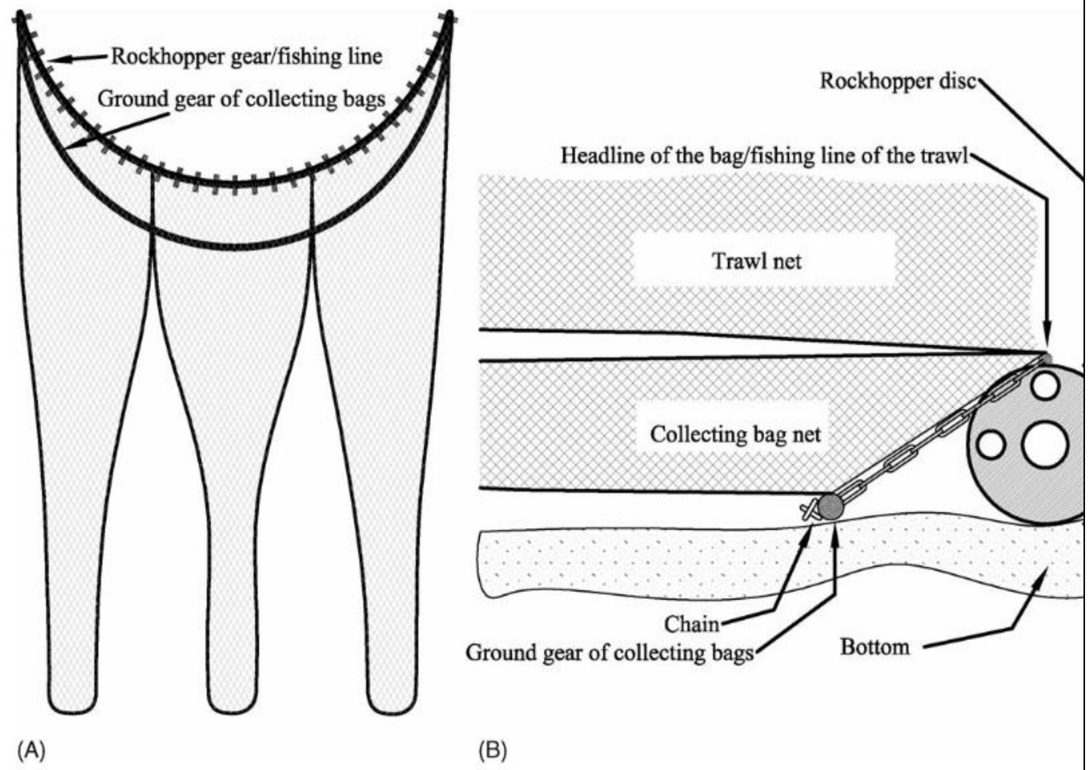
shrimp fishery.

The most important reduction was the catch of juvenile An analysis of length frequencies for the targeted shrimp and major bycatch species revealed no size-related selection between the gears with regular bridles and floating bridles. The reductions in flounder bycatch indicate reduced herding of benthic species when the bridles are kept off bottom. This easy modification may be readily adopted in the northern shrimp fisheries in the North Atlantic, and can also possibly be applied in other shrimp and prawn fisheries with further experimentation.

Results/Conclusions: As expected, no statistically significant differences in catch rates and size were found for the targeted northern shrimp (146.3+10.58 kg h^{-1} control vs. 140.8+9.35 kg h^{-1} , $p = 0.13$). Total finfish bycatch was reduced by 14.9%, and the difference was statistically different ($p = 0.01$).

Reference: Ingólfsson, Ó. A., Jørgensen, T., 2006. Escapement of gadoid fish beneath a commercial bottom trawl: Relevance to the overall trawl selectivity. Fisheries Research, 79(3), 303-312. doi: http://dx.doi.org/10.1016/j.fishres.2005.12.017
Type/part of ground-gear: Rockhopper ground gear in commercial trawls
Short description: This study investigated the escapement og cod, haddock and saithe under a commercially rigged bottom trawl with a rockhopper ground gear with Ø60 cm discs in the Barents Sea. Three small meshed collecting bags (A) was attached behind the groundgear (B).
Results/Conclusions: The results demonstrated a highly length depended escapement of cod. The results were less pronounced for haddock ant not length depended for saithe.

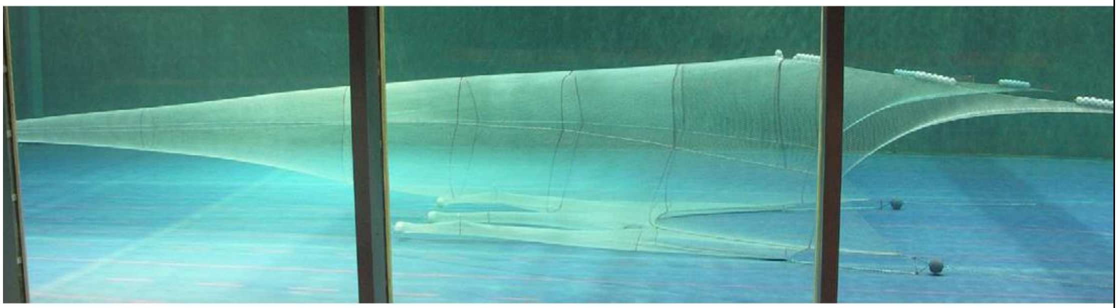




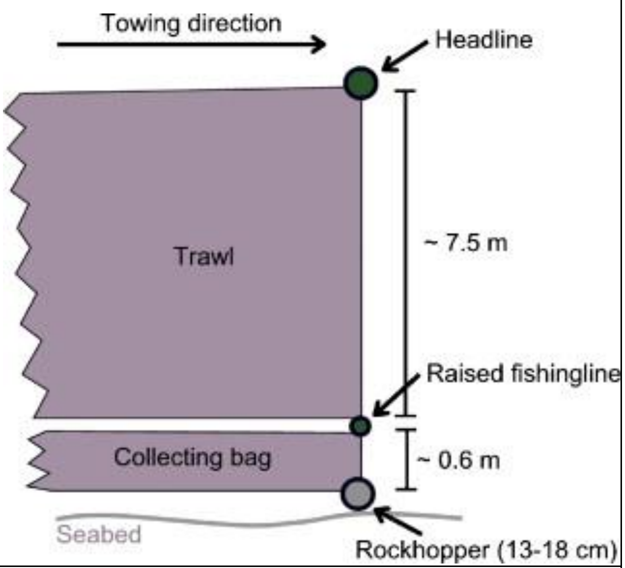
Reference: Krag, L. A., Holst, R., Madsen, N., Hansen, K., Frandsen, R. P., 2010. Selective haddock (*Melanogrammus aeglefinus*) trawling: Avoiding cod (*Gadus morhua*) bycatch. Fisheries Research, 101(1–2), 20-26. doi: http://dx.doi.org/10.1016/j.fishres.2009.09.001

Type/part of ground-gear: Raised fishing line in commercial trawls

Short description:



In a mixed fishery, owing quotas for only a few species makes fishing difficult. This is the vase in the North Sea bottom trawl fishery for cod and haddock. Using the behavioral differences between the two species (cod seeks an escape route downwards, while haddock upwards), this study investigates the effect of rising the fishing line 60 cm above the seabed.



Results/Conclusions: The results demonstrated that lifting the fishing line 60 cm above the seabed reduced the catches of cod by 55% during the day and 82% during the night. Compared to regular rigging the haddock catches were 99 % during the day and 89% at night.

Reference: Lomeli, M. J. M. W., Wakefield, W. and Herrmann, B. 2018. Illuminating the headrope of a selective flatfish trawl: Effect on catches of groundfishes, including Pacific halibut. Marine and Coastal Fisheries. https://doi.org/10.1002/mcf2.10003

Type/part of ground-gear: Rockhopper with green LED lamps along the headline

Short description:

This study evaluated how illuminating the headrope of a selective flatfish trawl can affect catches of groundfishes, including Pacific Halibut *Hippoglossus stenolepis*, in the U.S. West Coast limited-entry (LE) groundfish bottom trawl fishery. Over the continental shelf, fishermen engaged in the LE bottom trawl fishery target a variety of flatfishes, roundfishes, and skates.

Green LED fishing lights (Lindgren-Pitman Electralume) were used to illuminate the headrope. The lights were grouped into clusters of three, with each cluster attached ~1.3 m apart along the 40.3-m-long headrope. Catch comparisons and ratios of mean fish length classes were compared between tows conducted with (treatment) and without (control) LEDs attached along the trawl head-rope.

Images of an LED cluster attached **(A)** near the center of the trawl headrope on the starboard side and **(B)** along the wing tip on the port side, and their orientations.

Fewer Rex Sole *Glyptocephalus zaphirus*, Arrowtooth Flounder *Atheresthes stomias*, and Lingcod *Ophiodon elongatus* were caught in the treatment than in the control trawl, though not at a significant level. Pacific Halibut catches differed between the two trawls, with the treatment trawl catching an average of 57% less Pacific Halibut. However, this outcome was not significant due to a small sample size. For Dover Sole *Microstomus pacificus* 31–44 cm in length and Sablefish *Anoplopoma fimbria* 43–61 cm in length, significantly fewer fish were caught in the treatment than in the control trawl. On average, the treatment trawl caught more rockfishes *Sebastes* spp., English Sole *Parophrys vetulus*, and Petrale Sole *Eopsetta jordani*, but not at a significant level.

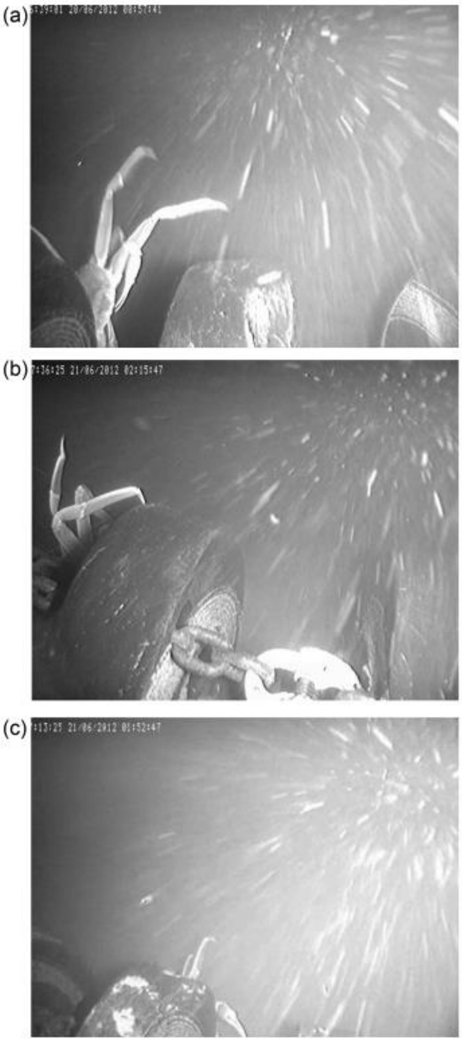
Results/Conclusions: These findings show that illuminating the headrope of a selective flatfish trawl can affect the catch comparisons and ratios of groundfishes, and depending on fish length and species the effect can be positive or negative.

Reference: Nguyen, T. X., Winger, P. D., Legge, G., Dawe, E. G., Mullowney, D. R., 2014. Underwater observations of the behaviour of snow crab (*Chionoecetes opilio*) encountering a shrimp trawl off northeast Newfoundland. Fisheries Research, *156*, 9-13, http://dx.doi.org/10.1016/j.fishres.2014.04.013

Type/part of ground-gear: Rockhopper gear

Short description: This study investigated the behavior of snow crab encountering shrimp trawls. Applying video cameras enabled observation of the orientation of the snow crabs, reaction behaviour (i.e., direction of movement), and nature of encounter (i.e., different types of encounters, duration of encounter, and fate of encounter).

Article abstract: Trawl-mounted video camera observations were conducted to understand how individual snow crabs (*Chionoecetes opilio*) interact with the rockhopper footgear components of a traditional inshore shrimp trawl used in Newfoundland and Labrador, Canada. Observations of individual snow crab interactions with different footgear components were recorded and evaluated including their orientation, reaction behaviour (i.e., direction of movement), and nature of encounter (i.e., different types of encounters; duration of encounter, and fate of encounter). The analysis demonstrated that snow crabs were quickly overtaken by the approaching trawl and about 54% of the crabs observed experienced an encounter with the footgear (either disc or spacer/chain). The study also revealed that the majority of the crabs observed appeared to be aware of the trawl and were actively responding and/or reacting to the approaching threat. We discuss the impacts of shrimp trawling on the snow crab resource, further research required to better understand the interactions between snow crab and bottom trawls, as well as potential gear modifications to reduce impacts.



Example images showing different types of encounter. (a) The crab got stuck into the disc; (b) the crab was snagged into the spacer/chain; (c) the crab went under the disc.

Results/Conclusions: The results in this study demonstrated that 54% observed in the trawl opening encountered the footgear. Furthermore, the majority of the crabs appeared to be aware of the approaching trawl and responded to the approaching threat.

Reference: Pol, M. & Carr, H.A. 2000. Overview of gear developments and trends in the New England commercial fishing industry. Northeastern naturalist, 7(4): 329-336.

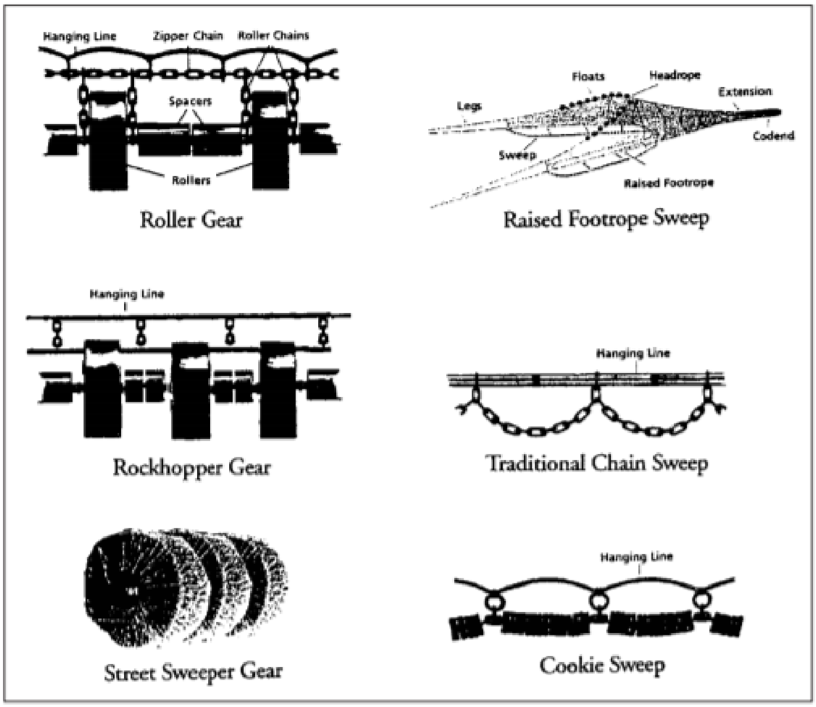
Type/part of ground-gear: Roller gear, raised footrope sweep, rockhopper gear, chain sweep, street sweeper gear (brush gear) and cookie sweep.

Short description: In this article Pol and Carr describes general gear developments in New England (Northwest Atlantic).

Increasing horsepower of boats, a development that affected all fisheries, has led to new designs in the footrope, or sweep of the trawl net (the leading edge of the bottom half of the net opening). The development of different sweeps (and the power and ability to deploy them) has allowed trawlers broader access to fishing grounds. The introduction of cookie, roller, and rockhopper sweeps allowed access to fishing grounds initially inaccessible to trawlers due to rocky and un-even bottom (Fig. 2).

The development of bristle sweeps and modification of rockhopper sweeps also increased the efficiency of the gear by blocking any escape of fish between elements of the sweep.

The bristle sweep, or “street sweeper” gear, appeared in 1995 in New Bed-ford, Massachusetts and was felt to be so efficient that it was quickly banned.



Six types of sweeps used on the footropes of trawl nets in New England.

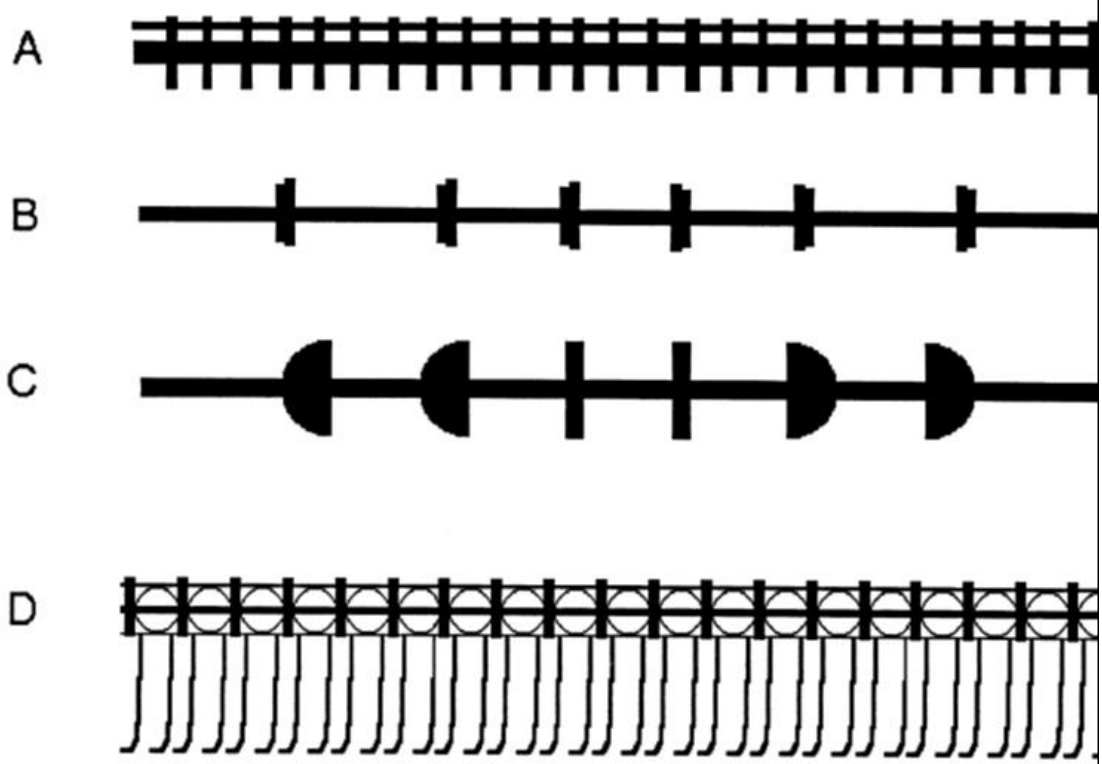
Current (year 2000) trends in footropes are working toward the goals of in-creased selectivity and reduction in bottom habitat impacts, in part by separating the multiple functions of the footrope.

Results/Conclusions: Trawl nets can be adjusted and modified to fish more cleanly and with less impact. We may reach a time when all fish caught in the net can or must be landed.

Reference: Rose, C S. 1999. Injury rates of red king crab, *Paralithodes camtschaticus*, passing under bottom-trawl footropes. Marine Fisheries Review 61.2, 72-76.

Type/part of ground-gear: Rockhopper gear with different diameter and spacing's.

Short description: This study investigated the injury rates of red king crab that passes under three different commercially applied footrope configurations. The different footropes tested where A = 38 cm rockhopper disks at 17 cm spacing, B = 36 cm disks at 60–90 cm spac-ing, C = 48 cm disks and 46 cm cones at 38–46 cm spacing. D = float and chin suspended footrope had as purpose to function as a control, assuming no contact with the footrope.



Results/Conclusions: Compared to the control footrope (D) the three different commercial footropes demonstrated significant higher injury rates, 7, 10, and % for footrope A, B, and C, respectively. The results did not demonstrate a significant difference between the three different commercial footropes.

Reference: Rose, C. S., Gauvin, J. R., Hammond, C. F., 2010. Effective herding of flatfish by cables with minimal seafloor contact. Fishery Bulletin, 108(2), 136-145.
Type/part of ground-gear: Modified sweeps
Short description: This study aimed to reduce the seafloor impact of bottom trawls targeting flatfish by elevating the sweeps, which account for most of the area affected by bottom trawls. Applying a twin trawl setup this study investigated the effect of elevating the sweeps 5, 7.5 and 10 cm. the sweeps were elevating applying disc clusters at 9 m intervals.

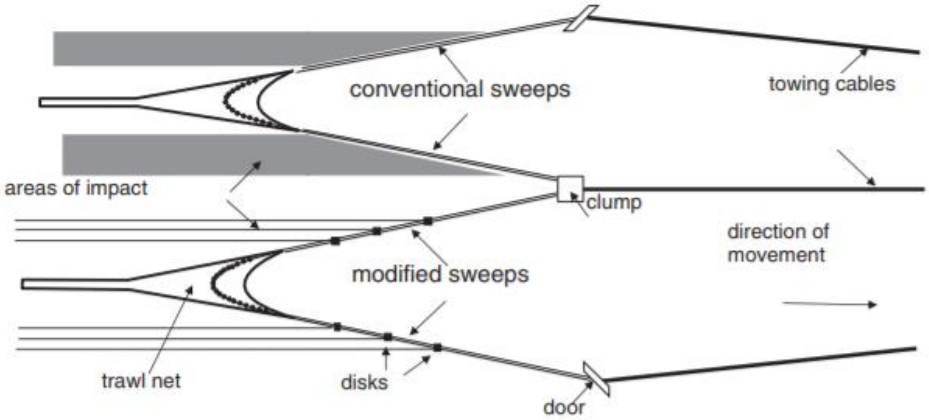


Figure 1

Diagram of the twin trawl system, complete with sweeps (conventional and modified), towed simultaneously behind a vessel and used to test whether raised trawl sweeps reduce flatfish herding. Actual total width was approximately 250 m. Shaded areas represent the area of contact with the seafloor.

Schematic diagram of a cluster of disks (disk cluster) attached to trawl sweeps to raise the sweeps above the seafloor to test whether this gear modification reduces flatfish herding. Rubber disks (A, 20 cm-diameter, and B, 15 cm-diameter) were installed over the sweep cable, between clamps (D) that fix their location on the cable. Steel washers (C) prevented rubber disks from passing over clamps. Ropes seized over and tucked through cable (E) blocked clamps from shifting.

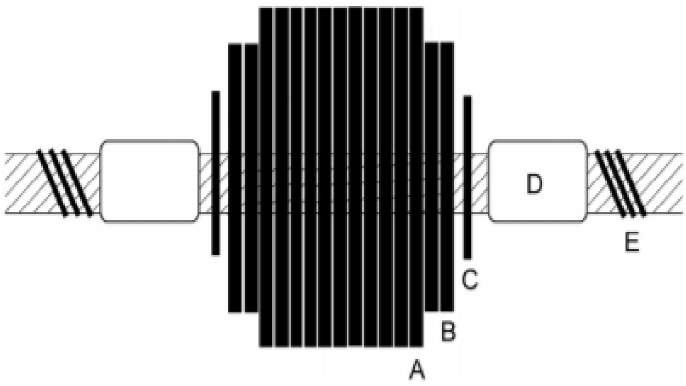


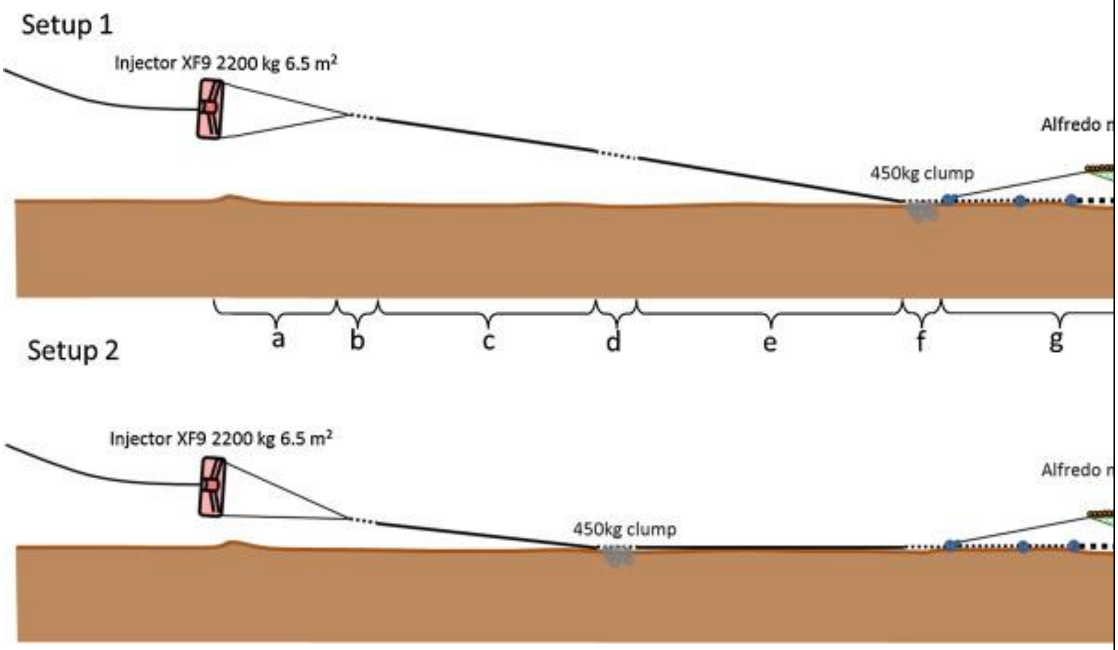
Figure 2

Results/Conclusions: No significant losses were observed until the sweeps were raised 10 cm. For the sweeps elevated 10 cm the loss of flatfish was 5-10%. Alaska Pollock was caught at higher rates when the sweeps were elevated. Sonar observations confirmed that the area that impacted by the sweeps was greatly reduced by the elevated sweeps.

Reference: Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R. B., Tatone, I., 2015. Effect of lifting the sweeps on bottom trawling catch efficiency: A study based on the Northeast arctic cod (*Gadus morhua*) trawl fishery. Fisheris Research, 167, 164-173. doi:10.1016/j.fishres.2015.01.015

Type/part of ground-gear: Sweeps in commercial trawls

Short description:
Fuel consumption and environmental concerns have led bottom trawlers fishing for cod (*Gadus morhua*) in the Barents Sea to use semi-pelagic doors. However, this change may affect fish herding and consequently the catch efficiency of the gear. This study compared the catch efficiency of two different setups where the sweep length with bottom contact was different. This setup also enabled us to estimate the herding efficiency of the sweeps on the seabed.

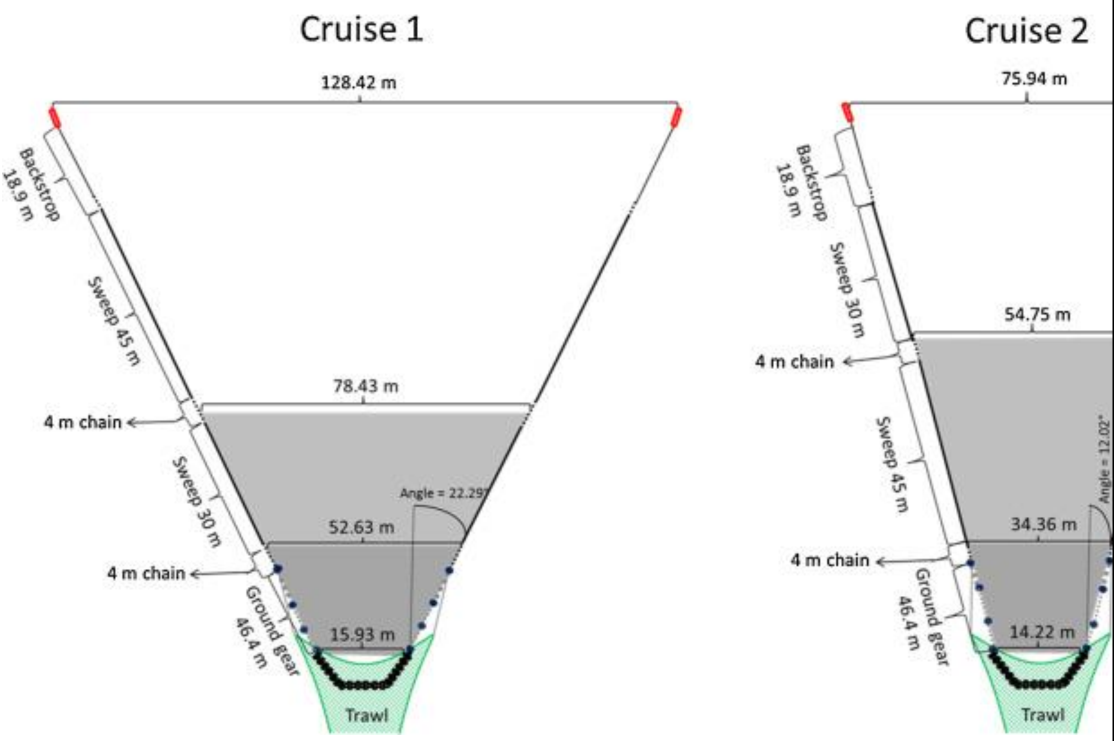


Results/Conclusions: It was estimated that the setup with the lifted sweeps captured on average 33% fewer cod than the setup that kept the sweeps at the seabed. The loss of catch for cod was length independent and significant for a length span between 41 and 104 cm. When sweeps were lifted above the seabed, herding was negatively impacted and fish were lost; in contrast, when on the seabed, the sweeps were able to herd (on average) 45% of the cod into the catch zone of the gear. Lifting the trawl doors from the seabed is touted as a positive development for this fishery. However, the results show that lifting the doors and consequently the sweeps can lead to substantial catch losses.

Reference: Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R. B., & Tatone, I., 2016. The effect of sweep bottom contact on the catch efficiency of haddock (*Melanogrammus aeglefinus*). Fisheries Research, *179*, 302-307, http://dx.doi.org/10.1016/j.fishres.2016.03.016

Type/part of ground-gear: Sweeps in commercial trawls

Short description: This paper illustrates the importance of length, angle and bottom contact of the sweep that connects the trawl and the otterboard for haddock (*Melanogrammus aeglefinus*) in Barents Sea. The study compares the fishing efficiency of two different trawl setups over two cruises. During cruise 1, the sweep angle was 22.3° and the difference in sweep length with actual bottom contact was 30 m. During cruise 2, the average sweep angle was 12.0°, and the difference in length with actual bottom contact was 45 m. Setup 1 had less sweep bottom contact for both cruises. The study estimates the relative change in length dependent catch efficiency of haddock between the two setups for each of the two cruises using catch comparison and catch ratio analyses.



Results/Conclusions: The results showed the importance of the length of sweep that actually contacted with the seabed for catching haddock. The differences between the two setups were significant for a limited range of length classes in both cruises, indicating that effect of the sweep bottom contact for this species is length dependent. The results also demonstrate that lack of control over the position of the doors in the water column when fishing semi-pelagic may cause loss of contact of the sweep with the seabed, reducing fishing efficiency for haddock.

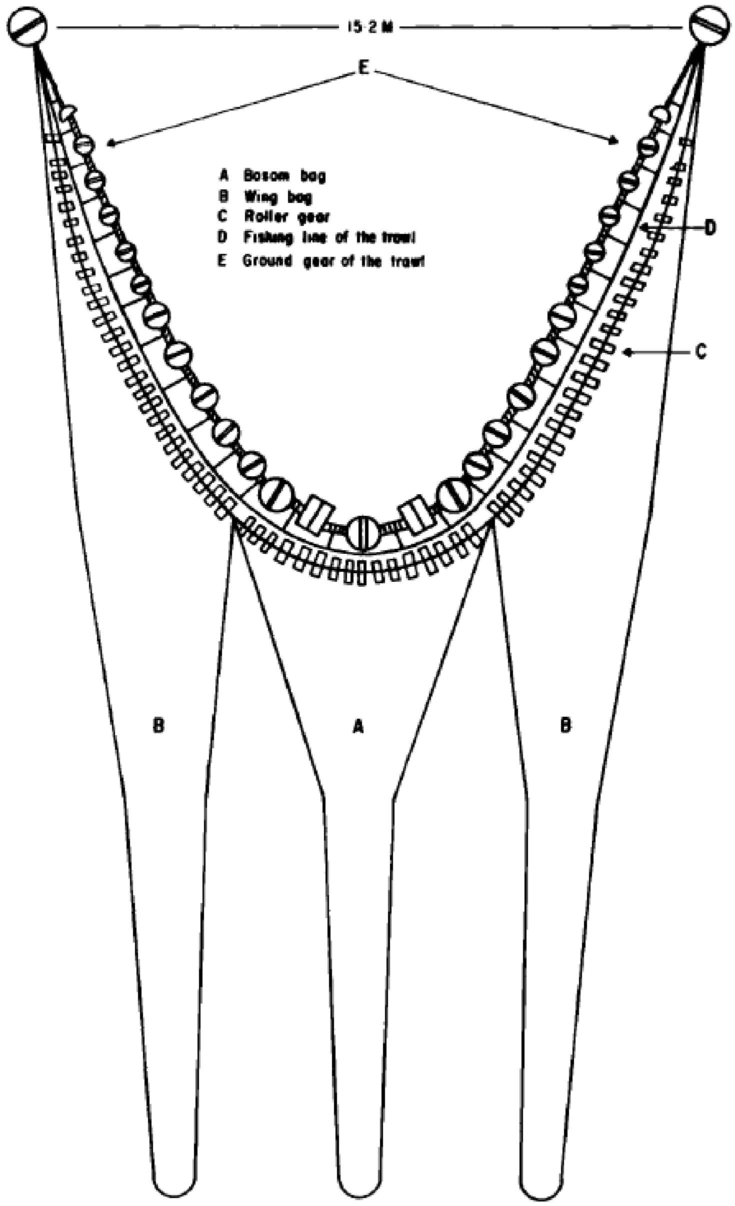
Reference: Walsh, S. J., 1992. Size-dependent selection at the footgear of a groundfish survey trawl. North American Journal of Fisheries Management, 12(3), 625-633. doi: 10.1577/1548-8675(1992)012<0625:SDSATF>2.3.CO;2

Type/part of ground-gear: Bobbins ground gear with a survey trawl

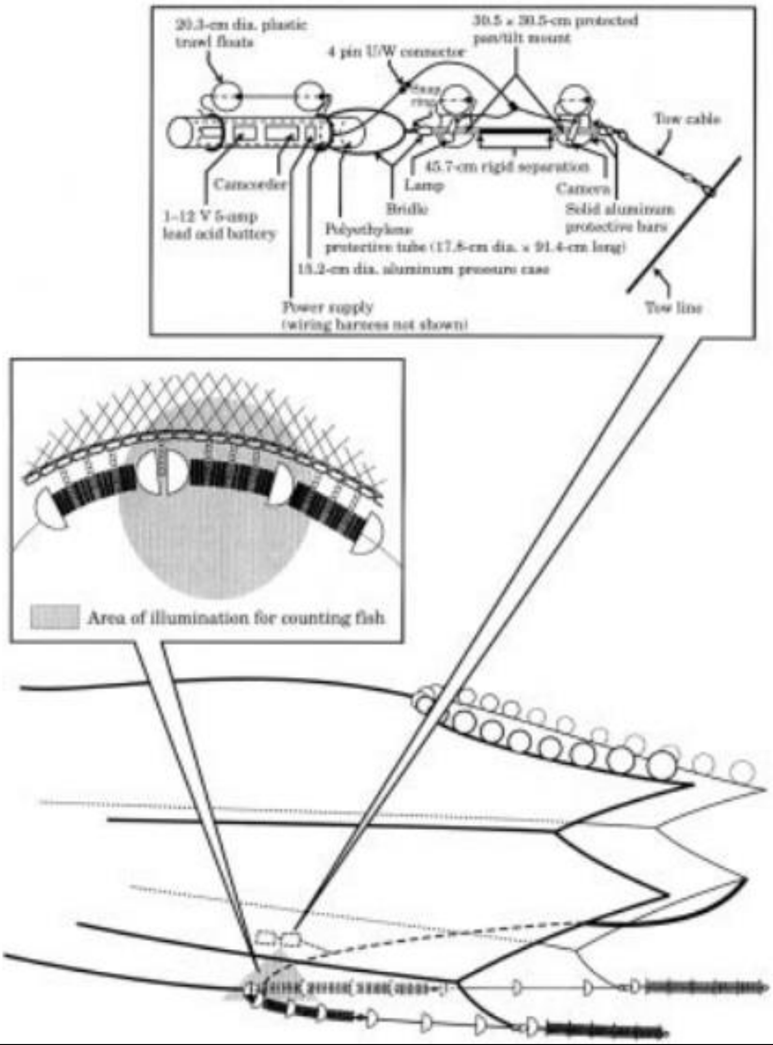
Short description: The study investigates the escapement of cod, American plaice, yellowtail flounder and thorny skate underneath a survey trawl.

Three trawl bags were attached underneath the footgear of a multispecies groundfish survey trawl to estimate escapement of Atlantic cod *(Gadus morhua.* American plaice (*Hippoghssoides platessoides),* yellowtail flounder (*Pleuronectes ferrugineus)* and thorny skate (*Raja radiata).*

Data from 26 fishing hauls on the Grand Bank, off the coast of Newfoundland, were used in the study. Net efficiency of the survey trawl reached 50% for the two flounder species greater than *24* cm and for Atlantic cod exceeding 35 cm, but efficiency never exceeded 42% for any si/e of thorny skate. Catchability coefficients ranged from 0.24 to 0.44.



Results/Conclusions: The results demonstrate a catching efficiency for the two flounder species larger than 24 cm and for cod larger than 45 cm of 50%. Catching efficiency for thorny skate was 42%.

Reference: Weinberg, K. L., Munro, P. T., 1999. The effect of artificial light on escapement beneath a survey trawl. ICES Journal of Marine Science: Journal du Conseil, 56(3), 266-274. doi: 10.1006/jmsc.1999.0442
Type/part of ground-gear: Rubber bobbin roller gear in a survey trawl
Short description: The light effect on escapement was examined by attaching the video system onto a trawl fitted with an auxiliary capture bag to retain those fish which would have otherwise escaped beneath. A paired towing experiment (unlit vs. lit) was conducted to test the hypothesis that there is no effect on capture proportion due to the addition of artificial light.

Results/Conclusions: Using ANOva and t-test on experimental data the study investigated if artificial light affected the escapement of six different fish species underneath the fishing line; Arrowtooth flounder, Flathead sole, Rock sole, Yellowfin sole, Pacific cod, Walleye pollock. No statistical significant differences were detected for five of the six species, except for flathead sole (*Hippoglossoides elassodon*).

8. Suggested readings

In this section we list some examples of relevant litterature from studies discussing seabed impacts from bottom trawling. These artlicles describe in detail the possible effects on seabed and its fauna. Moreover, accurate studies describe how components, their shape and weights, affects the footprint on sediments. Only abstract are copied into this report. The full article can be found by following the attached links.

- **J. Collie et al. 2017.** Indirect effects of bottom fishing on the productivity of marine fish. Fish and Fisheries, 2017, Vol. 18: 619–637. J. Collie et al., 2017

- **C.R. Pitcher et al. 2017**. Estimating the sustainability of towed fishing-gear impacts on seabed habitats: a simple quantitative risk assessment method applicable to data-limited fisheries. Methods in ecology and evolution , 2017, Vol.8(4), p.472-480. ISSN: 2041210X , 2041-210X; DOI: 10.1111/2041-210X.12705. CR Pitcher et al., 2017

- **M.J. Kaiser et al. , 2016**. Prioritization of knowledge-needs to achieve best practices for bottom trawling in relation to seabed habitats. Fish and Fisheries, 2016, Vol. 17: 637-663. https://doi.org/10.1111/faf.12134. MJ Kaiser et al., 2016

- **F.G. O’Neill and A. Ivanovic, 2015.** The physical impact of towed demersal fishinggears on soft sediments. ICES Journal of Marine Science; doi:10.1093/icesjms/fsv125. FG O'Neill and A Ivanovic, 2015

- **A. Ivanovic et al., 2011**. Modelling the physical impact of trawl components on the seabedand comparison with sea trials. Ocean Engineering 38 (2011) 925–933. A Ivanovic, 2011

- **M.J. Kaiser et al., 2003.** Impacts of fishing gear on marine benthic habitats. Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem, Reykjavik, Iceland, 1-4 October 2001. CABI Publishing. DOI: 10.1079/9780851996332.0197. MJ Kaiser et al. 2003

- **J.M. Hall-Spencer, 2000.** Effects of towed demersal fishing gear on biogenic sediments: A 5-year-study. *In:* Impact of trawl fishing on benthic communities - Proceedings: 9-24, 19 November 1999. ©2000 ICRAM. JM Hall-Spencer, 2000

INDIRECT EFFECTS OF BOTTOM FISHING ON THE PRODUCTIVITY OF MARINE FISH https://onlinelibrary.wiley.com/doi/full/10.1111/faf.12193

J Collie, JG Hiddink, T van Kooten, AD Rijnsdorp, MJ Kaiser, S Jennings & R Hilborn, 2017. Indirect effects of bottom fishing on the productivity of marine fish. Fish and Fisheries, 2017, Vol. 18: 619–637

ABSTRACT

One quarter of marine fish production is caught with bottom trawls and dredges on continental shelves around the world. Towed bottom-fishing gears typically kill 20–50 per cent of the benthic invertebrates in their path, depending on gear type, substrate and vulnerability of particular taxa.

Particularly vulnerable are epifaunal species, which stabilize the sediment and provide habitat for benthic invertebrates. To identify the habitats, fisheries or target species most likely to be affected, we review evidence of the indirect effects of bottom fishing on fish production.

Recent studies have found differences in the diets of certain species in relation to bottom fishing intensity, thereby linking demersal fish to their benthic habitats at spatial scales of ~10 km.

Bottom fishing affects diet composition and prey quality rather than the amount of prey consumed; scavenging of discarded by-catch makes only a small contribution to yearly food intake. Flatfish may benefit from light trawling levels on sandy seabeds, while higher-intensity trawling on more vulnerable habitats has a negative effect. Models suggest that reduction in the carrying capacity of habitats by bottom fishing could lead to lower equilibrium yield and a lower level of fishing mortality to obtain maximum yield.

Trawling effort is patchily distributed small fractions of fishing grounds are heavily fished, while large fractions are lightly fished or unfished. This patchiness, coupled with the foraging behaviour of demersal fish, may mitigate the indirect effects of bottom fishing on fish productivity. Current research attempts to scale up these localized effects to the population level.

ESTIMATING THE SUSTAINABILITY OF TOWED FISHING-GEAR IMPACTS ON SEABED HABITATS: A SIMPLE QUANTITATIVE RISK ASSESSMENT METHOD APPLICABLE TO DATA-LIMITED FISHERIES https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.12705

CR Pitcher; N Ellis; S Jennings; JG Hiddink; T Mazor; MJ Kaiser; MI Kangas; RA McConnaughey; AM Parma; AD Rijnsdorp; P Suuronen; JS Collie; R Amoroso; KM Hughes; R Hilborn; R Freckleton, 2017. Estimating the sustainability of towed fishing-gear impacts on seabed habitats: a simple quantitative risk assessment method applicable to data-limited fisheries. Methods in ecology and evolution , 2017, Vol.8(4), p.472-480. ISSN: 2041210X , 2041-210X; DOI: 10.1111/2041-210X.12705.

SUMMARY

1. Impacts of bottom fishing, particularly trawling and dredging, on seabed (benthic) habitats are commonly perceived to pose serious environmental risks. Quantitative ecological risk assessment can be used to evaluate actual risks and to help guide the choice of management measures needed to meet sustainability objectives.

2. We develop and apply a quantitative method for assessing the risks to benthic habitats by towed bottom-fishing gears. The method is based on a simple equation for relative benthic status (RBS), derived by solving the logistic population growth equation for the equilibrium state. Estimating RBS requires only maps of fishing intensity and habitat type – and parameters for impact and recovery rates, which may be taken from meta-analyses of multiple experimental studies of towed-gear impacts. The aggregate status of habitats in an assessed region is indicated by the distribution of RBS values for the region. The application of RBS is illustrated for a tropical shrimp-trawl fishery.

3. The status of trawled habitats and their RBS value depend on impact rate (depletion per trawl), recovery rate and exposure to trawling. In the shrimp-trawl fishery region, gravel habitat was most sensitive, and though less exposed than sand or muddy-sand, was most affected overall (regional RBS = 91% relative to untrawled RBS = 100%). Muddy-sand was less sensitive, and though relatively most exposed, was less affected overall(RBS = 95%). Sand was most heavily trawled but least sensitive and least affected overall (RBS = 98%). Region-wide , >94% of habitat area had >80% RBS because most trawling and impacts were confined to small areas. RBS was also applied to the region's benthic invertebrate communities with similar results.

4. **Conclusions**. Unlike qualitative or categorical trait-based risk assessments, the RBS method provides a quantitative estimate of status relative to an unimpacted baseline, with minimal requirements for input data. It could be applied to bottom-contact fisheries world-wide, including situations where detailed data on characteristics of seabed habitats, or the abundance of seabed fauna are not available. The approach supports assessment against sustainability criteria and evaluation of alternative management strategies (e.g. closed areas, effort management, gear modifications).

PRIORITIZATION OF KNOWLEDGE-NEEDS TO ACHIEVE BEST PRACTICESFOR BOTTOM TRAWLING IN RELATION TO SEABED HABITATS

https://onlinelibrary.wiley.com/doi/full/10.1111/faf.12134

MJ Kaiser, R Hilborn, Sn Jennings, R Amaroso, M Andersen, K Balliet, E Barratt, OA Bergstad, S Bishop, JL Bostrom, C Boyd1, EA Bruce, M Burden, C Carey, J Clermont, JS Collie, A Delahunty, J Dixon, S Eayrs, N Edwards, R Fujita, J Gauvin, M Gleason, B Harris, P He, JG Hiddink, KM Hughes, M Inostroza, A Kenny, J Kritzer, V Kuntzsch, M Lasta, I Lopez, C Loveridge, D Lynch, J Masters, T Mazor, RA McConnaughey, M Moenne, Francis, AM Nimick, A Olsen, D Parker, A Parma, C Penney, D Pierce, R Pitcher, M Pol, E Richardson, AD Rijnsdorp, S Rilatt, DP Rodmell, C Rose, SA Sethi, K Short, P Suuronen, E Taylor, S Wallace, L Webb, E Wickham, SR Wilding, A Wilson, P Winger & WJ Sutherland, 2016. Prioritization of knowledge-needs to achieve best practices for bottom trawling in relation to seabed habitats. Fish and Fisheries, 2016, Vol. 17: 637-663. https://doi.org/10.1111/faf.12134

ABSTRACT

Management and technical approaches that achieve a sustainable level of fish production while at the same time minimizing or limiting the wider ecological effects caused through fishing gear contact with the seabed might be considered to be ‘best practice’.

To identify future knowledge-needs that would help to support a transition towards the adoption of best practices for trawling, a prioritization exercise was undertaken with a group of 39 practitioners from the seafood industry and management, and 13 research scientists who have an active research interest in bottom-trawl and dredge fisheries.

A list of 108 knowledge-needs related to trawland dredge fisheries was developed in conjunction with an ‘expert task force’. The long list was further refined through a three stage process of voting and scoring, including discussions of each knowledge-need. The top 25 knowledge-needs are presented, as scored separately by practitioners and scientists.

There was considerable consistency in the priorities identified by these two groups. The top priority knowledge-need to improve current understanding on the distribution and extent of different habitat types also reinforced the concomitant need for the provision and access to data on the spatial and temporal distribution of all forms of towed bottom-fishing activities. Many of the other top 25 knowledge-needs concerned the evaluation of different management approaches or implementation of different fishing practices, particularly those that explore trade-offs between effects of bottom trawling on biodiversity and ecosystem services and the benefits of fish productionas food.

The physical impact of towed demersal fishing gears on soft sediments

https://www.researchgate.net/publication/284454183_The_physical_impact_of_towed_demersal_fishing_gears_on_soft_sediments

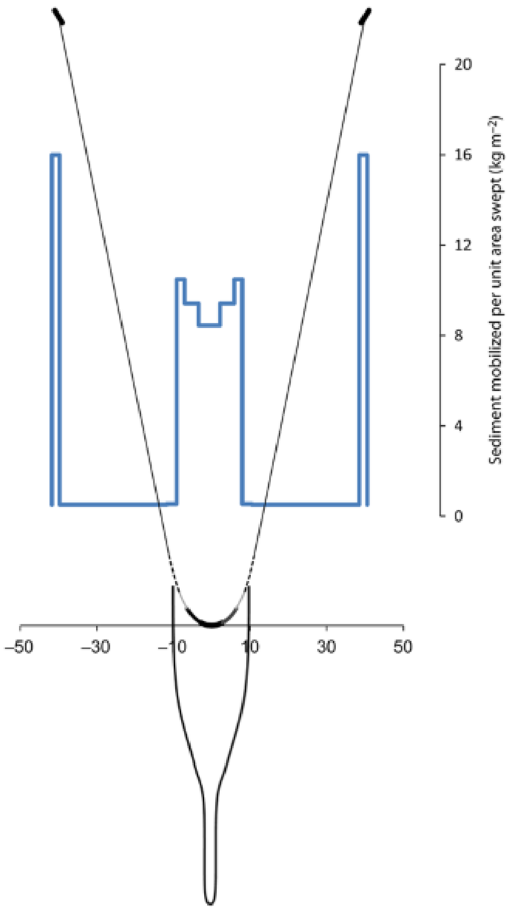
F. G. O'Neill and A. Ivanovic, 2015. The physical impact of towed demersal fishing gears on soft sediments. ICES Journal of Marine Science; doi:10.1093/icesjms/fsv125

ABSTRACT

An improved understanding of the physical interaction of towed demersal fishing gears with the seabed has been developed in recent years, and there is a clearer view of the underpinning mechanical processes that lead to the modification and alteration of the benthic environment.

The physical impact of these gears on soft sediments can be classified broadly as being either geotechnical or hydrodynamic in nature: penetration and piercing of the substrate, lateral displacement of sediment, and the influence of the pressure field transmitted through the sediment can be considered geotechnical, whereas the mobilization of sediment into the water column can be considered hydrodynamic.

A number of experimental and numerical approaches have been used to gain better insights of these physical processes. These include small-scale modelling in towing tanks and sand channels; large-scale modelling in the field; measurements behind full-scale towed gears at sea; numerical/mathematical modelling of sediment mechanics; and numerical/ mathematical modelling of hydrodynamics. Here, we will review this research, and that in associated fields, and show how it can form the basis of predictive models of the benthic impact of trawl gears.



A schematic of a typical 1000 – 1400 hp Scottish whitefish demersal trawl. Superposed is an estimate of the distribution of sediment put into the water column across the swept width assuming a sediment silt fraction of 0.2 and a towing speed of 1.5 ms $^{-1}$.

MODELLING THE PHYSICAL IMPACT OF TRAWL COMPONENTS ON THE SEABEDAND COMPARISON WITH SEA TRIALS https://reader.elsevier.com/reader/sd/pii/S002980181000209X?token=2539EE7B6FFECD3AF-BCCA1D43F2EFD9E8236DB48F1B6E7FE85825FE260A4C3D3C324D573E549D4BFAA9730094FA1A9C5

Ivanovic, A., Neilson, R.D. and O'Neill, F.G., 2011. Modelling the physical impact of trawl components on the seabedand comparison with sea trials. Ocean Engineering 38 (2011) 925–933.

ABSTRACT

Quantitative measurement of the response of benthic habitats to impact from towed fishing gears is of great importance to the ecosystem and the long-term management of sustainable fisheries. To date, most studies on the effects of trawling on the benthos have focussed on before/after, control/impactcomparative studies.

This research has proved important in terms of describing general trends and has identified taxa that suffer high levels of mortality, and habitat types where impact is the greatest. A limitation, however, to this comparative work is the lack of prediction-based methodology and it would be very beneficial to develop a more mechanistic approach that would allow trawling impact on the benthos to be estimated for a wider range of species and habitats.

This paper is a first step in this approach and focuses on modelling the physical interaction between gear components and the seabed. In particular the penetration and disturbance to the seabed caused by (i) the roller clump of a twin trawl and (ii) a trawl door, are examined. A finite element (FE) model of the interaction of these components and the seabed is developed using the different soil models and features available within the Abaqus finite element software package.

The resulting models are able to predict the penetration depth and sediment displacement associated witheach gear component and the predictions are compared with the results obtained during sea trials. The sea trials were undertaken on two sediment types at depths accessible to scientific divers using SCUBA diving techniques who measured and profiled the physical alteration to the seabed following the passage of a roller clump and a trawl door. In addition, drag forces obtained from the sea trials are compared with numerical predictions of the drag related to the soil and the estimated fluid drag. Good agreement between the experimental trials and numerical simulations is found and hence this study provides the basis for investigation of the interaction of other components and sediment types.

IMPACTS OF FISHING GEAR ON MARINE BENTHIC HABITATS

https://www.researchgate.net/publication/230659975_Impacts_of_fishing_gear_on_marine_benthic_habitats

M.J. Kaiser, J.S. Collie, S.J. Hall, S. Jennings and I.R. Poiner, 2003. Impacts of fishing gear on marine benthic habitats. Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem, Reykjavik, Iceland, 1-4 October 2001. CABI Publishing. DOI: 10.1079/9780851996332.0197.

ABSTRACT

Fishing affects seabed habitats worldwide. However, these impacts are not uniform and are affected by the spatial and temporal distribution of fishing effort, and vary with the habitat type and environment in which they occur. Different fishing methodologies vary in the degree to which they affect the seabed. Towed bottom fishing gears and hydraulic harvesting devices re-suspend the upper layers of the sedimentary habitat and hence re-mobilize contaminants and fine particulate matter into the water column. The ecological significance of these fishing effects has not yet been determined.

Structurally complex habitats (e.g. seagrass meadows, biogenic reefs) and those that are relatively undisturbed by natural perturbations (e.g. deep-water mud substrata) are more adversely affected by fishing than unconsolidated sediment habitats that occur in shallow coastal waters. Structurally complex and stable habitats also have the longest recovery trajectories in terms of the re-colonization of the habitat by the associated fauna.

Comparative studies of areas of the sea bed that have experienced different levels of fishing activity demonstrate that chronic fishing disturbance leads to the removal of high-biomass species that are composed mostly of emergent seabed organisms. These organisms increase the topographic complexity of the seabed and have been shown to provide shelter for juvenile fishes, reducing their vulnerability to predation. Conversely, small-bodied organisms, such as polychaete worms and scavengers, dominate heavily fished areas. Such a change in habitat may lead to changes in the composition of the resident fish fauna. Fishing also has indirect effects on habitat through the removal of predators that control bio-engineering organisms such as algal-grazing urchins on coral reefs. However, such effects are only manifested in those systems in which the linkages between the main trophic levels are confined to less than ten species.

Management regimes that aim to incorporate both fisheries and habitat conservation objectives can be achieved through the appropriate use of a number of approaches, including total and partial exclusion of towed bottom fishing gears, and seasonal and rotational closure techniques. Different management regimes can only be formulated and tested once objectives and criteria for seabed habitats have been defined.

EFFECTS OF TOWED DEMERSAL FISHING GEAR ON BIOGENIC SEDIMENTS: A 5-YEAR-STUDY https://pearl.plymouth.ac.uk/bitstream/handle/10026.1/1391/Hall-Spencer%202000.pdf?sequence=2&isAllowed=y

Hall-Spencer, J. M. 2000. Effects of towed demersal fishing gear on biogenic sediments: A 5-year-study. *In:* Impact of trawl fishing on benthic communities - Proceedings: 9-24, 19 November 1999. ©2000 ICRAM.

ABSTRACT

Experimental scallop fishing was carried out using towed commercial dredges on sediments deposited by unattached coralline algae in order to quantify their sensitivity to damage from current fishing practices.

These biogenic sediments are patchily distributed in European coastal waters (to -30 m depth around the UK and to -120 m in the Mediterranean) and are of international conservation importance.

This paper describes the short and long-term effects of scallop dredging on previously unfished and fished areas of biogenic algal sediment in SW Scotland. Sediment cores taken biannually from 1994-99 were used to assess live coralline abundance on marked test and control plots.

Living corallines had <3% cover at a fished site and experimental dredging had no discernible effect on their abundance. Dense populations of live coralline thalli (~20% cover) were located on a previously unfished ground. Although coralline cover remained high in control plots on the
unfished site, experimental fishing led to ~ 70% reduction in live corallines on test plots with no signs of recovery over the subsequent 5 years.

Appendix I:

ICES WGFTFB REPORT 2016

SCICOM/ACOM STEERING GROUP ON INTEGRATED ECOSYSTEM OB-SERVATION AND MONITORING. ICES CM 2016/SSGIEOM:22
REF. ACOM AND SCICOM
Report of the Working Group on Fishing Technology and Fish Behaviour (WGFTFB)
25-29 April 2016 Mérida, Mexico

12.3 Topic Groups for the 2017 WGFTFB Meeting

New Topic Group: Evaluation of trawl groundgear for efficiency, bycatch and impact on the seabed (Groundgear)

a) A WGFTFB topic group convened by Roger B. Larsen (Norway), Antonello Sala (Italy) and Pingguo He (USA) will be formed and will meet in April 3-7, 2017 in Nelson, New Zealand to discuss and summarize status and progress and knowledge of designs of groundgear and other components dragged along the seabed during bottom trawling. The topic group will evaluate current and past work regarding to their efficiency for target and bycatch species, effect on the seabed, and energy use. This topic will include past, current and future studies from a wide range of scientific fields, such as hydrodynamics, drag and gear design, strategies and technology enhancing reduced fuel consumption and reduction in gas emissions, selectivity and behaviour on fish, shrimp and crab.

b) Terms of reference:

1. Describing and summarizing current and past work in relation to seabed contact/impact of various types of bottom-trawl groundgear.
2. Discussing and describing possible methods to reduce unnecessary bottom contact and fuel use due to the groundgear.
3. Discussing and summarizing the effect of trawl groundgear on the efficiency and selectivity for target and bycatch species.
4. Making recommendations on future experimental and theoretical work to understand and improve the function of groundgear of bottom trawls.
5. Making recommendations on the “best practice” regarding the design and operation of bottom trawls with less effect on ecosystem and emission.

Justification:
With uncertainties around the use of groundgear in bottom trawling and its impact on bottom fauna, it is important to review the current status of the design and use of groundgears in various fisheries and to propose new investigations that will contribute to more environmentally-friendly fishing gears. Continuous contact between gear and seabed during bottom trawling is believed to be of importance for efficient harvesting in many groundfish fisheries, but in some bottom trawls, total weight of the trawl may be out of proportions for the purpose. High fuel consumption in trawl fisheries is often associated with heavy groundgear being dragged along the seabed.

Recent research and practices in the North Pacific and Northwest Atlantic bottomtrawl fisheries indicate that ground-contacting components including groundgear can be modified with no or little impact on the catch of target species. In the Northeast Atlantic, bottom trawling is often performed in areas of important fisheries for king crab and the rapid growing snow crab fishery, with unknown impact on these crab stocks. As crab fisheries increase in intensity, more gears will be damaged and lost due to collisions between trawl and pot fisheries. Alternative and lighter groundgears have been tested, but it is unclear if they are efficient for retaining target species and not increasing the catch of unwanted bycatch compared to conventional configurations. Discussion and summary of current knowledge and possible future development of bottom trawl gear or its alternatives for harvesting traditional groundfish species.

Appendix II:

ICES WGFTFB 2017 REPORT

STEERING GROUP ON INTEGRATED ECOSYSTEM OBSERVATION AND MONITORING ICES CM 2017/SSGIEOM:13 REF ACOM AND SCICOM
Interim Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) 4-7 April 2017 Nelson, New Zealand

9 Topic Group: Evaluation of trawl groundgear for efficiency, bycatch and impact on the seabed (Groundgear)

9.1 Introduction

A WGFTFB topic group convened by Pingguo He with remote supports from cochairs Roger Larsen (Norway) and Antonello Sala (Italy) was formed and met on 3–7 April 2017 in Nelson, New Zealand to discuss and summarize status and progress and knowledge of designs of groundgear and other components dragged along the seabed during bottom trawling. The topic group was to evaluate current and past work regarding to their efficiency for target and bycatch species, effect on the seabed, and energy use. This topic group examines past, current and future studies from a wide range of scientific fields, such as hydrodynamics, drag and gear design, strategies and technology enhancing reduced fuel consumption and reduction in gas emissions, selectivity and behaviour on fish, shrimp and crab.

Terms of reference were:

- Describing and summarizing current and past work in relation to seabed contact/impact of various types of bottom-trawl groundgear
- Discussing and describing possible methods to reduce unnecessary bottom contact and fuel use due to the groundgear
- Discussing and summarizing the effect of trawl groundgear on the efficiency and selectivity for target and bycatch species
- Making recommendations on future experimental and theoretical work to understand and improve the function of groundgear of bottom trawls
- Making recommendations on the “best practice” regarding the design and operation of bottom trawls with less effect on ecosystem and emission

Justification:

With uncertainties around the use of groundgear in bottom trawling and its impact on bottom fauna, it is important to review the current status of the design and use of groundgear in various fisheries and to propose new investigations that will contribute to more environmentally-friendly fishing gears. Continuous contact between gear and seabed during bottom trawling is believed to be of importance for efficient harvesting in many groundfish fisheries, but in some bottom trawls, total weight of the trawl may be out of proportions for the purpose. High fuel consumption in trawl fisheries is often associated with heavy groundgear being dragged along the seabed. Recent research and practices in the North Pacific and Northwest Atlantic bottomtrawl fisheries indicate that ground-contacting components including groundgear can be modified with no or little impact on the catch of target species. In the Northeast Atlantic, bottom trawling is often performed in areas of important fisheries for king crab and the rapid growing snow crab fishery, with unknown impact on these crab stocks. As crab fisheries increase in intensity, more gears will be damaged and lost due to collisions between trawl and pot fisheries. Alternative and lighter groundgears have been tested, but it is unclear if they are efficient for retaining target species and not increasing the catch of unwanted bycatch compared to conventional configurations. Discussion and summary of current knowledge and possible future development of bottom-trawl gear or its alternatives for harvesting traditional groundfish species.

9.2 Participants

The Topic Group met on 6 April 2017 with the following participants (listed in a random order). Chairs Roger Larsen and Antonello Sala were not able to participant the meeting in person, but provided remote support to the Topic Group.

Pingguo He (Chair) University of Massachusetts Dartmouth USA
Noëlle Yochum NOAA Alaska Fisheries Science Center USA
Brianna King Alaska Pacific University USA
Aileen Nimick Alaska Pacific University Fisheries USA
Josh Cahill Australian Fisheries Management Authority Australia
Liuxiong Xu Shanghai Ocean University China
Ludvig Ahm Krag DTU Aqua, Danish Technical University Denmark
Petri Suuronen FAO Fisheries and Aquaculture Italy
Craig S. Rose FishNext Research USA
Darcie E. Hunt IMAS Australia
Haraldur Einarsson Marine and Freshwater Research Institute Iceland
Paul Winger Memorial University of Newfoundland Canada
Tomas Schmidt Memorial University of Newfoundland Canada
Mark Lomeli Pacific States Marine Fisheries Commission USA
Chun Woo Lee Pukyong National University Korea
Liming Song Shanghai Ocean University China
Jure Brčić University of Split Croatia
Pieke Molenaar Wageningen Marine Research Netherlands
Steve Kennelly IC Independent Consulting Australia
Paul Freeman Hampidjan NZ New Zealand
Carolyn Collier Hampidjan NZ New Zealand
Valentina Melli DTU Aqua, Danish Technical University Denmark
Hyun Young Kim National Institute of Fisheries Research Korea

9.3 The accomplishment

The Topic Group defined the type of fishing gear that this group will focus – the bottom trawl as defined in the FAO classification of fishing gears. It will thus include beam trawls, otter trawls, pair trawls, Nephrops trawls, shrimp trawls, and other unspecified bottom trawls. However, other bottom-tendering gears such as dredges will not be included in the Topic Group's work.

The Topic Group defined "groundgear". The "groundgear" in this topic group (and its report) refers all components of a trawl that typically contact the seabed during fishing process, including, but not limited to:

• Groundrope, and tickler chains
• Sweeps and lower bridles
• Trawl doors
• Center weight of twin/triple rigs
• Shoe/head of a beam trawl

The example of "groundgear" in a typical bottom trawl is shown (in red) in Figure 9.3.1.

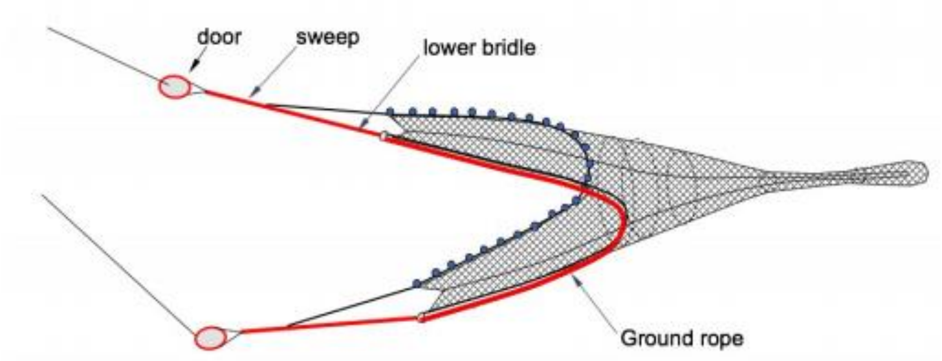


Figure 9.3.1. A typical bottom trawl with the 'groundgear' highlighted in red.

The Topic Group defined scope of this topic group, and reaffirmed the Term of References of this TG:
• Seabed contact and impact of groundgear;
• Fuel consumption and emission reduction regarding the groundgear;
• Selectivity and bycatch characteristics of groundgear.

The Topic Group will identify gaps of knowledge and technology and recommend future research directions related to groundgear of a bottom trawl. From the knowledge gathered, we will attempt to recommend "best practice" on the design of groundgear of bottom trawls with regard to minimal seabed impact, low fuel consumption and emission, high capture efficiency for target species, and best possible reduction of bycatch.

The Topic Group heard seven presentations related to the topic:
• Aileen Nimick: Fishing effects in 3D – it's not all about bottom contact anymore;
• Roger Larsen (presented by Pingguo He): Groundgear and trawl systems used in the Northeast Atlantic;
• Paul Winger: Comparative fishing to evaluate the viability of an aligned footgear designed to reduce seabed contact in Northern shrimp bottom trawl fisheries;
• Craig Rose: Groundgear and crab mortality in Alaska trawl fishery;
• Mark Lomeli: Use of lights on the footrope of a shrimp trawl for pink shrimp to reduce;
• Steve Kennelly: Groundgear modifications in Australian river shrimp trawls;
• Pingguo He: Examples of groundgear in use in New England.

9.4 The Work Plan

Members will work during the inter session and to provide a summary of various types of groundgear in use in respective bottom-trawl fisheries. This will be used to compile a list of groundgear in bottom-trawl fisheries around the world. FAO representative will contact South American and Southeast Asian country colleagues to provide groundgear information in these regions. Topic Group members will work during the inter session to provide relevant information related to the ToR and to report at the 2018 WGFTFB meeting. The Topic Group will meet in person at the 2018 WGFTFB meeting in Bergen, Norway. It was also suggested that the "groundgear" may be considered as a Mini-symposium topic during the 2019 FAO-sponsored WGFTFB meeting.

Over the "Groundgear" TG lifetime, the group will:

- Compile a catalog of "groundgear" used in different parts of the ocean (North Sea, Baltic Sea, Mediterranean, Northeast Atlantic, Northwest Atlantic, Northeast Pacific, Northwest Pacific, Oceania, and others)
- Review and synthesize literature to provide the state-of-art account on the subject
- Identify gaps in knowledge and potential areas of further development/research
- Produce a final report to the WGFTFB in 2019.
- Possible publication of the report (or part of it) in FAO Fisheries Report or in a peer-reviewed journal

Appendix III: ICES WGFTFB 2018 REPORT

ICES ECOSYSTEM OBSERVATION STEERING GROUP ICES CM 2018/EOSG:12 REF ACOM AND SCICOM. Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) 4 — 8 June 2018 Hirtshals, Denmark

1 Topic Group: Evaluation of trawl groundgear for efficiency, bycatch and impact on the seabed (Groundgear)

1.1 Introduction:

The WGFTFB topic group convened by Roger Larsen and Pingguo He (with remote support from co-chair Antonello Sala) met on 4–8 June 2018 in Hirtshals, Denmark to continue the work on the knowledge of designs of groundgear and other components dragged along the seabed started during bottom trawling during the 2017 WGFTFB meeting in Nelson, New Zealand.

The topic group was to evaluate current and past work regarding to their efficiency for target and bycatch species, effect on the seabed, and energy use. This topic group examines past, current and future studies from a wide range of scientific fields, such as hydrodynamics, drag and gear design, strategies and technology enhancing reduced fuel consumption and reduction in gas emissions, selectivity and behaviour on fish, shrimp and crab.

While the WGFTFB meeting in Nelson, NZ had 23 participants and 7 presentations, the WGFTFB meeting in Hirtshals, DK had 20 participants and 0 presentations. As most of the participants (17 out of 20) during the WGFTFB meeting in Hirtshals were new inside the topic group, substantial time was spent on discussing and re-defining the term “groundgear” and revising the terms of reference.

1.2 Justification:

With uncertainties around the use of groundgear in bottom trawling and its impact on bottom fauna, it is important to review the current status of the design and use of groundgear in various fisheries and to propose new investigations that will contribute to more environ-mentally-friendly fishing gears. Continuous contact between gear and seabed during bottom trawling is believed to be of importance for efficient harvesting in many ground fish fisheries, but in some bottom trawls, total weight of the trawl may be out of proportions for the purpose. High fuel consumption in trawl fisheries is often associated with heavy groundgear being dragged along the seabed. Recent research and practices in the North Pacific and Northwest Atlantic bottom trawl fisheries indicate that ground-contacting components including groundgear can be modified with no or little impact on the catch of target species. In the Northeast Atlantic, bottom trawling is often performed in areas of important fisheries for king crab and the rapid growing snow crab fishery, with unknown impact on these crab stocks. As crab fisheries increase in intensity, more gears will be damaged and lost due to collisions between trawl and crab-pot fisheries. Alternative and lighter ground gears have been tested, but it is unclear if they are efficient for retaining target species and not increasing the catch of unwanted bycatch compared to conventional configurations. Discussion and summary of current knowledge and possible future development of bottom trawl gear or its alternatives for harvesting traditional groundfish species.

1.3 Revised and specific terms of reference were:

- Creating a collection with example-factsheets of selected/commonly used types of bottom-trawl groundgear.
- Discussing and describing methods to reduce bottom contact and fuel use.
- Discussing and providing examples on the effect of trawl groundgear on the efficiency and selectivity for target and bycatch species.
- Making recommendations on future experimental and theoretical work to understand and improve the function of groundgear of bottom trawls.
- Discussing implications (trade-offs and legislation requirements) regarding the design and operation of groundgear with less effect on seabed and greenhouse gas emission contributing to the development of best practices of bottom trawling.

1.4 Participants:

The Topic Group met on June 7 and 8, 2018 with the following participants (listed in a random order). Co-chair Antonello Sala was not able to participate the meeting in person.

First name	Last name	Country	Work	Email
Matthew	**McHugh**	Ireland	Board Iascaigh Mhara	matthew.mchugh@bim.ie
Pingguo	**He***	USA	University of Massachusetts Dartmouth	pingguo.he@fao.org
Hans	**Nilsson**	Sweden	Swedish University of Agricultural Sciences	Hans.Nilsson@slu.se
Geir	**Gudmunds-son**	Iceland	Optitog ehf/Innovation Center Iceland	geir@nmi.is
Uwe	**Lichtenstein**	Germany	University of Rostock	uwe.lichtenstein@uni-rostock.de
Gebremeskel	**Kebede**	Canada	Memorial University, Newfoundland	Gebre.Kebede@mi.mun.ca
Liming	**Song**	China	Shanghai Ocean University	lmsong@shou.edu.cn
Liuxiong	**Xu**	China	Shanghai Ocean University	lxxu@shou.edu.cn
Yunus Emre	**Fakıoğlu**	Turkey	Fisheries Faculty, Mersin	emrefakioglu@gmail.com
Thomas	**Noack**	Denmark	Technical University of Denmak, DTU Aqua	thno@aqua.dtu.dk
Rikke Petri	**Frandsen**	Denmark	Technical University of Denmak, DTU Aqua	rif@aqua.dtu.dk
Mathias	**Paschen**	Germany	University of Rostock	mathias.paschen@uni-rostock.de
Karsten	**Bredder-mann**	Germany	University of Rostock	karsten.breddermann@uni-rostock.de
Roger B,	**Larsen***	Norway	The Arctic University of Norway UIT	roger.larsen@uit.no
Jesse	**Brinkhof**	Norway	The Arctic University of Norway UIT	jesse.brinkhof@uit.no
Suresh	**Sethi**	USA	Cornell University, Ithaca (New York)	suresh.sethi@cornell.edu
Bradley	**Harris**	USA	Alaska Pacicific University, Ancorage	bharris@alaskapacific.edu
T. Scott	**Smeltz**	USA	Cornell University, Ithaca (New York)	ts428@cornell.edu
George	**Legge**	Canada	Memorial University, Newfoundland	george.legge@mi.mun.ca
Ulrik Jes	**Hansen**	Denmark	CATch-Fish	ujh@catch-fish.net

* Chairs: Roger B. Larsen and Pingguo He

1.5 The accomplishment:

The Groundgear topic group will focus on otter trawls, pair trawls and other unspecified bottom trawls for fish and crustaceans (shrimp, Nephrops). It will cover single-, twin- triple- and multi-rig trawls towed on the seabed. However, other bottom-tendering gears such as beam trawls and dredges will not be included in the topic group's work.

The Groundgear topic group defined "groundgear" as the bottom-tending components between wing-ends. The topic group on "Groundgear" (and its report) will focus on both groundgear and the bottom-contacting cables connecting the trawl and the doors, including, but not limited to:

- Ground rope (footrope), fishing line and tickler chains.
- Sweeps and lower bridles and other cables attached.
- (Trawl doors).
- Center weights and sleds of twin-, triple- or multi-rigs.

The example of "groundgear" in a typical bottom trawl is shown (in red) in Figure 1.

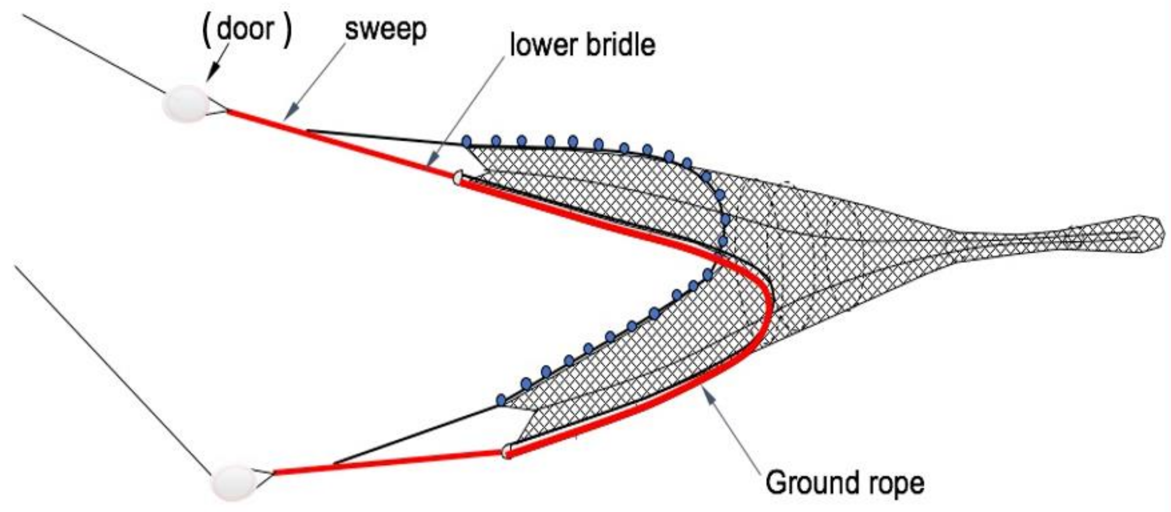


Figure 1. A typical bottom trawl with the "groundgear" highlighted in red.

The Groundgear topic group defined scope of this topic group, and reaffirmed the Term of References of this topic group:

- Seabed contact and impact of groundgear.
- Fuel consumption and greenhouse gas emission reduction regarding the groundgear.
- Selectivity and bycatch characteristics of groundgear.

The Topic Group will identify gaps of knowledge and technology and recommend future research directions related to groundgear of a bottom trawl. From the knowledge gathered, we will attempt to recommend "best practice" on the design of groundgear of bottom trawls with regard to minimal seabed impact, low fuel consumption and greenhouse gas emission, high capture efficiency for target species, and best possible reduction of unwanted bycatch.

The groundgear topic group had no presentations related to the topic during this meeting, while seven presentations were given during the 2017 WGFTFB in Nelson, NZ.

1.6 The work plan:

Members will work during the inter-session to provide a summary of various types of groundgear in use in respective bottom trawl fisheries. This will be used to compile examples (type factsheets) of selected and commonly used types of bottom-trawl groundgear. The Groundgear topic group members will work during the inter-session to provide relevant information related to the ToR and produce the final report of this topic group for the 2019 FAO-sponsored WGFTFB meeting.

1.7 Final report:

A final report from the Groundgear topic group will be provided at the ICES-FAO WGFTFB meeting in April 2019. We aim at a publication of the report (or part of it) in FAO Fisheries Report or in a peer-reviewed journal. The list of content for the report was during the WGFTFB meeting in Hirtshals, Denmark, decided to include:

1.7.1 Content of the final report:

Definition and extent of a groundgear

- Commonly used names (and rigging):
- Grasrope
- Cookie
- Bobbin gear
- Rockhopper gear
- Rollergear
- Brushgear
- Plategear
- Others

Types of commonly used groundgears (illustrated):
Rope, wire, lead line
Chain (drop, straight, loops)
Discs (rubber, plastics)
Bobbins (steel, rubber, plastic)
Chafing skirt
… and combinations of these types
Components, i.e. referring to drawings/”fact sheets”

1.7.2 Elements influencing the performance of the ground gear:

Weight of components (incl. otter boards)
Shape and size of components
Seabed type
Operation
Spread of the groundgear
Towing speed
Design of trawl
Bridle and sweep configuration

Effect of groundgear on catch efficiency, selectivity and fuel consumption
Current and future developments (examples)
Lifted sweeps (due to trawl door operation)
Plate gear/Semicircular spreading-ground gear
Aligned gears
Experimental/others

Members of the 2017 and 2018 Groundgear topic group (and the whole FTFB family) will be asked to add information relevant for the ToR. We will produce a template for collecting information on typical groundgears being used and drawings (with explanations) would be appreciated. The "fact sheet" template will be provided to the FTFB group via the current FTFB email list.

Appendix IV:

ICES WGFTFB 2019 REPORT

STEERING GROUP ON INTEGRATED ECOSYSTEM OBSERVATION AND MONITORING ICES CM 2019/SSGIEOM:?? REF ACOM AND SCICOM
Interim Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) 8-12 April 2019 Shanghai, China

The WGFTFB topic group convened by Antonello Sala and Pingguo He (with remote support from co-chair Roger B. Larsen) met on 8–12 April 2019 in Shanghai, China (see appendix 4). The group continued their work on the knowledge of designs of groundgear and other components dragged along the seabed as discussed during the 2017 WGFTFB meeting in Nelson, New Zealand and 2018 WGFTFB meeting in Hirtshals, Denmark.

The terms of reference were:

1) Creating a collection with example-factsheets of selected/commonly used types of bottom-trawl groundgear.
2) Discussing and describing methods to reduce bottom contact and fuel use.
3) Discussing and providing examples on the effect of trawl groundgear on the efficiency and selectivity for target and bycatch species.
4) Making recommendations on future experimental and theoretical work to understand and improve the function of groundgear of bottom trawls.
5) Discussing implications (trade-offs and legislation requirements) regarding the design and operation of groundgear with less effect on seabed and greenhouse gas emission contributing to the development of best practices of bottom trawling.

The discussion on definitions of ground gear continues also in this meeting. It was decided that if new definitions are being recommended by the topic group, they need to be agreed upon by the full FTFB group.

It was decided that standard definitions and parameters should be included when describing fishing gears in technical reports and papers (e.g. defining mesh size measurement used).

It was agreed that the topic group will continue for one more year. The topic group will report this year and will describe conclusions (but no recommendations). Next year the topic group will discuss recommendation on definitions (as part of topic group or wider FTFB) and find agreement with the group. The will be a short session/meeting in this in 2020. The topic group meeting summed up as:

1. Factsheets on groundgear used around the world have been assembled to indicate the diversity and variety of groundgears used for different species and bottom type, but the latter information was insufficiently provided

2. Bottom trawls towing over seabed with its groundgear touching the seabed, while semi-pelagic trawls may either have trawl door or groundgear touch the bottom, but not both
3. A variety of groundgears is used in trawls, ranging from combination ropes, chains, rubber cookies, discs, rockhoppers, and bobbins. The sizes of the elements are typically related to the type of seabed
4. A variety of rigging of groundgear is used for different type of trawls, such as single bottom otter trawl, twin trawls, triple trawls, or multiple trawls
5. Research on groundgear is often related to bottom handling capability of the gear, catch efficiency and selectivity for bottom-dwelling species
6. More recently, some research start to focus on energy efficiency and seabed friendliness
7. Historically, comparative fishing trials are carried out to compare catch (efficiency and selectivity), and robustness
8. Optical methods are used to document fish reaction to different groundgear, and their escape under the groundgear
9. Flume tank tests and numerical simulations are used to understand drag forces of different groundgear and their effect on trawl geometry. Numerical tools are also used to examine flow pattern and force of groundgear on the sediments.

Recommendations

1. More researches are needed to investigate fish reaction to groundgear, the environmental impact and energy efficiency of groundgear, or mudclouds stirred up by it, on the survival of fish escaped under the groundgear
2. Research on efficient and seabed-friendly groundgear are needed to harvest bottom-dwelling species with minimal impact to seabed and benthic species
3. Whenever possible, light groundgear, or semi-pelagic trawl or otterboard should be used to reduce seabed impact and fuel consumption
4. Specification of the bottom type is an important part when studying the groundgear and should be provided.

List of participants during FAO-FTFB WG meeting in Shanghai, China 8-12 April 2019 on the the topic group Groundgear.

Name	Institution	Country	Email
Dérien Lucie Vernetti Duarte	Centro Nacional de Pesquisa e Conservação da Biodiversidade Marinha do Sudeste e Sul do Brasil	Brazil	derienvernetti@yahoo.com.br
Cheng Zhou	Ocean University of China	China	zhoucheng286@126.com
Daomei Cao	Shanghai Ocean University	China	dmcao@shou.edu.cn
Ying Dai	Dalian University of Foreign Languages	China	286143216@qq.com
Yu Zhang	Chinese academy of fishery sciences	China	zhang-yu@126.com
Breddermann Karsten	University of Rostock	Germany	karsten.breddermann@uni-rostock.de
Uwe Lichtenstein	Thünen Institute of Baltic Sea Fisheries	Germany	uwe.lichtenstein@uni-rostock.de
Stephan Schacht	University of Rostock	Germany	stephan.schacht@uni-rostock.de
Ema Fatima	WWF-India	India	efatima@wwfindia.net
Matthew McHugh	Irish Seafood Development Agency	Ireland	Matthew.McHugh@bim.ie
Antonello Sala	Italian National Research Council	Italy	a.sala@ismar.cnr.it
Daniel Aguilar Ramirez	Instituto Nacional De Pesca	Mexico	daniel.aguilar@inapesca.gob.mx
Isara Chanrachkij	Southeast Asian Fisheries Development Center	Thailand	isara@seafdec.org
Pingguo He	Food and Agriculture Organization (FAO) / University of Massachusetts Dartmouth	USA	phe@umassd.edu
Hao Tang	Shanghai Ocean University	China	htang@shou.edu.cn
Liuxiong Xu	Shanghai Ocean University	China	lxxu@shou.edu.cn

Appendix V: Copy of Table 2.

Ref.	Factsheet code	FAO gear code	System	Groundgear type	Sweep		Seabed type	C/E/S	Location	Target species	Catch increase	Fuel use reduction	Seabed impact	Bycatch reduction
					No.	Material								
1	RKH 01	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	C	Barents Sea, Norway	COD	No			
1	SCS 01	OTB 03.12	Single	SCSG	2	Steel rope (wire)	Rocky-sand	E	Barents Sea, Norway	COD	Yes(a)	Yes(a)	Yes	
2	RKH 02	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	C	Barents Sea, Norway	COD,HAD,POK	No	-	-	No
3	RKH 03	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	E	Barents Sea, Norway	HAD	Yes(b)	-	-	
4	RKH 04	OTB 03.12	Single	Rockhopper + steel bobbins + chain clump	2	Steel rope (wire)	Rocky-sand-mud	E	Barents Sea, Norway	COD	No	Yes	Yes	
4	RKH 04	OTB 03.12	Single	Rockhopper + steel bobbins + chain clump	2	Steel rope (wire)	Rocky-sand-mud	E	Barents Sea, Norway	COD	No	Yes	Yes	
5	RKH 05	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand-mud	S	Barents Sea, Norway	COD,HAD				
5	BOB 01	OTB 03.12	Single	Bobbins	2	Steel rope (wire)	Rocky-sand-mud	S	Barents Sea, Norway	COD,HAD				
6	ROL 01	OTB 03.12	Single	Bobbin roller & rubber disk	2	Rubber encased wire	Rocky-sand	S	Newfoundland, Canada	COD,PLE,YEL				
7	RKH 06	OTB 03.12	Single	Rockhopper & raised fishing line	2	Steel rope (wire)	Sandy	E	North Sea	COD,HAD, POK, WHG,LEM,PLE				Yes(a)
8	RKH 07/COK 01	OTB 03.12	Single	Rockhopper & large footrope	2	Combination rope	Rocky-sand	C	West Coast (USA)	Demersal species			Yes(a)	
8	RKH 07/COK 01	OTB 03.12	Single	Rockhopper & small footrope	2	Combination rope	Rocky-sand	C	West Coast (USA)	Demersal species			-	
9	CHA 01	OTB 03.12	Single	Looped Chain	2	Combination rope	Sandy	C	Thailand	NPP,YEU			Yes	
10	CHA 02	PTB 03.15	Pair-trawl	Looped Chain	2	Steel rope (wire)	Mud-sandy	C	Vietnam	SQC,JAX, *(+demersal fish)*			Yes	
11	CHA 03	OTB 03.12	Pair-trawl	Combination Chain and Lead (pb)	2	Combination rope & PP	Mud-sandy	C	Vietnam	Loligo spp, Sepia spp and demersal fish		Yes		
12	LED 01	OTB 03.12	Single	Lead (Pb)	2	Lead rope	Mud-sandy	C	Philippines	Scad, herring, Mackeral, Sardine, Squid		Yes		
13	CHA 04	OTB 03.12	Single	Chain	2	PP (Polypropylene)	Mud-sandy	C	Cambodia	Parapenaeopsis spp. and Trachypenaeus spp.		Yes		
14	CHA 05	OTB 03.12	Single	Chain	2	PP (Polypropylene)	Sandy	C	Malaysia	Shrimp		Yes		
15	COK 02	OTB 03.12	Single	Rubber (Cookie)	2	PVA (polyvinyl alcohol)	Mud-sandy	C	Malaysia	Demeral fish		Yes		
16	CHA 06	OTB 03.12	Single	Dropchain Ø8-10 mm	2	Steel rope (wire)	Mud-sandy	C	New South Wales, Australia	Prawns (Peneaids)				-
16	CHA 07	OTB 03.12	Single	Dropchain Ø6 mm	2	Steel rope (wire)	Mud-sandy	E	New South Wales, Australia	Prawns (Peneaids)		Yes	Yes	Yes(a)
16	CHA 08	OTB 03.12	Single	Soft-brush chain	2	Steel rope (wire)	Mud-sandy	E	New South Wales, Australia	Prawns (Peneaids)			Yes	-
17	CHA 09	OTB 03.12	Single	Cookie + chain	2	Steel rope (wire)	Rocky-sand-mud	E	Oregon, California (USA)	PRA (Pandalus jordani)	No		Yes(a)	Yes
18	CHA 10	OTB 03.12	Single	Drop chain	2	Steel rope (wire)	Rocky-sand-mud	E	Oregon, California (USA)	PRA (Pandalus jordani)	No		Yes	Yes
19	CHA 11	OTT 03.13	Twin	Looped chain	4	Steel rope (wire)	Rocky-sand-mud	C	Irish Sea, west of Ireland, ...	NEP				
20	CHA 12	PTB 03.15	Quad	Looped chain	8	Steel rope (wire)	Rocky-sand-mud	C	Irish Sea, west of Ireland,	NEP				
21	COK 03	OTB 03.12	Single	Cookie	2	Steel rope (wire)	Rocky-sand-mud	C	Irish Sea, west of Ireland,	NEP, FLATFISH				
22	CHA 13	OTB 03.12	Single	Looped chain	2	Combination rope	Mud-sandy	C	Mediterranean, Italy	HKE, MUX, CEP	Yes			
23	CHA 14	OTB 03.12	Single	Comb. rope + Looped chain	2	Combination rope	Mud-sandy	C	Mediterranean, Italy	HKE, MUX, CEP, NEP	Yes	-		
23	CHA 15	OTB 03.12	Twin	Comb. rope + Looped chain	2	Combination rope	Mud-sandy	C	Mediterranean, Italy	HKE, MUX, CEP, NEP	Yes	Yes		
24	LED 01	OTB 03.12	Single	Comb. rope + Lead (Pb)	2	Combination rope	Mud-sandy	C	Mediterranean, Italy	HKE, MUX, CEP, NEP	No			
25	RHK 08	OTB 03.12	Single	Rockhopper + chain	2	Steel rope (wire)	Mud-sandy	E	Irish Sea, west of Ireland	COD, WHG, HAD, flatfish, monkfish, skate, ray	Yes			
26	RHK 09	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	E	Barents Sea, Norway	COD, HAD				
27	CHA 16	OTB 03.12	Single	Looped chain + PA with LED	2	Steel rope (wire)	Mud-sandy	C	Mediterranean, Turkey	PRA, red mullet, lizard fish, pandora				
28	RHK 10	OTB 03.12	Single	Rockhopper	2	Steel rope (wire)	Rocky-sand	E	Barents Sea, Norway	COD, HAD	No			Yes

(a) Assumed/not quantified (b) *For a limited range of sizes*

Annex 5: Factsheets

fish behaviour trials
to determine the phototactic response in fish to coloured LED lights

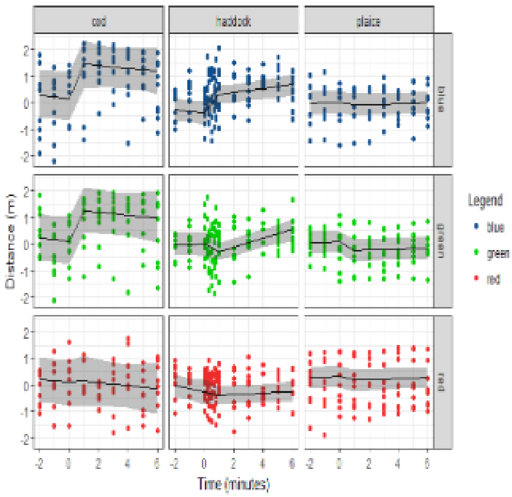
AIM
To try to identify species specific reactions to different coloured LED lights

TARGET SPECIES
Cod, haddock and plaice

LOCATION
These trials took place within the Marine Scotland Science's Fish Behaviour Unit (FBU). 81 trials in total were carried out across all 3 species. Trials took place between February 2017 to August 2018.

GEAR TRIALS
Fish were exposed to a strip of LED lights positioned vertically at the end of a fibreglass tank (7m x 3m x 1.5m). Three colours of light were trialled; blue, green and red.
For each experiment 3 batches of 8 fish were tested, each batch of fish was exposed to a single colour of light 3 times. The distances of the fish from the light were measured at set time points throughout the trials.
This included measurements before the light was turned on to get control measurements.

RESULTS
- **The blue light evoked an aversive response in both cod and haddock but overtime for cod this distance was reduced but for haddock it increased. No significant effect was found for plaice.**
- **The green light showed a significant effect for all 3 species. Cod quickly move away from the light and remain distant. Haddock move towards the light initially but soon became habituated to the light. Plaice showed a small but significant attraction.**
- **The red light did not have a significant influence on the behaviour of any of the 3 species tested.**



FURTHER INFORMATION
Emma Mackenzie
emma.mackenzie@gov.scot

marine scotland science | Scottish Government Riaghaltas na h-Alba gov.scot | SMARTFISH H2020 Innovation for sustainable fisheries

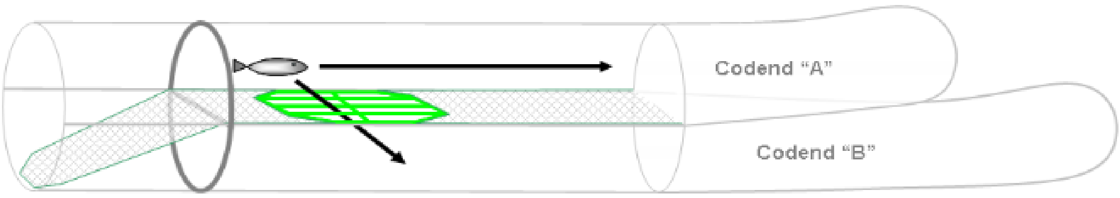
using an illuminated rigid grid to promote selectivity of towed fishing gear

AIM

To investigate whether light influences fish behaviour in the extension of the trawl.

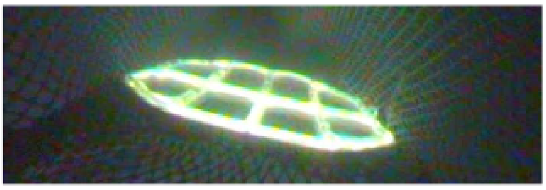
TARGET SPECIES

Mixed round and flat fish, Nephrops



AREA, VESSEL

28 hauls were carried out in the North Sea on board the MRV Alba Na Mara in March 2018.



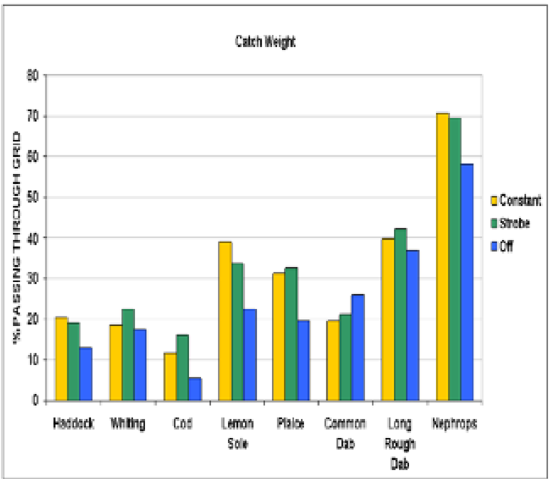
RESULTS

In general strobing and constant light elicits similar results within each species.

For all species except common dab, the light increases the fishes willingness to pass through the panel.

GEAR TRIALS

A prawn trawl was fitted with a panel of netting that diverts all the fish into the upper half of the extension and then runs between the selvedges to separate 80mm codends. Fish could pass through a grid mounted in the central panel, to be retained in the lower codend. Two light fibre lines were permanently attached to the grid, one illuminating the upper half and one illuminating the lower half of the grid. The LED light units emit green light and hauls were conducted with either the light on constantly, light off or flashing at 4 Hz.



FURTHER INFORMATION

Emma Mackenzie
emma.mackenzie@gov.scot

marinescotland science

Scottish Government
Riaghaltas na h-Alba
gov.scot

SMARTFISH H2020
Innovation for sustainable fisheries

Effect of SMP area and position on the release efficiency in a multispecies trawl gear

AIM

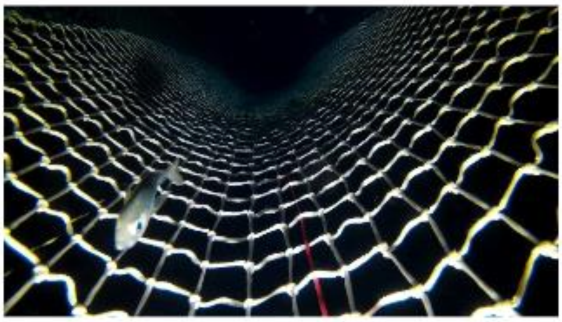
Asses on the effect of different configurations of the previously used Square Mesh Panel (SMP) to reduce discards of unwanted catch.

TARGET SPECIES

Hake, blue whiting, mackerel and horse mackerel.

AREA, VESSEL

12 hauls were carried out in the Bay of Biscay (ICES 8b & 8c) on board the R/V Emma Bardan.



GEAR TRIALS

Bottom trawl gear with modifications in a 80 mm SMP used in previous trials. In one experiment the SMP was placed in the lower panel, in the other experiment, the surface of the SMP set in the upper panel was increased.

RESULTS

With the SMP set in the lower panel a significantly higher escape of hake was observed.
Increasing the surface of the SMP set in the upper panel leads to an increase in the escape rate for all the tested species, notably for blue whiting and horse mackerel.

FURTHER INFORMATION

Luis Arregi (larregi@azti.es); Mikel Basterretxea mbasterretxea@azti.es
Elsa Cuende (ecuende@azti.es)

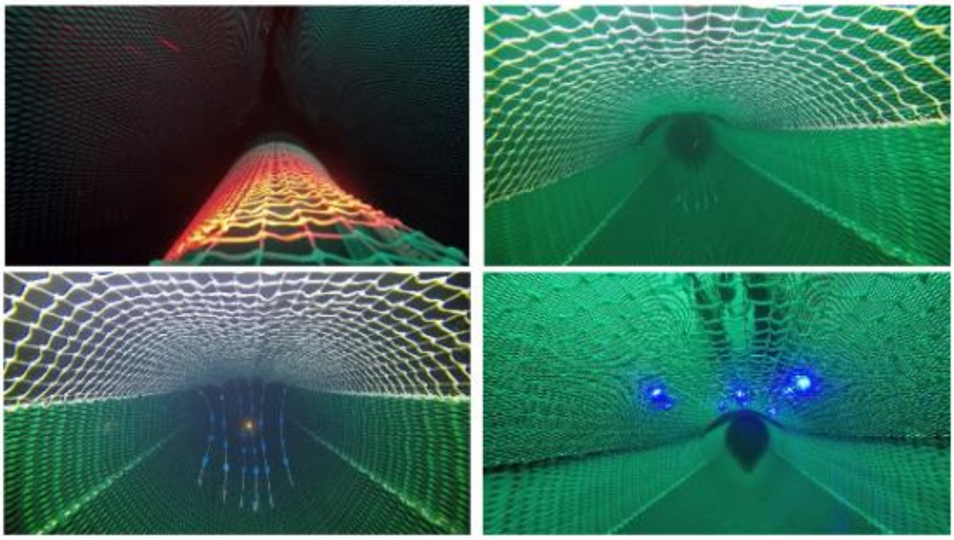
ICES CIEM International Council for the Exploration of the Sea / Conseil International pour l'Exploration de la Mer

Food and Agriculture Organization of the United Nations

Stimulating release of unwanted fish through a SMP in Basque otter trawl fishery

AIM

To determine if release efficiency of the SMP could be improved by using different stimulators: ropes, ropes with floats and blue LED lights.



TARGET SPECIES

Hake, horse mackerel and blue whiting.

AREA, VESSEL

32 hauls were carried out in the Bay of Biscay (ICES 8b & 8c) on board the R/V Emma Bardan.

GEAR TRIALS

A 2 m long and 1 m width SMP with 80 mm mesh size was inserted into the upper panel of the extension piece of a bottom trawl gear. 8 hauls were carried out for each of the following configurations: without stimulation, with ropes, with ropes and floats and with blue LED lights.

RESULTS

-Different stimulators used did not improve the escape of neither hake nor horse mackerel through the SMP.
-The combination of ropes and floats improved the release efficiency of 10-15 cm blue whiting. On the contrary, blue LED lights had a negative effect on the escape of this species.

FURTHER INFORMATION

Luis Arregi (larregi@azti.es)
Mikel Basterretxea (mbasterretxea@azti.es)
Elsa Cuende (ecuende@azti.es)

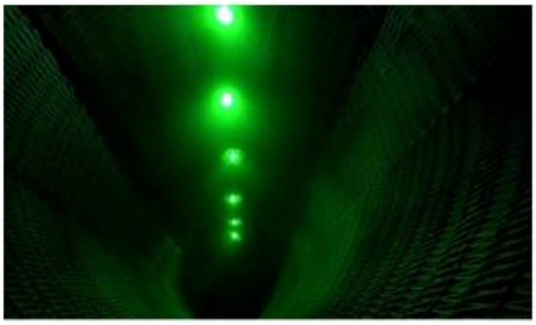
ICES CIEM · Food and Agriculture Organization of the United Nations · azti tecnalia

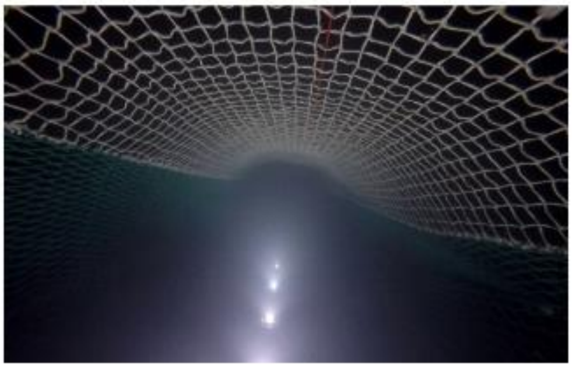
using LED lights to increase the contact probability with the SMP in a multispecies trawl gear

AIM
Asses on the effect of LED lights in the increase of the contact with the Square Mesh Panel (SMP) to reduce discards of unwanted catch.

TARGET SPECIES
Hake, blue whiting, mackerel and horse mackerel.

AREA, VESSEL
24 hauls were carried out in the Bay of Biscay (ICES 8b & 8c) on board the R/V Emma Bardan.





RESULTS
The LED lights in their different configurations did not produce significant increment in the escapement through the SMP. No relevant change in the behaviour was observed for selected species.

GEAR TRIALS
Bottom trawl gear with a 80 mm SMP in the upper panel combined with LED lights using different configurations (position and wave length).

FURTHER INFORMATION
Luis Arregi (larregi@azti.es); Mikel Basterretxea mbasterretxea@azti.es

ICES CIEM

Food and Agriculture Organization of the United Nations

using a square mesh panel to reduce the catches of choke species in a multispecies trawl gear

AIM

Minimization of discards of species subject to TAC in relation to the new EU regulation on discard reduction.

TARGET SPECIES

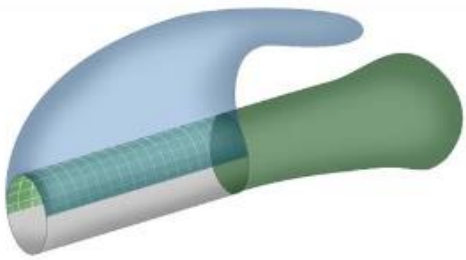
Hake, megrim, anglerfish

CHOKE SPECIES

Saithe, haddock, greater silver smelt.

AREA, VESSEL

30 hauls were carried out in the west of Scotland (ICES VIa) on board a commercial trawler.



GEAR TRIALS

A commercial bottom trawl gear with a 120 mm SMP ≥ 4,5 m^2 located in the upper panel just before the codend is compared with the regularly used gear.
31 experimental hauls were carried out during two cruises: September 2017 (15 hauls) and May 2018 (16 hauls).

RESULTS

The SMP tested in the cruise contributes to a significant reduction in the catch of the choke species and therefore to the problem of discards of the fleet.
As a result of the experiment, this SMP was implemented in the regulation for Spanish vessels fishing in area VIa.

FURTHER INFORMATION

Luis Arregi (larregi@azti.es); Mikel Basterretxea mbasterretxea@azti.es

ICES CIEM

Food and Agriculture Organization of the United Nations

Estimating in-water volume of purse seines implications on fish densities

AIM

Estimate in-water volume of purse seines as a function of proportion seine retrieved and seine size.

TARGET SPECIES

Mackerel (*Scomber scombrus*) and herring (*Clupea harengus*)

AREA, VESSEL

The pelagic purse seiners Ms “Libas”, Ms “Kings Bay” and MS “Asbjørn Selsbane” were used in the Norwegian Sea

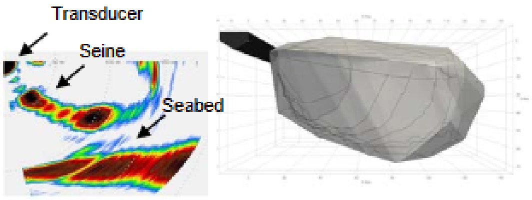


Figure 1. Vertical seine cross-section from an acoustic image (left) and 3-D reconstruction of the seine generated from several cross-sectional images of the seine (right).

GEAR TRIALS

Purse seine geometry was monitored with fishing vessel mounted multibeam sonar as the seine was hauled in. Seine contours were extracted from acoustic images and volume was estimated from 3-D reconstructions of the seine. In-water volume was modelled as a function of proportion of seine hauled and seine size using a log-linear mixed effects model.

FURTHER INFORMATION

Maria Tenningen, maria.tenningen@hi.no

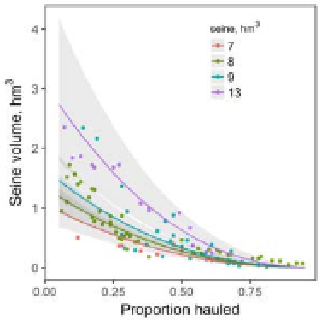


Figure 2. Purse seine in-water volume estimated as a function of seine size and proportion of seine hauled in.

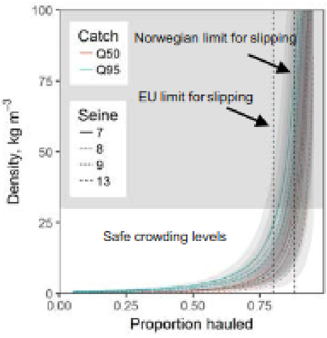


Figure 3. Expected fish densities in common sized mackerel catches (Q50 = 270 t; Q95=650 t) in different seine sizes. Catch size was divided by estimated mean and 95 credible intervals of seine volume from the model.

RESULTS

- **In-water seine volume was predicted to reduce 33-fold from 0 – 80% seine hauled**
- **Few data are available beyond 80% seine hauled and the model fit is poor.**
- **Fish density in the seine is expected to vary greatly depending on catch and seine size, but generally expected to be within safe crowding levels at 80% seine hauled.**

ICES CIEM · Institute of Marine Research · Food and Agriculture Organization of the United Nations

Purse seine gear monitoring with transponders

AIM

Develop a system for monitoring purse seine lead line position relative to vessel and school.

TARGET SPECIES

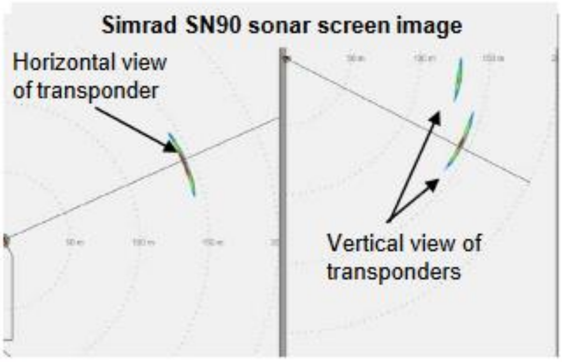
All pelagic

AREA, VESSEL

The system has been tested onboard purse seiner MS "Eros" in commercial mackerel and herring fisheries in the Norwegian Sea and the North Sea.

MS «Eros» (picture from fiskebåt)

Transponders are attached to the purse seine lead line



GEAR TRIALS

Simrad (Kongsberg maritime AS) have developed transponders that actively receive and send acoustic signals to the SN90 sonar transceiver that is mounted on the hull of a fishing vessel. This system, using three transponders has been tested in commercial fisheries.

RESULTS

Accurate positioning of the seine lead line relative to the fish school will provide better control of the catch process. This may help to improve catch efficiency and reduce the risk of bottom contact and gear damage.

The system works well, but needs to be further developed before it can be useful in commercial fisheries. Transponder signals need to be integrated into the fishing sonar mode.

FURTHER INFORMATION

Maria Tenningen, maria.tenningen@hi.no and Hèctor Peña, hector.pena@hi.no
http://crisp.imr.no/

Effect of increasing circumference of T90 codends on Baltic cod selectivity

COD-1

AIM

To observe what effect increasing circumference in a T90 codend has on the selectivity of cod (*Gadus morhua*).

TARGET SPECIES

Cod (*Gadus morhua*)

AREA, VESSEL

Baltic Sea (ICES 24 and 25)

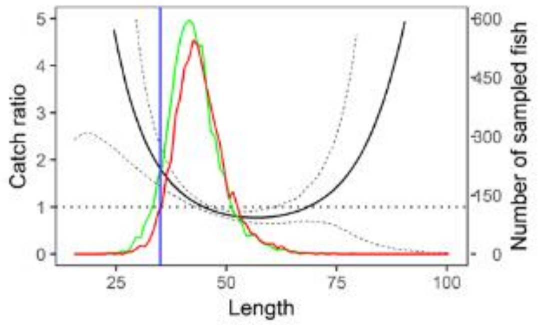
R218 Judith Bechmann (26 m, 485 kW)

GEAR TRIALS

A 120 mm T90 codend with a circumference of 92 meshes was compared with a standard T90 120 mm codend with a circumference of 50 meshes

RESULTS

The codend with a larger circumference caught significantly more cod under 47 cm. Increasing the circumference is therefore not optimal as it results in significantly more cod under the MCRS (35 cm) being caught.



FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU
DANMARKS FISKERIFORENING
Producent Organisation
HAV & FISK
Den Europæiske Union
Den Europæiske Hav- og Fiskerifond

Effect of codend material type on the selectivity of Baltic cod

COD-2

AIM

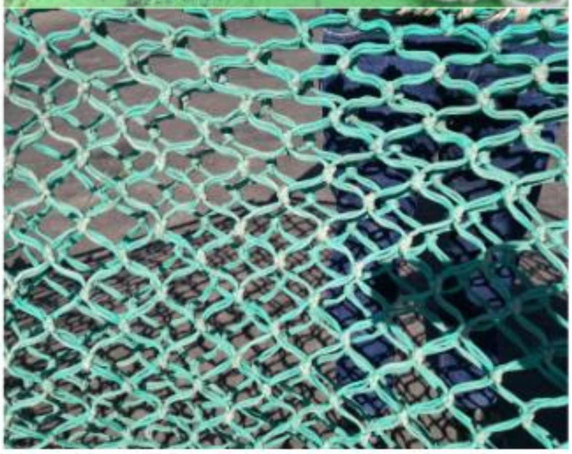
To observe what effect changing the codend material from polyethylene to polyester has on the selectivity of cod.

TARGET SPECIES

Cod (*Gadus morhua*)

AREA, VESSEL

Baltic Sea (ICES 24 and 25)
R218 Judith Bechmann (26 m, 485 kW)

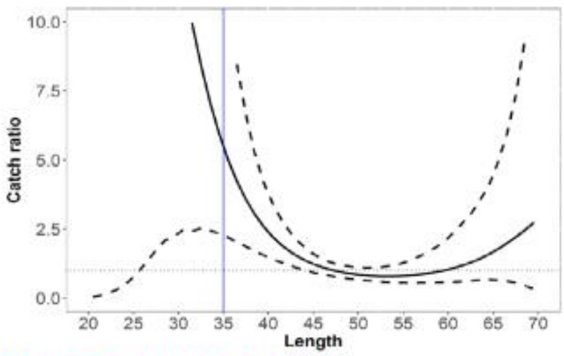


GEAR TRIALS

A 120 mm T90 codend made out of polyester was compared with a standard 120 mm T90 codend made out of polyethylene.

RESULTS

The codend constructed out of polyester caught significantly more cod under 44 cm. The use of polyester is therefore not optimal as it results in significantly more cod under the MCRS (35 cm) being caught.



FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU
DANMARKS FISKERIFORENING
Producent Organisation
HAV & FISK
Den Europæiske Union
Den Europæiske Hav- og Fiskerifond

Industry self-sampling to describe gear selectivity

COD-3

AIM

To determine whether it is possible for fishermen to collect data pertaining to the performance of fishing gears.

TARGET SPECIES

Cod (*Gadus morhua*)

AREA, VESSEL

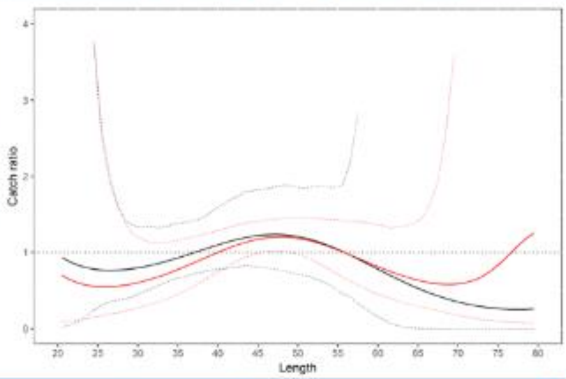
Baltic Sea (ICES 24 and 25)
R218 Judith Bechmann (26 m, 485 kW)

GEAR TRIALS

Fishermen were asked to measure 1 basket of cod per codend (80 individuals in total) from approximately 7 hauls (550 cod). These catch comparison data were compared to scientifically collected data from 6 hauls (5856 cod; no subsampling).

RESULTS

The catch comparison data collected by the fishermen (black line) showed the same trend as the data collected during the scientific trial (red line), although with larger uncertainties. This shows that fishermen can and should be involved in the collection of gear selectivity data.



FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU
DANMARKS FISKERIFORENING
Producent Organisation
AALBORG UNIVERSITET
HAV & FISK
Den Europæiske Union
Den Europæiske Hav- og Fiskerifond

Reducing circumference and increasing mesh size in the Baltic cod trawl fishery – Trial 1

COD-4

AIM

To reduce loss of cod (*Gadus morhua*) above the MCRS (35 cm) in the Baltic Sea cod trawl fishery.

TARGET SPECIES

Cod (*Gadus morhua*)

AREA, VESSEL

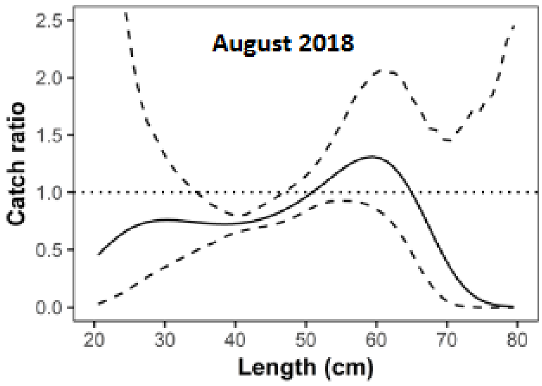
Baltic Sea (ICES subdivision 24 and 25)
R222 Bornø (17 m, 219 kW)

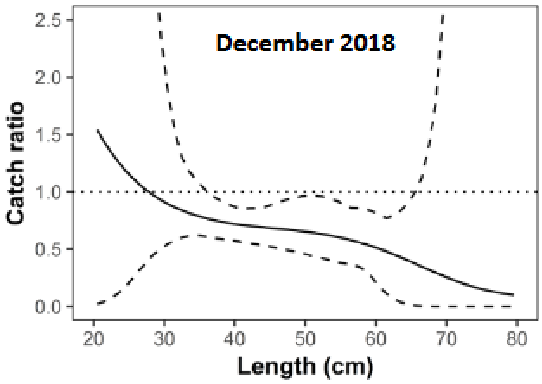
GEAR TRIALS

A T90 codend with a mesh size of 110 mm and a circumference of 40 meshes (test codend) was compared to a T90 codend with a mesh size of 115 mm and a circumference of 80 meshes (standard). The standard codend has been implemented in legislation since 1st Jan 2018 and the test codend was implemented in legislation until 2009, where it was replaced with a larger mesh size (120 mm).

RESULTS

2 trials were conducted in Aug (10 hauls) and Dec 2018 (10 hauls). Catch comparison results from the two trials were quite different. During the first trial, the test codend caught significantly less cod from 35-48 cm & indicated that catches of larger individuals may be higher, while in the second trial the test codend caught significantly less cod from 37-65 cm. The difference in results is possibly attributed to differences in catch sizes (1588 kg (719-3077) & 3385 kg (700-8400)).





FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU DANMARKS FISKERIFORENING Producent Organisation AALBORG UNIVERSITET HAV & FISK Den Europæiske Union Den Europæiske Hav- og Fiskerifond

Reducing circumference and increasing mesh size in the Baltic cod trawl fishery – Trial 2

COD-5

AIM

To reduce loss of cod (*Gadus morhua*) above the MCRS (35 cm) in the Baltic Sea cod trawl fishery.

TARGET SPECIES

Cod (*Gadus morhua*)

AREA, VESSEL

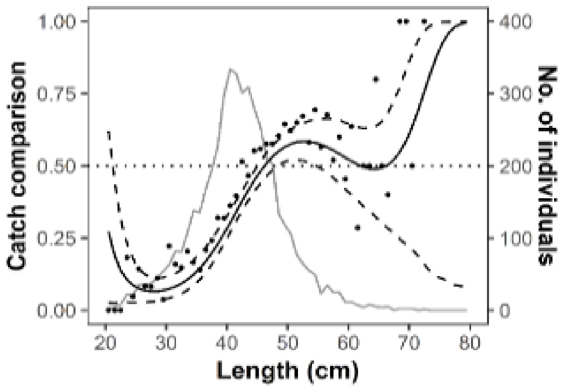
Baltic Sea (ICES subdivision 25)
R3 Orion (16 m, 270 kW)

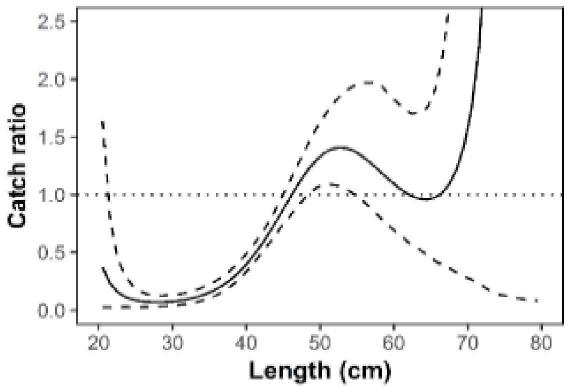
GEAR TRIALS

A T90 codend with a mesh size of 110 mm and a circumference of 40 meshes (test codend) was compared to a T90 codend with a mesh size of 115 mm and a circumference of 80 meshes (standard). The standard codend has been implemented in legislation since 1st Jan 2018 and the test codend was implemented in legislation until 2009, where it was replaced with a larger mesh size (120 mm).

RESULTS

9 hauls were carried out in the beginning of September 2018. Catch comparison results indicated that the test codend (110 mm codend) caught significantly less cod below 45 cm and significantly more cod between 48 and 54 cm than the standard codend (115 mm codend).





FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU
DANMARKS FISKERIFORENING Producent Organisation
AALBORG UNIVERSITET
HAV & FISK
Den Europæiske Union
Den Europæiske Hav- og Fiskerifond

Use of an escape grid to optimise the size selectivity of *Pandalus borealis*

PAN-1

AIM

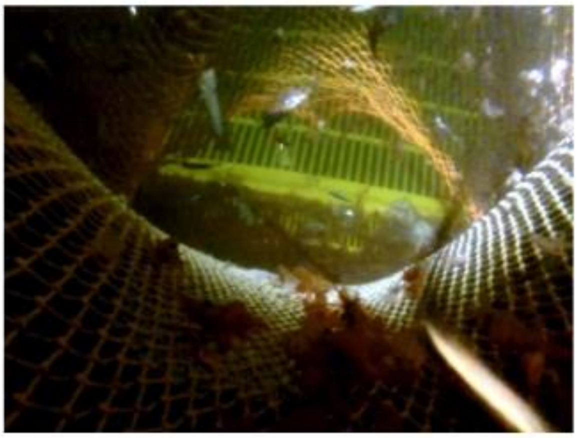
To reduce the capture of small Northern prawn (*Pandalus borealis*) in a shrimp trawl using an escape grid.

TARGET SPECIES

Northern prawn (*Pandalus borealis*)

AREA, VESSEL

Skagerrak (ICES IIIa)
S486 Sajoni (28 m, 746 kW)

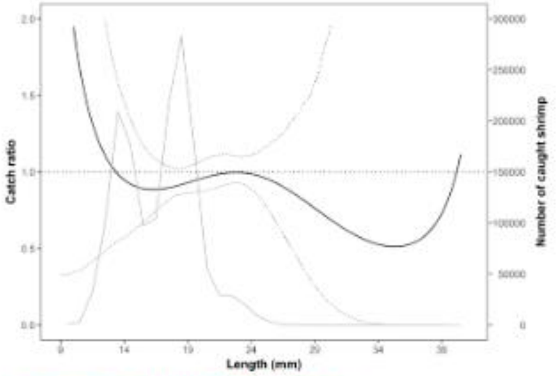


GEAR TRIALS

A gear with a grid consisting of two sections, a lower (10 mm bar spacing) and an upper section (19 mm bar spacing) was tested with a standard gear that had a grid with a 19 mm bar spacing.

RESULTS

Shrimp catches in the two gears were very similar. There was no significant difference in catches across all length classes. Underwater observations showed that there were large issues with clogging of the escape grid.



FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU DANMARKS FISKERIFORENING Producent Organisation HAV & FISK Den Europæiske Union Den Europæiske Hav- og Fiskerifond

Use of a T90 codend to optimise the size selectivity of *Pandalus borealis*

PAN-2

AIM

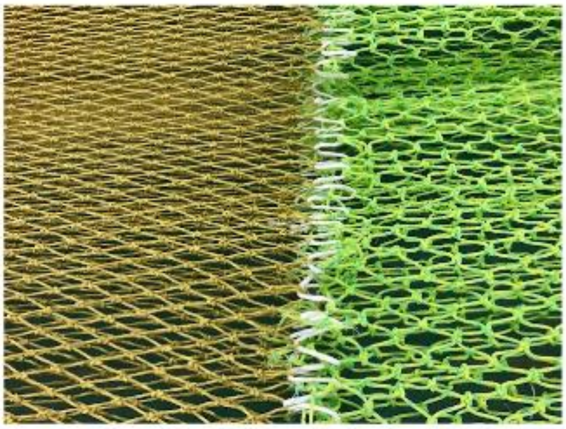
To reduce the capture of small Northern prawn (*Pandalus borealis*) in a shrimp trawl using a T90 codend.

TARGET SPECIES

Northern prawn (*Pandalus borealis*)

AREA, VESSEL

Skagerrak (ICES IIIa)
S486 Sajoni (28 m, 746 kW)



GEAR TRIALS

A T90 codend was tested against a standard diamond mesh codend. Both codends had a nominal mesh size of 36 mm. Standard grids, with a bar spacing of 19 mm, were mounted in both gears.

RESULTS

Initial feedback from the skipper indicated that the catch of small shrimp was reduced. However, the perceived reduction became less apparent further into the development phase. A possible explanation is that the netting knot size and twine thickness may have been too small, resulting in the initial improvement being reduced once the netting lost its initial bending stiffness. Further development trials are planned for 2019 under Fast-Track II.

FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU DANMARKS FISKERIFORENING Producent Organisation · Aalborg Universitet · HAV & FISK · Den Europæiske Union Den Europæiske Hav- og Fiskerifond

Modifying the bottom panel ahead of a grid to optimise the size selectivity of *Pandalus borealis*

PAN-3

AIM

To reduce the capture of small Northern prawn (*Pandalus borealis*) in a shrimp trawl using a T90 codend.

TARGET SPECIES

Northern prawn (*Pandalus borealis*)

AREA, VESSEL

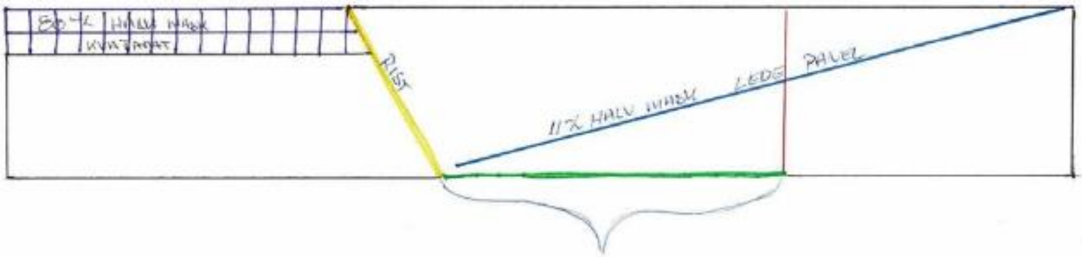
Skagerrak (ICES IIIa)
S486 Sajoni (28 m, 746 kW)

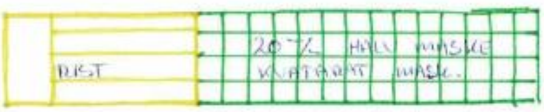
GEAR TRIALS

A square mesh panel (36 mm nominal mesh size) was inserted in the lower panel directly before the grid. Both codends had a nominal mesh size of 36 mm and were mounted with standard 19 mm grids.

RESULTS

Initial feedback from the skipper indicated that catches of small shrimp were similar to what was caught using the standard gear. Based on these preliminary results the trial was stopped.





FURTHER INFORMATION

Jordan Feekings
(jpfe@aqua.dtu.dk)

DTU
DANMARKS FISKERIFORENING
Producent Organisation
AALBORG UNIVERSITET
HAV & FISK
Den Europæiske Union
Den Europæiske Hav- og Fiskerifond

A modified SELTRA panel to reduce catches of fish in the *Nephrops* fishery

NEP-2

AIM

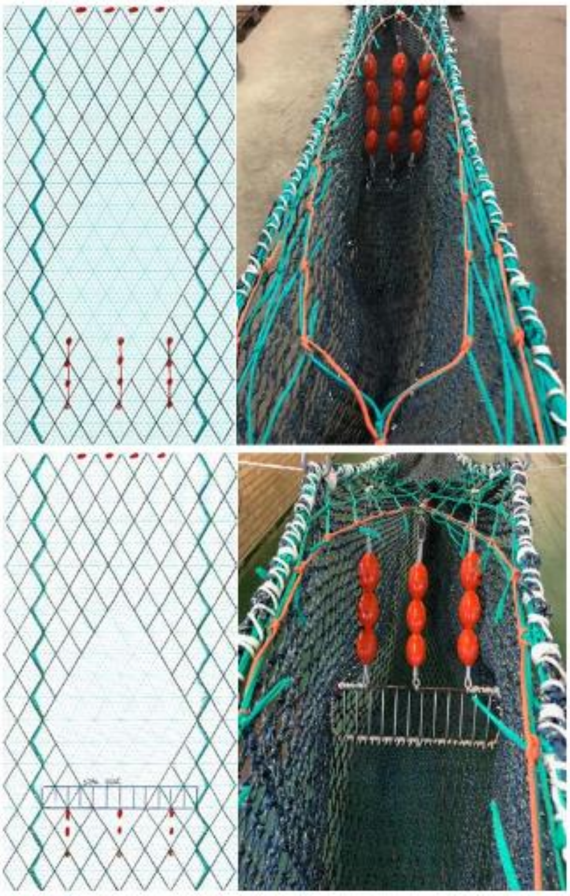
To reduce the capture of fish (E.g. cod, whiting, plaice) in the *Nephrops* trawl fishery.

TARGET SPECIES

Norway lobster (*Nephrops norvegicus*)

AREA, VESSEL

Kattegat and Skagerrak (ICES IIIa)
FN 459 M Jerup (15 m, 253 kW)



GEAR TRIALS

A modified SELTRA panel was tested in conjunction with two different devices to stimulate the escape of round and flatfish.

The first design consisted of three rows of floats, each with four floats. The second design consisted of three rows of floats, each with three floats, and a small grid mounted to the bottom panel to help stimulate the escape of flatfish.

RESULTS

Preliminary results indicate that catches of both round and flatfish are considerably reduced. In the few hauls worked up, catches of round and flatfish were reduced by approximately 60 %, while no reduction in *Nephrops* was observed. Scientific trials are planned under Fast-Track II.

FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU
DANMARKS FISKERIFORENING
Producent Organisation
AALBORG UNIVERSITET
HAV & FISK
Den Europæiske Union
Den Europæiske Hav- og Fiskerifond

A sorting grid to minimize catches of fish in the *Nephrops* fishery

NEP-3

AIM

To minimize the capture of fish (E.g. cod, whiting, plaice) in the Norway lobster (*Nephrops norvegicus*) trawl fishery.

TARGET SPECIES

Norway lobster (*Nephrops norvegicus*)

AREA, VESSEL

Kattegat and Skagerrak (ICES IIIa)
HG398 Nitrime (15 m, 253 kW)

GEAR TRIALS

As in *Pandalus* grids, the escape hole feeds into a large mesh fish codend (125 mm diamond mesh) allowing retention of high value fish by-catch. Bar spacing is 35 mm and the grid is divided and hinged into four off-set sections to ease handling and to reduce the risk of loosing large *Nephrops*.

RESULTS

Nitrime has tested and adjusted the gear over a long period. According to the fisherman, good reductions in fish bycatch were obtained while there was no loss of *Nephrops*. The grid is sensitive to seaweed and plastic and the multi hinge construction induces an extra risk of bending. As for by-catch grids in general, minor changes in angle may cause severe loss of the target species.

FURTHER INFORMATION

Rikke P Frandsen (rif@aqua.dtu.dk)

DTU | DANMARKS FISKERIFORENING Producent Organisation | Aalborg Universitet | HAV & FISK | Den Europæiske Union Den Europæiske Hav- og Fiskerifond

Testing of a real-time catch sensor in the *Nephrops* trawl fishery

NEP-5

AIM

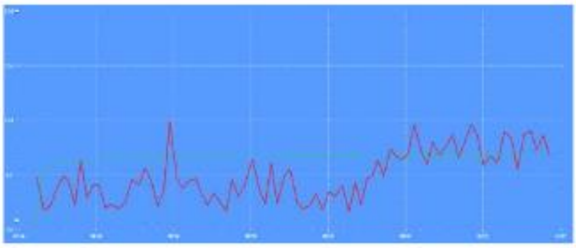
To optimise catches of Norway lobster (*Nephrops norvegicus*) in the *Nephrops* trawl fishery.

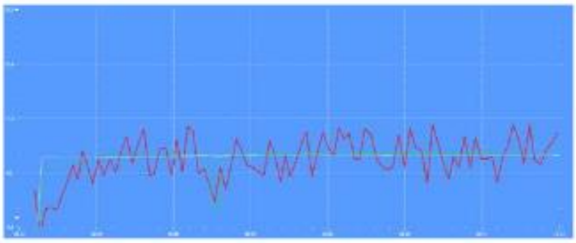
TARGET SPECIES

Norway lobster (*Nephrops norvegicus*)

AREA, VESSEL

Skagerrak (ICES IIIa)
O91 Albatros (17 m, 220 kW)





GEAR TRIALS

A real-time catch sensor (Notus ECHO) was mounted on a grid which covered the bottom half a SELTRA codend. The Notus ECHO was used to indicate, in real-time, when good catches of the target species, *Nephrops*, were obtained.

RESULTS

8 hauls were carried out in December 2018. There are indications that catch rates of the target species, *Nephrops*, can be detected in real-time when using the sensor. However, further testing is needed. Other hard shelled organisms, e.g. sea urchins, and hard objects such as stones may add noise to the results, making the results more inaccurate. Further testing is planned under Fast-Track II.

FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU
DANMARKS FISKERIFORENING Producent Organisation
Aalborg Universitet
HAV & FISK
Den Europæiske Union
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Testing a counter-herding device (FLEXSELECT) in the *Nephrops* trawl fishery

NEP-6

AIM

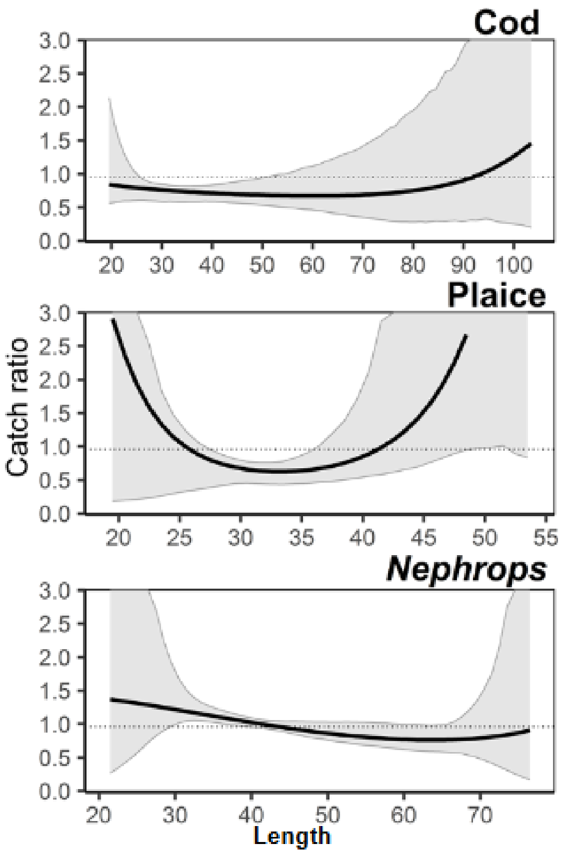
To determine if scaring lines could reduce fish catches in the *Nephrops* trawl fishery.

TARGET SPECIES

Norway lobster (*Nephrops norvegicus*), cod (*Gadus morhua*), saithe (*Pollachius virens*), and plaice (*Pleuronectes platessa*).

AREA, VESSEL

Skagerrak and Kattegat (ICES IIIa)
FN436 Tove Kajgaard (22 m, 299 kW)

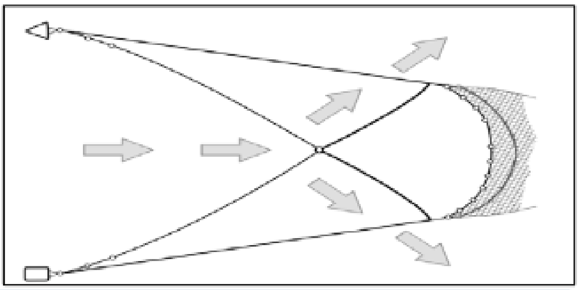


GEAR TRIALS

The counter-herding device (FlexSelect) was tested in a twin trawl design, where the scaring lines were mounted ahead of one of the trawls. In both trawls, the same codend (SELTRA) was used.

RESULTS

The scaring lines were found to significantly reduce the catch of fish, in particular cod (26-50 cm), plaice (27-35 cm), and saithe (48-59; 97-106 cm; figure not shown). With regard to the target species, *Nephrops*, catches of individuals between 30 and 39 mm (carapace length) were significantly higher in the trawl with scaring lines compared to the control (SELTRA).



FURTHER INFORMATION

Valentina Melli (vmel@aqua.dtu.dk)

DTU
DANMARKS FISKERIFORENING Producent Organisation
AALBORG UNIVERSITET
HAV & FISK
Den Europæiske Union
Den Europæiske Hav- og Fiskerifond