ICES WGFTFB 2018 REPORT

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Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB)

4 – 8 June 2018

Hirtshals, Denmark

ICES
International Council for the Exploration of the Sea
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Executive summary

The Working Group on Fishing Technology and Fish Behaviour (WGFTFB) is jointly supported be ICES and FAO and provides an international forum for scientists and technologists to present and discuss research on commercial and resource survey fishing gear and operations, and effect of fishing on re-source and environment. This year's meeting was hosted by DTU Aqua in Hirtshals, Denmark between the 4th and 8th of June 2018. This was one of the largest meetings the WGFTFB has held. One hundred and one participants (& 20 observers) from 22 countries attended the meeting, with the majority from ICES Member Countries, but also many others from non-ICES countries such as China, Japan, Korea, Turkey and New Zealand.

The science shared at the meeting included 45 presentations and 20 posters, describing a broad range of research topics. These included developing more environmentally responsible fishing methods and assessing the impact of fishing gears on the ecosystem, for example, biodegradable fishing nets that reduce marine litter and ghost fishing. There were many projects which tested innovative selective fishing gears in collaboration with the fishing industry. A lot of these have been catalysed by the implementation of the EU Landing Obligation and the incentives in reducing unwanted catches. These practical trials were supported by initiatives to communicate selective gear options to the fishing industry and to promote industry-led testing of selective gear. Also linked to the Landing Obligation, the effect of fishing gear design and fishing operation on the survival of discarded animals was described as under the new policy, species that demonstrate high discard survival rates can be exempted from the discard ban.

In addition, there were four dedicated topic groups focusing on: artificial light for bycatch mitigation; contact probability of selective devices; factsheets on fishing gear selectivity; and evaluation of trawl groundgear. Using artificial lights to modify catches is currently receiving a lot of attention and is showing great potential as a tool to improve species selectivity. It was shown that using lights in trawls and on fish pots can substantially modify the behaviour and catches of fish and other taxa. This work remains fundamental, but it has shown that different species react differently to light and this reaction can vary between night and day. In addition, light with different characteristics has been demonstrated to induce different fish reactions. Another Topic Group is working on developing a series of factsheets on fishing gear selectivity and catch comparison trials. As the ICES – FAO WGFTFB has a global membership and perspective, it is ideally positioned to both gather and disseminate this type of information. It also has technological expertise to ensure that the factsheets address bycatch and discard issues that face the fishing industry. The third Topic Group is working on evaluating trawl groundgear for efficiency, bycatch, and impact on the seabed. The last group is focusing on contact probability of selective devices and address key factors influencing the effectiveness of selectivity devices. The contact probability Topic Group ends this year and its outcome is included in this year's full report. For next year's meeting, a new Topic Group on passive fishing gears will be established to examine many urgent issues such as unwanted bycatch, and to identify potential synergies in developing new approaches to promote sustainability of passive gears.

Next year's meeting, which will be sponsored and led by FAO and is proposed to be held in Shanghai (China), will be focusing on responsible fishing technology for a healthy ecosystem and clean environment with a mini-symposium addressing environmental issues related to fishing gears and their operations.

1 Administrative details

Working Group name

ICES-FAO Working Group on Fish Technology and Fish Behaviour (WGFTFB)

Year of Appointment within the current three-year cycle

2018

Reporting year concluding the current three-year cycle

2

Chairs

Haraldur Arnar Einarsson (ICES Chair), Iceland

Pingguo He (FAO Chair), Italy

Rapporteur: Thomas Catchpole, UK and Michael Breen, Norway

Meeting venue

Hirtshals, Denmark

Meeting dates

4-8 June 2018

2 Introduction

Directive

The directive of the WGFTFB is to initiate and review investigations of scientists and technologists concerned with all aspects of the design, planning, and testing of fishing gears used in abundance estimation, selective fishing gears for bycatch, and discard reduction, as well as environmentally benign fishing gears and methods with reduced impact on the seabed and other non-target ecosystem components.

The Working Group's activities shall focus on all measurements and observations pertaining to both scientific and commercial fishing gears, design and statistical methods and operations including benthic impacts, vessels, and behaviour of fish in relation to fishing operations. The Working Group shall provide advice on application of these techniques to aquatic ecologists, assessment biologists, fishery managers, and industry.

3 Terms of Reference

The ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) chaired by Haraldur A. Einarsson, Iceland and Pingguo He, FAO, met on 4–8 June 2018 in Hirtshals, Denmark to work on the following specific Terms of References that were developed from WGFTFB's multi-annual ToRs (Annex 5).

The Term of Reference for this year Topic groups was following:

Evaluating the application of artificial light for bycatch mitigation (Light)

A WGFTFB Topic Group convened by Noëlle Yochum (USA), Darcie Hunt (Australia), and Junita Karlsen (Denmark) was formed this year to evaluate the application of light as a mechanism for bycatch mitigation.

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.

Factsheets on fishing gear selectivity and catch comparison trials (Facts)

A WGFTFB Topic Group convened by Barry O'Neill (Scotland) and Jordan Feekings (Denmark) was formed this year to develop a series of factsheets on fishing gear selectivity and catch comparison trials

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.

Contact Probability of Selective Devices (Contact)

A WGFTFB topic group of experts convened by Daniel Stepputtis (Germany) and Bent Herrmann (Denmark) will continue to investigate, understand and improve the contact probability of specific selective devices (e.g. grids, netting). It will document and evaluate current and past work regarding the influence and improvement of contact probability. This will include studies from a wide range of scientific fields, such as selectivity, behaviour, hydrodynamics and gear design. Special attention was given to investigating how to improve the performance of gears and selective devices with suboptimal selective properties.

Terms of reference:

1. Summarize current and past work in relation to contact probability
2. Discuss and describe methods (experimental and statistical) to investigate and quantify contact probability
3. Investigate and make recommendations on how to improve contact probability in selective devices, including:
    a) Identification of gears and selective devices with suboptimal contact probability (preferably based on current gear trials from group members)
    b) Discussion on potential causes and solutions
    c) Recommendations on experimental/theoretical work to understand and improve the contact probability

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

A WGFTFB topic group convened by Roger B. Larsen (Norway), Antonello Sala (Italy) and Pingguo He (USA) met to discuss knowledge of groundgear designs and other components that contact the seabed during bottom trawling.

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.

4 Participants and Meeting Agenda

A full list of participants I given in Annex 1. The agenda is included in Annex 2.

5 Explanatory Note on Meeting and Report Structure

The meeting was comprised primarily of three sessions; an open session of presentations to plenary, a topic group session, and a session discussing WGFTFB business. The open session was further divided into sub-sessions, with presentations related to the following:

1. Fishing-gears and impact;
2. Selectivity in a broad sense;
3. Mean and methods in survival, biodegradable and design simulations;
4. Species and size selectivity in crustacean fishery;
5. Gear technology for better selectivity;
6. Artificial lights with fishing gears;
7. Poster session;

The session, WGFTFB business included reports by topic group conveners on the outcomes of the respective topic group, as well as other important procedural matters.

The conveners of ToRs prepared a working document, reviewing their progress on their ToRs and recommendations and conclusions based on the topic group's work. The summaries and recommendations for the working documents for each ToR were reviewed by WGFTFB and were accepted at the meeting, rejected or modified accordingly to reflect 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. The abstracts are included in this report, together with the authors' names and affiliations. Although discussion relating to the individual presentations was encouraged but 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 displayed in this report like has been the practice in the WGFTFB annual report before.

6 Opening of the meeting

6.1 The opening and background of the meeting

The meeting was opened by Ludvig Ahm Krag, a senior researcher at DTU Aqua in Hirtshals followed by a video message to the WGFTFB from the Danish Minister of Fisheries, Eva Kjer Hansen. The ICES-chair of the WGFTFB Haraldur Arnar Einarsson took control over the meeting and welcomed all to one of the largest gatherings this group have held. Pingguo He FAO-chair followed with a briefing on relevant activities of FAO.

The registered number to the meeting was one hundred and one participants (plus 20 observers) from 22 countries. The majority from ICES Member Countries were represented, but also many non-ICES countries such as China, Japan, Korea, Turkey and New Zealand attended the meeting (see more detailed in figure 6.1). The last two meetings where held in locations a long distance from the majority of the ICES Member Countries. The proximity to many of the member countries could explain the high turnout at this year's meeting. 45 oral presentations in six open sessions were given. A poster session with 20 posters, a record for the working group, was held. Many new young scientists attended the meeting. This was well received and is a very positive development for the WGFTFB. While proximity is on factor for high attendance, the topics and current issues are another. General concern about ocean health from fisheries activity, EU's implementation of a landing obligation, marine plastics as well as bycatch of unwanted species could be among the reason for greater interest in fishing gear technology. There were a four Topic Groups working at this meeting. Some had organized additional oral presentations, but all Topic Groups worked as scheduled by terms of references.

Some business issues were taken up at the meeting as usual for example the meeting had an introduction to issues about two recommendations from ICES system but most of WGFTFB business issues were on the agenda on Friday afternoon.

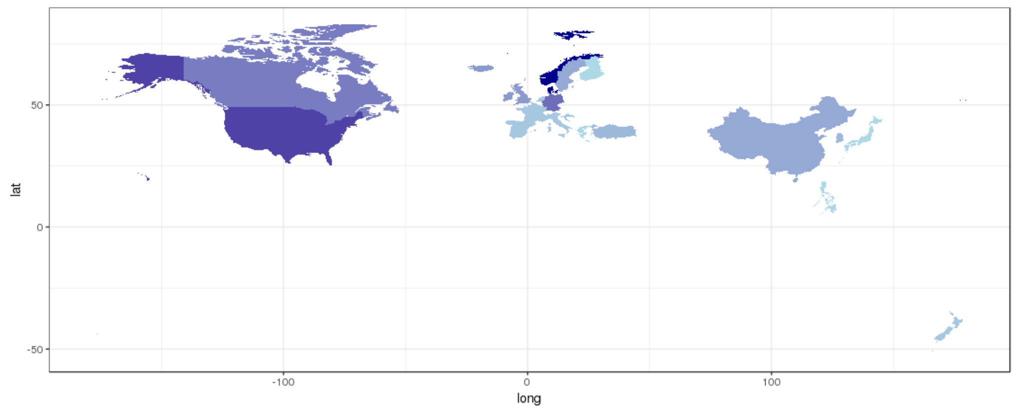

Figure 6.1. The figure shows the countries of origin of the WGFTFB participants. The strength of the colour represents how many was from each country. (Denmark 15, Norway 15, USA 11, Germany 8, Canada 7, Iceland 5, Ireland 5, UK 5, China 4, Sweden 4, South Korea 3, Turkey 3, Croatia 2, France 2, Italy 2, Netherlands 2, New Zealand 2, Spain 2, Finland 1, Greece 1, Japan 1, Philippines 1).

6.2 FAO Briefing on Relevant Activities

(Contact: Pingguo He, E-mail: Pingguo.he@fao.org, or phe@umassd.edu)

The Food and Agriculture Organization of the United Nations (FAO) works to secure food, including seafood, for a growing world population. The FAO Fishing Operation and Technology Branch (FIAO) deals with many topic areas that fall in the purview of WGFTFB. FIAO provides technical guidance on design, construction, operation and use of vessels and fishing gear. FIAO is also the main branch for the development of international instruments and guidelines related to fishing operations and its impact on the environment. FIAO provides technical assistance to increase economic efficiency, reduce waste, and minimize environmental damage caused by fishing operations and fishing practices, improve socio-economic viability and livelihoods in small-scale fisheries, make vessels and fishing gear safer for all users, assist in responding to emergencies, support disaster preparedness and disaster risk management implementation and policies, and enhance operational effectiveness of monitoring, control and surveillance, in particular to combat illegal, unreported and unregulated (IUU) fishing. Currently FIAO has activities in the following areas related to ICES-FAO WGFTFB.

6.2.1 Global assessment of discards

Bycatch and discards constitute a sustainability threat in the fisheries sector by inflicting undue mortalities that jeopardize long-term food security and livelihoods of coastal communities. Thus, FAO paid continued attention to bycatch and discards to ensure that they are addressed comprehensively in conservation and management of fisheries through an ecosystem approach to fisheries management.

During the last twenty-five years, FAO has commissioned two global assessments of fisheries discards and published two influential reports:

1. A global assessment of fisheries bycatch and discard by Alverson *et al.* (1994). http://www.fao.org/docrep/003/t4890e/t4890e00.htm
2. Discards in world marine fisheries – an update by Kelleher (2005). http://www.fao.org/docrep/008/y5936e/y5936e00.htm

FAO considered it very important to have updated information on how the world fisheries is performing in reducing discards. The new Global Assessment of Marine Fisheries Discards focuses on the scale of discards, trends in discarding and on fisheries management issues and practices associated with discards.

The new global discard project estimate takes the ‘fishery-by-fishery’ approach adopted by Kelleher (2005). The new study includes publicly available discard data published in the last 20 years to establish the baseline of a time-series of global marine fisheries discards for monitoring the status and trends of discard management. In addition, the new study developed a new fisheries database incorporating landings data from the FAO Global Capture Production database (FishStat J) over 2010 to 2014 which allocates landings to over 2000 fisheries worldwide, and the discard database. The project also provides the detailed method employed for estimating global discarding rates, making this global estimate transparent and replicable.

This project also compiled a list of measures for managing bycatch and reducing discards, as well as description of related issues (i.e. pre-catch and post-release mortality), which are key for the effective management of this critical issue. The report also includes a chapter on bycatch and discards of Endangered, Threatened and Protected species, providing an updated overview of this specific dimension of the bycatch and discard issue. The report will be published as a FAO Fisheries Technical Paper by the end of 2018.

6.2.2 Regional project on bycatch and discards

At regional level, two projects are under implementation to develop trawl fisheries management plans incorporating ecosystem approach to fisheries (EAF) principles. One of them took place in Southeast Asia (REBYC-II CTI project) and was completed in 2017 and the other is ongoing in Latin America and Caribbean (REBYC-II LAC project).

The project, "Strategies for trawl fisheries bycatch management" (REBYC-II CTI) contributed to the sustainable use of fisheries resources and healthier marine ecosystems in the Coral Triangle and Southeast Asian waters by reducing bycatch and fishing impact by trawl fisheries. It was implemented in Indonesia, Papua New Guinea, Philippines, Thailand, and Viet Nam between 1 November 2011 and 31 May 2017. The implementing partners include the Southeast Asian Fisheries Development Center, and governments/institutions of Indonesia, Philippines, Papua New Guinea, Thailand, Vietnam and Philippines. The project had four components:

1. Policy, legal and institutional frameworks;
2. Resource management and fishing operations;
3. Information management and communication; and
4. Awareness and knowledge.

The ongoing project "Sustainable management of bycatch in Latin America and Caribbean trawl fisheries" (REBYC-II LAC) was launched in July 2015 and will finish in June 2020. It involves stakeholders from six countries in Latin America and the Caribbean (Brazil, Colombia, Costa Rica, Mexico, Suriname, and Trinidad and Tobago). The project is a part of FAO's commitment to implement the International Guidelines on Bycatch Management and Reduction of Discards and is executed through partnerships with government institutions as well as fishers, fish workers, vessel owners, local universities and research institutions, RFBs and NGOs. The project has four components:

1. Improving institutional and regulatory arrangements for shrimp/bottom trawl fisheries and bycatch co-management (within EAF management framework);
2. Strengthening bycatch management and responsible trawling practices within an EAF framework;
3. Promoting sustainable and equitable livelihoods through enhancement and diversification; and
4. Project progress monitoring, evaluation and information dissemination and communication.

6.2.3 Trawling best practice

To objectively assess the impact of bottom trawls on a global scale and to develop trawling best practices in support of the Code of Conduct for Responsible Fisheries, FAO, in collaboration with the Trawl Study Committee, held three expert workshops between 2014 and 2017. The Trawl Study Group led by Professors Ray Hilborn (University of Washington), Mike Kaiser (Bangor University) and Simon Jennings (International Council for the Exploration of the Sea), coordinates an international initiative "Finding common ground on the scientific knowledge regarding best practices in trawling". The workshops were held in Asia (Bangkok, Thailand; http://www.fao.org/3/a-i6611e.pdf), Latin America (Cartagena, Colombia), and Africa

(Marrakech, Morocco), and were titled "Use of best available science in developing and promoting best practices for trawl fishing operations".

The workshops identified several best practice measures that might limit or reduce impact of trawling, such as:

1. Gear design and operation (prohibition by gear type, gear and operation modifications)
2. Spatial control (freeze fishing footprint, nearshore restrictions, habitat - type related prohibitions, broad - scale habitat management, rolling hot spots, move - on rules)
3. Impact quotas (invertebrate bycatch quotas, habitat impact quotas)
4. Effort control (effort reduction)

The workshops also established a set of performance metrics of management measures and industry practices that would compare the efficacy of different approaches, using an evidence - based analytical framework:

1. Benthic biota - Biomass, species diversity/richness, species composition, size spectra, and other ecological proxies for indirect impacts on fish populations
2. Sustainable food production and food security - Harvest levels and catch composition affecting domestic consumption and export markets
3. Ecosystems and ecosystem services - Spatial extent and inclusion of representative habitats, especially those supporting vital ecological functions such as spawning, feeding, and growth to maturity
4. Fleet performances - Direct costs affecting operational efficiency, including those related to gear changes or modification, fuel usage, and catch rates.

It was recognized that best practices to minimize trawling impacts on the benthos in overfished systems would include efforts to rebuild stocks to increase target biomass, which would not only reduce effort required to harvest the quota (thus impacts), but also support a variety of other socio-economic goals including less fuel consumption and greenhouse gas emission, and reduced poverty and improved livelihood of many coastal communities. It was understood that the definition of best trawling practices might differ by location, region, or country, and by prevailing circumstances; therefore, useful guidelines and performance metrics should be flexible and account for a broad range of biologic al, technical, socio-economic factors, and the local and regional policy drivers for fishery management. Developing best trawling practice guidelines would need to include stakeholder consultations on elements of the best practice analytical framework, a global review of successful and unsuccessful applications of the different management options, and continuing collaborations with researchers, managers and fishing industry from all continents.

Managing bottom trawling involves trade-offs between production of food and jobs from fishing, and protection of biota. Different countries or regions may make different choices on where along this trade-off they wish to be, and thus best practice guidelines should identify management actions that would achieve the best outcomes at a minimum social and economic costs.

6.2.4 Voluntary Guidelines on the Marking of Fishing Gear for combating ALDFG and Ghost Fishing

In April 2016 FAO organized an Expert Consultation on the Marking of Fishing Gear. The Consultation. The main outcome was Draft Guidelines on Marking of Fishing Gear. Then in 2018, FAO convened a Technical Consultation on the Marking of Fishing

Gear. The Technical Consultation adopted the Voluntary Guidelines on the Marking of Fishing Gear (http://www.fao.org/3/MX136EN/mx136en.pdf). The Voluntary Guidelines are considered an important tool in minimizing the impact of ALFDG including ghost fishing by ALDFG, and in IUU fishing. The Technical Consultation also recommended the development of a global strategy to address ALDFG and its harmful impacts, including food loss through ghost fishing, and that States should consider the development and implementation of national action plans to address ALDFG.

Potential long-term benefits of appropriate marking of fishing gear include reduced quantity of ALDFG, reduced entanglement risk for marine species, and reduced habitat damage caused by ALDFG. Furthermore, reduced loss of potential catch, easier recovery of lost gear and reduced time spent trying to recover lost gear would be of direct benefit for the fishing sector. Appropriate marking may also contribute in reducing illegal operations and thereby provide more fish for authorized fishers. Finally, safety at sea would improve.

Two pilot projects on gear marking were completed recently. The projects were to demonstrate feasibility and benefits of gear-marking, and to test new or emerging gear marking technologies. One of the pilot projects deals with the gillnet fisheries in Indonesia (http://www.fao.org/3/BU654en/bu654en.pdf) and the other with Fish Aggregating Devices (FADs) (http://www.fao.org/3/BU653en/bu653en.pdf). A paper on "Technologies for the marking of fishing gear to identify gear components entangled on marine animals and to reduce abandoned, lost or otherwise discarded fishing gear" was published in Marine Pollution Bulletin.

6.2.5 Marine mammal bycatch in fisheries

FAO members have expressed concern about the bycatch of marine mammals at recent sessions of COFI. FAO thus convened an "Expert Workshop on Means and Methods for Reducing Marine Mammal Mortality in Fishing and Aquaculture Operations", from 20 to 23 March 2018 in Rome to review findings of recent international marine mammal bycatch workshops. The workshop evaluated relative merit of different strategies and measures for mitigating bycatch and mortality of marine mammals. The workshop produced some key technical outputs, including a table summarizing marine mammal bycatch mitigation techniques across different gear types and species, and a draft decision-making tool (decision tree) which could be used to support management decision-making processes.

The workshop recommended that:

1. FAO develop Technical Guidelines on means and methods for prevention and reduction of marine mammal bycatch and mortality in fishing and aquaculture operations to support FAO's Code of Conduct for Responsible Fisheries and to supplement International Guidelines on Bycatch Management and Reduction of Discards;
2. FAO consider establishing a mechanism to facilitate the collection of information on the global implementation of the proposed Technical Guidelines, within the broader framework of the International Guidelines on Bycatch management and Reduction of Discards, and including marine mammal bycatch prevention and reduction efforts in the biannual SOFIA publication; and
3. FAO consider establishing a global capacity development programme to support developing States in the application of the proposed guidelines.

The full report of this workshop, including the full list of recommendations and appendices, is available at http://www.fao.org/3/I9993EN/i9993en.pdf.

7 Open Session Presentations

50 years of fishing technology at the University of Rostock

Harry Stengel[1], Mathias Paschen[2]*, and Bob van Marlen[3]*

[1]Retired University Rostock, Germany – Faculty of Mechanical Engineering and Marine Technology, former Chair of Fishing Technology, [2]University Rostock, Germany – Faculty of Mechanical Engineering and Marine Technology, [3]Retired Wageningen Marine Research, IJmuiden, Netherlands.

This year it was 50 years ago that education in fishing technology officially started at the University of Rostock. We will look back at the major achievements in teaching and scientific research over these years. Two periods can be distinguished, the years 1968-1992 under the leadership of prof. Dr. H. Stengel, and the years: 1992-now (2018) under the leadership of prof. Dr. M. Paschen. Wageningen Marine research (former RIVO) started a cooperation with the University in 1988, and many collaborative projects have been carried out, as well as practical training of students at RIVO's facilities.

Our talk will focus on the following topics:

- Organizational aspects of the Chair of Fishing Technology (rededicated in: Chair of Ocean Technology, in 1992) of the University with numbers of graduates.
- Model tests of fishing gears using a wind tunnel.
- Application of photogrammetry for 3D acquisition of trawls in wind tunnels.
- Development of rope trawls, and other drag reduction designs.
- The tension element method (TEM) as a replacement of the finite element method (FEM) for hydrodynamically loaded flexible rope and netting systems.
- The interaction of fishing gear components and the seabed.
- Prediction of the dynamics of flexible multi-body systems including integrated rigid bodies in real time.
- Analyses of fluid-net-structure interactions by CFD and PIV.
- The development of a single door trawl for towing at the surface outside the wake of the vessel.
- The cooperation between RIVO and the University of Rostock in times of great political changes.

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7.1 Open session: Fishing-gears and impact

Global marine mammal bycatch in fisheries through the List of Foreign Fisheries: An analysis of fishing regions and gear types

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The United States' Marine Mammal Protection Act (MMPA) states that the United States can 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. Under this regulation, 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. We analysed fishing areas with the highest incidental mortality in their fishing practices and the gear types with high marine mammal incidental mortality. We found that these two are one and the same as gillnets disproportionally entangle and kill marine mammals more than alternative gear types and the two regions with the highest marine mammal interactions also have the highest usage of gillnets in their fishing practices: fisheries operating in the Northeast Atlantic Ocean region and fisheries operating in the western Indian Ocean. Harbour porpoise dominate the marine mammal bycatch in the Northeast Atlantic Ocean while no one species is predominantly impacted in the western Indian Ocean, instead greater than 10 species of dolphins are commonly taken as bycatch here. A tried and true mitigation method to reduce harbour porpoise mortality is net pingers that warn away porpoise in the area of submerged nets. However, for fisheries impacting multiple marine mammal species, no one method has been proven effective to reduce interaction with nets. Compounding this challenge is many of the fisheries operating in the western Indian Ocean are small-scale or artisanal. We pose the questions for discussion: How can bycatch levels be mitigated in these disparate fisheries? How can we explore mitigating strategies and increase scientific capacity in fisheries where multiple species of marine mammals are impacted?

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Fish and shout: understanding the acoustic reflectivity of modified gillnets

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The importance of mitigating bycatch of harbour porpoises in gillnets has long been recognized. Despite indications that echolocating porpoises are able to detect gillnets, it is still unclear what the exact mechanism behind entanglement is, as we lack an understanding of how well gillnets are perceived by the animals. Provided that the animal is actively using its' sonar, the echo of gillnets may be perceived too late, too weak or not identified as an obstacle due to masking effects. The echo largely depends on the acoustic reflectivity of the target (here: the gillnet) which, in turn, comprises two major factors: the size and shape of the object as well as its' physical characteristics (e.g. density and compressibility). An important step forward in developing gear that reduces porpoise bycatch would be to comprehensively understand and raise the acoustic reflectivity of gillnets, and hence to increase the detection distance for echolocating animals. Most studies so far lack a systematic approach to the problem of finding a compromise between acoustic reflectivity and elasticity (and consequently net behavior), which influences the catch efficiency of the net.

Within the German STELLA-project we aim to develop a "design-guide" that will facilitate the selection of promising net configurations that provide optimal acoustic reflectivity while maintaining elasticity and thus catch efficiency of gillnets. To this end, we determine the acoustic and elastic properties of a large range of potential netting materials and/or additional objects systematically. So far, the acoustic properties of a wide range of materials and shapes were modelled using the software package COMSOL and subsequently verified experimentally in an acoustic tank. The preliminary results will be presented. In the next phase, the elastic properties of different materials will be determined experimentally using standardized methods for nets. Simultaneously a tool is being developed that will allow to simulate net behavior given the physical properties of the net and/or objects hung in the meshes.

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Swedish small-scale coastal seining

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Seal populations along the Swedish coastline have increased rapidly since 2000. In parallel, seal inflicted damage on fishing gear and catch has increased, causing great economic losses for small-scale fisheries. With small-scale coastal fisheries being both economically and socially important for Swedish coastal communities, it is essential to reduce this conflict between seals and fisheries. Furthermore, with the introduction of the EU's landing obligation there is also an increasing demand for the development of sustainable fishing gear which is both environmental friendly and seal-safe. In 2015, the Seals and Fisheries program at the Swedish University of Agricultural Sciences performed primary trials with a small-scale seine. Small-scale seine nets have, with their short haul duration, a high potential to reduce seal inflicted damage for the smaller vessel segment. The general design was of a mobile seine system small enough to be fitted on smaller vessels. The system is built upon two hydraulic winches, which may be run either on the boats internal hydraulic system or by an external, gasoline-driven, hydraulic pump. The gear contains 2x400 m lines on either side of the seine net with wings of 40 m and opening of 20m. The system allow for a 45 min process from start of deployment until the gear is retrieved back on the boat. We have successfully evaluated the seine system for different target species including vendace (*Coregonus albula*) and flounder (*Platichthys flesus*), with potential also for other coastal species as cod (*Gadus morhua*), perch (*Perca fluviatilis*) and turbot (*Scophthalmus maximus*). Furthermore, using video and faunal monitoring, we have evaluated the short-term effects from the seine on the benthic community. Our results show that small-scale seine nets may have the potential to meet the demands for a seal-safe gear in sustainable, small-scale coastal fisheries.

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Estimating the sediment put into the water column by towed demersal fishing gears

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The physical impact of towed demersal fishing 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.

Here we look exclusively at the hydrodynamic effects and examine the sediment mobilized in the wake of a gear component that occurs because of the pressure drop and the turbulent shearing on the seabed. O'Neill and Ivanović (2016) and O'Neill and Summerbell (2011) show that the amount of sediment mobilized into the water column is related to the hydrodynamic drag of the component and the sediment type over which it is towed.

Hence, by estimating the hydrodynamic drag of the various gear components that are in contact with the seabed we can estimate the amount of sediment each component mobilizes into the water column and subsequently estimate the total amount mobilized by a whole gear. We will demonstrate this approach by carrying out a number of worked examples.

A seascape scale fishing impacts model to assess trade-offs between spatial closures and gear modifications

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Spatial closures and technological solutions such as gear modifications that lift gear components off the seafloor are two potential strategies fisheries managers may employ to reduce habitat impacts from fishing. Evaluation of the efficacy of any such policy requires a quantitative framework that can incorporate fleet dynamics, gear specifications, and habitat characteristics at seascape scales and produce outputs that are readily integrated into existing management workflows. To meet these needs, we developed a 'Fishing Effects' model that incorporates spatially and temporally explicit impact and recovery dynamics in a discrete-time framework to produce a time-series of cumulative habitat disturbance across spatial regions of interest to fisheries managers. We implement the Fishing Effects model in the North Pacific, producing monthly estimates of habitat disturbance on 5 km grid cells over a spatial domain encompassing 1.2 million km^2. Domain-wide, we estimated that less 2% of the North Pacific shelf is currently disturbed from fishing impacts, and that implementation of gear modifications in flatfish trawls beginning in 2011 have led to an estimated 28% reduction in habitat disturbance. As a tool to evaluate management policies, we used the Fishing Effects model framework to assess the trade-offs managers need navigate when evaluating the potential efficacy of spatial closures and gear modifications. We simulated fishing effort by modelling fleet dynamics using an ideal free distribution and considered a range of fishing intensity, habitat recovery, local abundance, local depletion dynamics, closure sizes, and gear modifications scenarios. We found that the efficacy of a spatial closure is determined primarily by the balance between reductions in catch efficiency and dispersion/aggregation of effort after implementation of a closure. Comparing closures to gear modifications, we found that reducing habitat disturbance from spatial closures tends to be most effective when fishing intensity is high, whereas gear modifications tend to be more effective where fishing intensity is low.

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7.2 Open session: Selectivity in a broad sense

Research on trawl selectivity and selective fishing technology in China

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Trawling is the main fishing method in China's inshore and offshore waters, with its annual catch accounting for more than 45% of the total marine catch. Both inshore and offshore bottom-trawl fisheries are multispecies fisheries targeting various demersal species according to fishing area along the coast. China's trawl gear selectivity study has mainly focused on bottom pair trawls and shrimp beam trawls, with few research on pelagic trawls and shrimp otter trawls. Covernet method is the main method used in codend selectivity studies at sea, investigating the effect of mesh size, mesh shape and structure (such as diamond mesh, square mesh and T90 mesh) on the selection parameters for the main target species. Research on shrimp beam trawls has focused on shrimp-fish separation devices and designs, such as separator panels, vertically-separated codends, and rigid grids. In addition, some preliminary research on the survival rate of fish escaped through the meshes of the codend was also conducted. Research has produced some basic results, such as selection parameters of the main target species and the theoretical minimum mesh size of the codend, providing scientific data for the implementation of the fishing gear access system in China. These trawl gear selectivity studies have been conducted mainly by Shanghai Ocean University, Ocean University of China, East China Sea Fisheries Research Institute and South China Sea Fisheries Research Institute, with funding mainly from the National Natural Science Fund, Public Charity Fund (agriculture), special funds from the Ministry of Agriculture, as well as specialized research funds for doctoral research programs, and provincial key discipline support funds. Overall, China still lacks of enough systematic and in-depth research on the trawl gear selectivity compared with many developed nations. With the strengthening of China's fishery management system and the implementation of the fishing gear access system in the offshore waters, study on trawl selectivity will likely be strengthened.

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Understanding size selectivity of 3 species in New Zealand inshore trawl fisheries.

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In the New Zealand inshore fishing industry, concerns over the bycatch of undersized and non-target species have prompted Industry-led efforts to improve trawl selectivity; e.g. increasing the size, and / or changing orientation of the meshes. Despite much grass-roots ingenuity in this area, the selective properties of trawlnets in New Zealand are not well documented, and this lack of information has hindered more widespread uptake, and the ability of the industry to demonstrate their improvements in sustainability. The aim of this project is to utilize the FISHSELECT software tool to better understand the selectivity of key New Zealand species, and how changes being made within the fleet will affect catches of undersized fish. Trials were carried out onboard an 11 m Hawkes Bay inshore commercial trawler FV "*Chips*". Paired selectivity tows compared a standard 5" (125 mm) diamond mesh commercial trawl codend, with a non-selective small mesh-lined codend.

A sample covering a wide length range for 3 species (snapper (*Pagrus auratus*), red gurnard (*Chelidonichthys kumu*) and English sole (*Peltorhamphus novaezeelandiae*)) was collected and used in "fall through" experiments to determine whether each individual could pass through meshes of different sizes and shapes. Based on this, a large set of "fall through" size selectivity curves were obtained covering many different mesh sizes and shapes to enable building predictive models for size selection. Preliminary analysis comparing the results from sea trial selectivity data with predictions obtained based on the "fall through" method, indicate that we should be able to successfully build selectivity models for all three species that will allow us to predict selectivity across a range of mesh sizes (100 – 200mm) and orientations (diamond, square and T90).

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Modelling gear and fishers size-selection for escapees, discards and landings: a case study in Mediterranean trawl fisheries

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Gear selectivity and discards are important issues related to fisheries management but separately modelled. The present work examines for the first time the overall size-selection pattern on the total amount of individuals of a species entering the trawl codend. An innovative approach was used based on modelling the escapement through the codend in the sea and the subsequently selection process by the fisher on the deck of the fishing vessel resulting into the discards and landings. Three different trawl codends and three species were investigated in the case study conducted. A dual sequential model accounting for both gear size-selectivity and the subsequent fisher-size-selectivity was applied, under the hypothesis that a fish entering the codend can follow a multinomial distribution with three probabilities, the escape, the discard and the landing probability, respectively. The model described the escape probability through the gear and the landing probability by the fisher as S-shaped curves leading to a bell-shaped curve for the discard probability affected by both gear and fisher selection. The model described well the experimental data in all cases. Sampling scheme of three compartments proved adequate. The model provides at the same time selectivity and discard parameters useful in fisheries management.

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Modelling the effects of mesh size on gillnet selectivity in the hake fishery to the South and West of Ireland

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Recent changes to the European Common Fisheries Policy, including the Landing Obligation (LO), require a reduction in discarding. Selectivity of fishing gear has a large influence on the retention of fish of varying sizes with the potential to partly mitigate for the impacts of the LO. Here, the effects of different mesh sizes (80, 100, 120, 140mm) on the retention of hake were investigated from a gillnet selectivity trial conducted by Bord Iascaigh Mhara in the south and west of Ireland. Selectivity models for the data were compared, including: traditional logistic regression models, additive variants, alternative distributional assumptions and an exploration of the application of a recently developed multinomial catch comparison method. Considerable differences in estimated selectivity were found under fixed or varying spread normal selectivity function assumptions. Similar selectivity curves were estimated from lognormal and gamma functional forms. Results suggest that mesh sizes of 80 or 100mm caught large quantities of non-marketable fish less than 60cm length. The 120 or 140mm mesh size caught very few hake under 60cm. A multinomial catch comparison method may be more appropriate for these data than selectivity models as assumptions on geometric similarity were not fully met. We discuss the advantages and disadvantages of selectivity or catch comparison of these data and resulting inference.

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Changes in operational tactics as a powerful tool to adjust to the landing obligation for bottom-set-nets

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The selection properties of gillnets may be improved by changing the gear characteristics, e.g. mesh size or netting material, but in many cases the fisher's operational tactic plays a preponderant role, as new selective technologies involving more complex gear are usually limited in passive fisheries.

Discard ratios of regulated fish species under the landing obligation in the Danish bottom-set-nets fisheries for cod (Gadus morhua), plaice (Pleuronectes platessa) and sole (Solea solea) in the North Sea were described using the discard data from observers at sea, and the effects of soak duration, depth, latitude and longitude on discards were investigated by the use of a beta distribution. Discard ratios ranged from 1.10 to 100%, with high variability between fishing operations, species and fisheries. High-grading and catch quality were the main reasons for discarding observed in the cod and plaice fisheries, and catch of undersized individuals due to the use of small mesh sizes was the main challenge identified in the sole fishery.

The effect of fisher's soak tactic on catch pattern was further investigated. The length-dependent catch efficiency, or relative size selectivity, of three different soak patterns, i.e. 12h at day, 12h at night and 24h was estimated in the Danish gillnet plaice fishery. In addition to the gear characteristics, changes in operational tactics, e.g. soak time, is a powerful tool to limit unwanted catch, which can be used by the net fisheries to adjust to the landing obligation.

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Using ecomorphology and functional traits to understand the efficiency of a selective device in a mutli-species fishery.

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Improving **selectivity of fishing gears** is one strategy to significantly reduce bycatch of non-commercial species or undersized individuals. The **efficiency of selective** device has mainly been estimated by comparing the biomass and length spectrum of caught and escaped individuals while the morpho-anatomical and functional parameters of species are rarely accounted for. Using an innovative technical device to reduce catches of undersized individuals in a multispecies bottom-trawl fishery in the Bay of Biscay, we measured a set **ecomorphological and functional traits** on both captured and escaped individuals of 18 species among which 15 species were common to both fractions. We identified ecomorphological and functional features differing between the two fractions. Escapees differed in length from caught individuals, and in traits related to visual ability and fins. A smaller size is expected to facilitate escape but escaped individuals tended also to be more streamlined, with a relatively bigger eye and fin characteristics involved in manoeuvrability and propulsion. Here, we provide one of the first studies that investigate the role of ecomorphological and functional characteristics in the context of selectivity.

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Shape your fish stock: Using a length- and age-based population model to find the optimal harvest strategy

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The western Baltic cod (*Gadus morhua*, L.) stock is heavily exploited and below its limit biomass point since 2008. Although the mesh size was increased from 110 mm to 120 mm in bottom trawls in 2010, the stock did not recover under consistent high fishing mortalities. Exploitation patterns and rates influence the size and demographic structure of fish stocks. Since the effects of different gears with their specific selectivity parameters L_{50} and SR cannot be tested in experiments in the wild, simulations are used that represent the reality as close as possible. A dynamic population model is parameterized to simulate different management strategies regarding the gear selectivity and fishing rates in theory. Since gear selectivity is size-dependent, a length- and age-based population model was used. It simulates how gear selectivity of bottom trawls, intensity of fishing mortality, and gillnet proportion affect (i) the spawning-stock biomass (SSB), (ii) catches above the minimum conservation reference size (MCRS), (iii) catches below the MCRS and (iv) the fishing mortality at the length of full retention in the short- to long-term. Larger meshes result in short-term losses of catches above MCRS which are compensated in the next years. The SSB increases and catches below MCRS decrease with increasing mesh size. A reduction in fishing mortality leads to a significant increase in SSB, but also to short- to medium-term losses in catches above MCRS. Additionally, a reduction in fishing mortality leads in the long-term to increases in yield-per-recruit (YPR) and the fishing effort is significantly reduced. Under larger mesh sizes when only larger cod are retained, the fishing mortality achieving maximum YPR is higher. An increase in gillnet proportion results in lower catches above MCRS and in higher fishing efforts, however only slightly influences the SSB. For recovery of the SSB to within safe biological limits, the fishing mortality needs to be reduced significantly and adapted to the fishing gears used which should optimally include a low gillnet proportion and stepwise increases in mesh size.

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7.3 Open session: Mean and methods in survival, biodegradable and design simulations

Effect of codend design on discard survivability

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A central part of the new European Common Fisheries Policy is the landing obligation, which prohibits discarding of quota-regulated species. Fish that previously were discarded need to be landed and are counted against the quota of the fishers. Exemptions from the landing obligation can be given for species caught in defined fisheries and areas if scientific studies can document high survival rates. European plaice (*Pleuronectes platessa*) is considered a relatively robust species and is discarded in large amounts (up to 70% of the total catches of plaice) in the Danish demersal trawl fisheries in Skagerrak. An experiment conducted from August-October 2017 in this fishery suggested that most of the undersized place survive when exposed to air for less than 20 minutes, and that the survival rates are much lower for longer air exposure times. A horizontally divided codend has proven to reduce the amount of catch related damages. Furthermore, separation of different species into an upper and lower compartment may reduce sorting time onboard the vessel, thus air exposure for the fish. The aim of the present study is to test if a horizontally divided codend can improve the survival rates of plaice compared with a standard codend fished in parallel in a twin-rig setup. The experiments will be conducted in March 2018 using the same commercial trawler as for the 2017 trial. Individuals will be sampled throughout the sorting process, vitality will be assessed and all individuals will be tagged before being transported to facilities ashore for direct observation of mortality for 14 days. Survival rates of all three compartments will be estimated using a parametric Weibull mixture distribution model, and factors influencing survival will be identified. The survival rate of the standard codend is expected to be higher in March-April than in August-October because of lower water temperatures. Together with other factors influencing survivability, gear design is among those that can be controlled by the fishers. If the use of a horizontally divided codend proves to improve discard survival of plaice substantially, this positive outcome will go hand-in-hand with increased catch quality and associated higher catch values.

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Monitoring individual-level behaviour of mackerel (Scomber scombrus) in relation to crowding and oxygen concentrations in commercial purse-seine catches.

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The behaviour of mackerel in relation to oxygen concentrations and crowding levels was monitored using "GoPro 4" cameras and a RINKO III oxygen meter, mounted together in a monitoring probe and deployed into the purse-seine using a compressed air cannon. Early in the capture process, the captive fish were generally unconstrained by the net and formed ordered, polarized schools. However, as the volume of the net became more constraining, the outer edges of the school were unable to avoid contact with the netting, and increased crowding densities were observed, associated with frequent fish-to-fish contact and disordered behaviour. Injurious contact occurred much earlier in the capture process than anticipated due to entrapment of fish in netting folds and pockets. Furthermore, localized increases in density and unpolarized behaviour were observed, particularly close to the netting wall. Oxygen concentrations were variable but generally declined throughout the hauling period, as the catch became more crowded. Concentrations less than 60 % saturation were only observed during high crowding densities in catches >195 tonnes and the lowest concentration observed was 51.74% saturation (5.53 $mg.l^{-1}$) in a 225 tonne catch. In the limited number of observations made so far, no oxygen concentrations lower than the "safe threshold" of 40% saturation (as defined by Handegard et al., 2018) have been observed, even in large and densely crowded catches. This is hypothesized to be due to the inherent water flow passing through the net, induced by the vessel being held away from the net using a combination of the wind and thrusters.

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Assessing physiological stress to understand collateral mortality in the Antarctic krill (Euphausia superba) trawl fishery

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Escape mortality constitutes part of the total fishing mortality and is an important parameter in managing marine stocks. Escapees may experience physiological stress and trauma when interacting with the fishing gear during the escapement process, which may cause immediate or delayed mortality. When assessing escape mortality, additional stressors related to collecting, holding, and monitoring the escapees may affect mortality rates. Physiological distress after interaction with the gear may leave individuals incapacitated, making them easy targets for predators, a source of mortality not accounted for in the captive observation method used in survival studies. Lactate concentration in the haemolymph appears to be consistently associated with stress in crustaceans and is commonly used as an index of physiological stress. We measured lactate levels in Antarctic krill (*Euphausia superba*) to identify causes of stress during the escapement, collection, and monitoring processes. We further quantified lactate clearance during recovery to discuss post-escape predation vulnerability. We observed the temporal development in stress level by measuring lactate levels from three different groups of krill; i) trawl escapees collected by the covered codend method during fishing (6 hauls), ii) onboard acclimated individuals penetrating commercial netting under controlled conditions (6 hauls), and iii) onboard acclimated individuals acting as a control group (5 hauls). Trawl escapees showed considerably elevated haemolymph lactate concentrations exceeding 6 mM. The experimental mesh-penetration group did not display elevated lactate levels (0.8 mM), and was not significant different from the control group (0.7 mM). The recovery time to normalize lactate levels were 6-8 hours. There was no correlation between the measured lactate level for the six trawl hauls and survival 60 hours after escapement. Escapees with elevated lactate levels may be prone to predation in the post-escape period. Lactate was a poor predictor for krill escape mortality, but could be used to separate the influence of different stressors.

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Biodegradable fishing gears in Korea; its challenge and future

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The research on biodegradable fishing gears in Korea was initially approached to reduce lost fishing gear problems, ghost fishing and marine litters since 2002. In the early study, the synthetic methods of raw material for fishing gears were one of the major problems. Various trials for them have been performed to find out proper raw materials for fishing gears with biodegradability. Then, candidate resins were tested whether they meet the requirements for commercial fishing gear's materials and biodegradability under the sea conditions. The twine made of biodegradable resins also were examined the biodegradation process and physical properties; flexibility, elongation, breaking strength under the wet and dry conditions. In the initial stage, the twining from the biodegradable resins was a major obstacle. The physical properties for the process were completely different compared to nylon. With collaboration of a chemical company and twining experts, the process was stabled and quantitative data were collected.

The PBS (Poly Butylene Succinate) was chose as a resin for gillnet. Researchers at National Institute of Fisheries Science (former: National Fisheries Research and Development Institute) have looked for the target fishery for fishing efficiency and feasibility study. Considering its physical properties, the biodegradable gillnet was first applied to the snow crab (Chionoecetes opilio) fishery in the East Sea, Korea. The result was successful but the process was difficult to identify the biodegradable fishing gears' performance. The PBAT (Polybutylene Adipate Terephthalate) was also examined with the same process for fishery purpose. Since 2007, the pilot scale project for the use of biodegradable fishing gears in commercial fisheries has been conducting for encouraging the environment-friendly fishing practices. From the experiences, National Institute of Fisheries Science, Korea is preparing for the new challenge and conducting new research for the biodegradable fishing gears.

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Comparison of fishing efficiency between biodegradable PBSAT gillnets and conventional nylon gillnets in the cod (Gadus morhua) fishery in northern Norway.

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Gillnets made of a new biodegradable resin (Polybutylene succinate co-adipate-co-terephthalate PBSAT; developed in Korea by LOTTE Fine Chemicals Co. Ltd. in 2016) was tested under commercial fishing condition to compare their fishing performance. The relative catch efficiency, catch rate and effect of use and wear (aging) was studied for biodegradable PBSAT gillnets and conventional polyamide 6 (nylon) gillnets, covering the entire winter fishing season for cod in northern Norway. The results generally showed better catch rates for the nylon gillnets for most sizes of cod, except for sizes between 80 and 90 cm. Aging had a larger negative effect on the catch efficiency of biodegradable gillnets than that of nylon gillnets. The reduction of catch efficiency observed in the PBSAT gillnets, especially for big fish, might be explained by the loss of tensile strength and elongation caused by use and wear of the material. Tensile strength measurements of the biodegradable PBSAT gillnets samples taken before and after the fishing trials showed in average a 9% loss of tensile strength and 13% loss of elongation. Although less catch efficient than nylon gillnets, biodegradable PBSAT gillnets still show a large potential for reduction of ghost fishing and plastic pollution at sea caused by this fishery.

Design and performance of software based trawl fishing simulator

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In this study, demonstrates the mathematical model and performance of a software based fishing simulator for trawl operation. The trawl fishing simulator model consists of fishing gear, fishing vessel, fishing winch and fish schools. The fishing gear is modelled as a flexible structure made up of ropes and nettings. The structure is divided into finite elements and the mass-spring model is applied. For the fishing vessel system, the speed and direction controllers govern the movement of the vessel. The fishing winch system connects the fishing gear to the vessel with wire ropes described as a line length control system. Two kinds of fish schools have been designed: horse mackerel, herring and demersal fish are targeted by the trawl gear and the schools react sensitively to the visual stimulus produced by the gear operation. The speed and direction of fish schools are recognized by an acoustic fish detection system. The trawl fishing simulator will help improve fishermen's skill to control the fishing system under the changeable ocean circumstances.

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Evaluating the drag and lift coefficients of self-spreading helical ropes against conventional PA, and PE ropes at different attack angles and towing speeds

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The use of self-spreading helical braided ropes or twines in making netting and bridles of midwater trawls has potential benefits associated with reduced drag, improved trawl stability, better selectivity, optimized aspect ratio, reduced fuel consumption, as well as the ability to maintain desired trawl shape at low towing speed. In this presentation, we report on the results of flume tank testing conducted on different samples of rectangular rope panels to determine their drag and sheer forces and related hydrodynamic coefficients. Sample panels were constructed of helical braided ropes as well as conventional ropes of PA and PE materials of comparable solidities. Samples were mounted inside a metal frame connected to a 3D component load cell. Rope panels were subjected to towing speeds between 0 - 2.0 kn at an interval of 0.5kn at the same time rotating at different attack angles ranging from 0 - 90°. The resulting dataset of loads were collected and processed using statistical tools to find the mean drag and shear forces for the specific test conditions. Mean values of drag and sheer coefficients were then calculated using generalized hydrodynamic equations and presented for the different rope types.

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Flow simulation in a double sorting grid system

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Sorting grids are commonly used to avoid catching undersized fish. However, issues with grid clogging have been reported and further development of grid systems is required. The reduced water flow through the grid section is suspected of causing the clogging of the grid system and accumulation of fish in front of the grid system. Conversely, an increased flow velocity in the section may make it difficult for undersized fish to orientate themselves correctly to escape through the grids.

To investigate the fluid flow through a sorting section with a double steel grid the flow through the sorting section and connected codend was simulated using "Reynolds averaged Navier-Stokes" (RANS) methods. The dimensions of the sorting section and codend were based on information given by Larsen et al. ("Size selection of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) in the Northeast Atlantic bottom-trawl fishery with a newly developed double steel grid system").

For the flow simulation, the sorting section and codend have been assumed to be rigid. The angle of attack of the lower sorting grid and its lifting panel were varied. Furthermore, the solidity of the lifting panels was varied. The variations are discussed.

In addition, compared with the experimental investigations made by Larsen et al., the possibilities and limitations of numerical flow simulations are assessed.

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7.4 Open session: Species and size selectivity in crustacean fishery

Understanding and predicting the size selectivity of mantis shrimp (Squilla mantis) in Nephrops creel fishery

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Mantis shrimp (Squilla mantis) is an important commercial species in the Mediterranean fisheries. In this study we present a new method of analysing creel selectivity data allowing us not only to estimate retention and release probabilities but also a sticking probability of mantis shrimp in creel meshes. Using the fall-through experiments we investigated what sizes of mantis shrimp could pass through the meshes of different sizes and shapes. Based on this we were able to understand the experimentally obtained size selectivity data for this species. The fall-through results allowed us to predict the size selection of mantis shrimp in creels for sizes and shapes not tested in the experimental size selectivity trials.

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Rope-panels for species separation in Nephrops trawls

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Separating Nephrops (Nephrops norvegicus) from fish species has the potential to improve the exploitation pattern of trawl fisheries. We investigate the efficiency of a rope-panel concept to sort Nephrops and fish species into separated codends. Two different designs varying space between transversal ropes were experimentally tested in September 2016 in the North Sea. Species length-dependent sorting efficiency were estimated for each of the two designs. The probability to sort Nephrops into the lower codend decreased with increasing carapace length in both designs. More than 90% of Nephrops below MLS were sorted into the lower codend, while the sorting efficiency above MLS decreased to between ~82% and ~85%, depending on the panel design. Most of the fish caught were found in the upper codend, independently of the species or sizes. Due to a better separation of fish species, the rope panel concept achieved

"cleaner" Nephrops catches compared to precedent investigations using sieve panels. However, the efficiency to sort the largest, most valuable Nephrops into the lower codend was found similar to that obtained by sieve panels, remaining too low to be considered for commercial fishing.

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Effect on selectivity during shrimp trawling by changing grid length, grid angle and by adding a second grid.

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The Nordmöre grid is regarded as an efficient bycatch reducing device during shrimp trawling, but still in some areas bycatch remains a problem that seriously impacts commercial trawl activities. Previous studies have reported that a reduced operating angle can lead to a lower grid passage probability for bycatch fish species and shrimp. In our study we tested and compared the performance of two versions of the Nordmöre grid in the Deepwater Shrimp (*Pandalus borealis*) fishery of the Barents Sea. The test setup comprised a standard version of the Normöre grid with an operating angle of ca. 45° and a 40% longer version of the grid with an operating angle of ca. 30°. Both Nordmöre grids were with 19 mm bar spacing. Using the longer grid, the grid passage probability for the bycatch of juvenile cod, haddock, American plaice and redfish increased significantly for certain size ranges of fish. The longer grid also resulted in a significant increase in grid passage probability for large shrimp. Our results demonstrate that a longer Nordmöre grid more than compensates for the reduced operational angle. During the second part of the study we inserted a second grid with 9 mm bar spacing 2 m behind the standard Nordmöre grid (at operating angle of 45°). Obtained results demonstrated that the additional grid improved the release of the smallest Deepwater shrimps significantly with an estimated 45% of these sizes of shrimp being released.

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Use of Swedish designed escape grids to optimize the size selectivity of Pandalus Borealis in the Danish trawl fishery

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Considerable work has been undertaken to optimize species selectivity in shrimp fisheries around the world through the use of sorting grids. More recently, there has been focus on using such grids to further optimize the size selectivity of the target species within these fisheries. In Sweden, a new version of the Nordmøre grid has been developed to reduce the capture of small deepwater shrimp (Pandalus borealis). The grid

has been developed following an extensive media debate in Sweden and Norway about discarding of small shrimp, the implementation of real-time closures in Norwegian waters in 2016 to protect juvenile shrimps, and also as a means of optimizing the value of the quotas (i.e. larger proportion of large shrimp), which are often restrictive in Sweden and Norway.

The combination grid consists of an escape grid for shrimp with 10 mm bar spacing mounted in the lower section and a standard grid with 19 mm bar spacing in the upper section to sort out fish bycatch, where the fish catch enters the upper codend through a hole in the top of the grid. Here, we tested the Swedish designed escape grid in the Danish Pandalus fishery to determine its suitability in the fishery.

A reduction in marketable shrimps has the possibility to reduce the economics in the fishery, and since almost the entire catch of shrimps caught by the Danish fleet are marketable, an alternative design or bar spacing in the escape grid may be required for the Danish fleet to avoid considerable economic loss. This international collaboration was facilitated as part of industry-science collaboration.

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Catch and release efficiency for bycatch and target species in shrimp fishery by using a Nordmøre grid or a sieve net

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Bycatch of fish juvenile is still today a serious challenge in many shrimp trawl fisheries like the Northeast Arctic deep-water shrimp (Pandalus borealis) fishery. In this fishery, the use of a Nordmøre grid in the gear is mandatory, and this type of grid and sieve nets are two of the main devices used to reduce bycatch of fish in shrimp trawls in many different fisheries. We investigated and compared the bycatch reduction efficiencies and patterns for several fish species between the standard Nordmøre grid and an experimental sieve net. In addition, we explored the efficiency of combining these devices. The bycatch reduction patterns differed significantly between the two devices and a more efficient reduction could be obtained by combining them. However, while the loss of commercial sized shrimp was only between 0 and 2% for the Nordmøre grid, it was estimated to be between 37 and 66% for the tested sieve net, which makes its application unacceptable for commercial fishing. Therefore, before a sieve net can be considered for the fishery, alternative sieve net designs with significantly lower loss in shrimp catches need to be found.

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Reducing trawl length improves size selection in the Northern Shrimp fisheries

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For improving size selectivity in the Northern shrimp *(Pandalus borealis)* fishery, the design of a conventional four panel trawl, with a fishing circle of 146 m, was modified.

The conventional trawl had a 60 m long bottom panel, cut 1N-4B in the foremost section, gradually reducing cutting steepness to 6N-2B in the rearmost section. The modified, shorter version, had a 42 m long bottom panel, cut 1N-8B, apart from the rearmost 12 m that was cut 4N-2B. Four trawls were constructed, conventional and short, of both 40 and 50 mm bottom panels. Their selectivity performances were compared, towing with two trawls simultanously, in fishing areas off S-Norway in November 2017.

The relative efficiencies of the test trawls were estimated applying a polynomial logistic regression. Five hauls were taken with the two conventional trawls with 50 mm mesh size in bottom panel of one of the trawls, and 40 mm on the other side. For longer trawls, mesh sizes of 40 and 50 mm yielded insignificant differences in size selection.

Eleven and nine hauls were obtained respectively with 40 and 50 mm mesh sizes, short versus long (conventional) trawls. The shorter trawls weres size selective, with less catches of smaller shrimp, compared to the conventional trawls.

Trawl length can thus effectively be used for reducing catches of undersized shrimp, and the effects can be further enhanced by altering the mesh sizes of the bottom panel.

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7.5 Open session: Gear technology for better selectivity

Gearing Up

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The *GearingUp* project is designed to help fishers, netmakers and fisheries managers find practical ways to reduce bycatch – or unwanted catches – in commercial fisheries. Launched to help identify solutions for different vessels to meet challenges of the Europe-wide 'Landing Obligation' (LO), the project aims to bring together data on gear selectivity trials and make that information available to fishers. So far, a database has been generated that brings together trials that have taken place around northern Europe and made it available via an online tool. *GearingUp* users have access to precise results from the applications of gear innovations anywhere, anytime, so they can make an informed decision about modifications to their fishing gear. The development of the *GearingUp* tool and its links to other initiatives will be described, the tool will be introduced, and the potential ongoing benefits to WGFTFB and its members will be discussed.

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Four years of the Swedish secretariat for Selective fishing

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Between 2014 and 2017 the Swedish government has set aside special funding for collaborative research on selective fishing gears. The main background was the need for a larger toolbox of documented and workable gears for the industry to choose from 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.

A project has two main phases: a development phase in which fisher's test and modify their prototype gear on their own in an iterative process, and an evaluation phase in which scientist study the effectiveness of the gear. Involved fishers are guaranteed normal income during fishing operations, thus minimizing their economic risks.

Project workflow in the Swedish Secretariat for Selective Fishing:

1. Mailbox/meetings for gathering ideas
2. Development of project ideas via science-industry collaboration
3. Pre-evaluation and funding process
4. Development phase (industry-led)
5. Scientific evaluation and reporting

During the project period between 2014 and 2017, 34 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.

A main focus area has been demersal trawl fisheries where the typically mixed catches are a large challenge in relation to the landing obligation. Focus in these fisheries has been to explore species selectivity in the catch process before the codend by using grid´s and species-specific behavior. Combination grid´s have been used to be both size and species selective in shrimp- and Nephrops trawl fishery. Other grids have been used to separate flatfish from gadoid species into different codends with more optimized size selectivity. Using different species natural escape behavior, we have tested vertical trouser trawls and topless trawls to minimize bycatches of non-target species. In this paper we briefly present some specific examples on how far we have come so far and a broader overview of the outcomes of all projects, with focus on success and failure factors for implementation and uptake by the industry.

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When is enough, enough? From theory to practice.

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The introduction of catch quotas as part of the reformed European Union's Common Fisheries Policy has increased the pressure on the fishing industry to eliminate or considerably decrease unwanted catch, since the unwanted portion of the catch now counts towards quotas. This, together with the proposal for a more flexible and inclusive technical measures regulations, means that there is the need for a larger number of fishing gear solutions available to the different fisheries. A way to increase the number of gear solutions available is to involve the industry in the development, testing, and data collection on the performance of new or modified gears. It has been shown theoretically that it should be possible for fishers to collect limited data describing the selective performance of fishing gears. To confirm these theoretical findings, fishers collected catch comparison data to provide a preliminary description of the gear's selective performance prior to a potential scientific trial. Preliminary results show that it is possible for fishers to collect data describing the selective performance of a gear. However, the sampling protocol needs to be clearly understood by the fishers to ensure that the necessary data are collected and the data correctly sampled. The interactive process of data collection and analysis is presented and the advantages and disadvantages of this framework discussed based on different case studies.

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Size selection in Dyneema netting codend compared to traditional codend in Mediterranean bottom-trawl fisheries

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In this study a 40 mm square mesh codends made out flexible Dyneema twine were tested. The main aim was to investigate the effect of the size selection in Dyneema netting codend compared to traditional codend on the size selection of some commercial species in Meditereanean bottom-trawl fisheries. Moreover, the obtained size selectivity for the 40 mm square mesh codends made of netting Dyneema were compared to previous results obtained for other traditional PE diamond mesh codends used in the same fishery. The experiments were carried out in the Eastern Aegean Sea during February and March 2018. A conventional bottom trawl was operated onboard a commercial trawl Efsane G. Selectivity parameters were obtained by using logistic equation with the maximum likelihood method and by taking into account between-haul variation. It was observed that the 40 mm square mesh Dyneema netting codend produced much higher L50 values than the other traditional codends made of generally standard 44 mm diamond mesh PE material. This demonstrates the high selective potential of the flexible Dyneema netting compared to nettings which are traditionally used in the construction of trawl codends.

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Flatfish behavior in electrified beam trawls

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In electrified beam trawl fisheries little is known about fish behaviour due to the proximity of the beam and trawl to the seabed. With the beam and footrope suspending the sediment in the trawl path visibility inside the trawl and codend is frequently hampered, and therefore no underwater video recordings on fish behavior in those trawls exist. With the introduction of the European landing obligation, fishers and scientists have been working on selective solutions for this fishery, however gear innovation has not been sufficient yet to meet the current landing obligation. With limited knowledge of fish behavior in this fishery, development of selective devices is frequently based on trial and error without understanding the mechanism behind these devices. With knowledge of fish behavior, targeted development of species-specific selective devices

can enhance and provide scientists and fishers with information to reduce unwanted bycatch.

Within this project a method was developed to collect underwater recordings of flatfish behavior in commercial electrified beam trawl fisheries. Initial ideas were successfully tested on scale model beam trawls in the Dutch tow tank. Subsequently this method was applied on two commercial vessels. Trawl headropes were modified, several kites and floats were applied to lift the extension and codend of the trawl, while the footrope and beam stayed on their position to retain commercial catches. Those modifications remove suspended sediment from the trawl. In combination with a compact recording system and a powerful light, the first underwater recordings of fish behavior in commercial electrified beam trawls were collected.

Collected underwater recordings showed that all fish entering the electrified trawls are alive and swimming. The target species sole (Solea solea) shows a strong swimming response when retained in the codend, while other flatfish as dab (Limanda limanda) and plaice (Pleuronectes platessa) have limited swimming abilities with the commercial towing speed. Therefore the development of selective devices should focus on sole behavior. The presented concepts are useful to obtain a better understanding of fish behavior and fishing technology, and can be applicable for other fisheries with limited visibility inside trawls.

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Reducing Flounder Bycatch in the Georges Bank Haddock Fishery: Application of a Modified European Grid System

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Georges Bank (GB) haddock is one of the few robust groundfish stocks in New England. The exploitation of the haddock resource depends on the status and quota allocations of bycatch species. Currently populations of all the major flatfish species in New England are significantly depressed, making them quota-limiting species. To reduce the catch of flatfish, a modular grid system with horizontal slots was placed in the extension of a commercial demersal trawl. The grid system was designed to allow the selective escape of flatfish and juvenile roundfish by exploiting the morphological differences between roundfish and flatfish. The results of twenty seven alternating tow pairs showed a 51.3% reduction in the catch rate of flounder, primarily winter flounder (*Pseudopleuronectes americanus*), and 29.4% reduction in skates, a major discard species. There was no significant reduction for Atlantic cod (*Gadus morhua*), the major round fish captured during sea trials. The overall catch rate of haddock (*Melanogrammus aeglefinus*) was reduced by 36.9%, however the reduction was solely associated with small fish. Video observations of fish behavior in the grid area showed species-specific escape behavior. Cod and flounder were observed escaping out of the lower sections of the grid with haddock primarily using the top sections. Overall the use of this modular grid system may be a tool which will allow fishers to quickly alter species and size selection properties on their nets to match their species quota and reduce the retention of undersized fish.

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Trawl separating flat- and round fish

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With the aim of being able to continue fishing once the quota of either flat- or round fish is filled, two evaluations of a trawl made to separate flat- and round fish into different codends by a modified grid were made during 2016 and 2017. The lower part of the grid consisting of horizontal slots was attached to one codend, while the upper part of the grid was open and attached to a second codend.

The first evaluation in 2016 targeted witch flounder (Glyptocephalus cynoglossus) and Atlantic cod (Gadus morhua). The slots of the lower part of the grid had a width of 5 cm except at the very bottom where the slot width was 8 cm. The upper part had an opening of 30 cm. The upper mesh size was 220-150 mm diagonal mesh and the lower mesh size was 120 mm diagonal - 126 mm square – 120 mm diagonal mesh.

The second evaluation in 2017 targeted European plaice (Pleuronectes platessa) and Atlantic cod. Modifications of the trawl compared to the 2016 evaluation consisted of an even slot width (5 cm) of the lower part of the grid. The opening of the upper part was increased to 50 cm. Mesh size in the upper codend was 180-200 mm and in the lower codend 120 mm diagonal mesh. The reference trawl had an even mesh size of 120 mm diagonal mesh in both evaluations.

Both evaluations show rather similar results. Flat fish are mainly selected by the lower codend of the experimental trawl while round fish are primarily selected by the upper codend.

No significant difference in catch of witch or plaice could be seen between the trawls. Also the two trawls caught similar sizes of witch and plaice 2016 and 2017 respectively.

The difference in the results lies with the catch of cod which was significantly lower in the experimental trawl the first year but not in the second. Yet a trend towards lower catch of cod could be seen also the second year. The experimental trawl did, however, catch less cod of small sizes than the reference trawl in both evaluations.

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Raising the fishing line in demersal whitefish trawls to reduce cod catches

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The recent reform of the Common Fisheries Policy (CFP) establishes a landing obligation (LO) where fishers will be incentivised (i.e. to use more selective gears) to avoid catching fish under minimum conservation reference size (MCRS), because they will be deducted from their catch quota. For many species the process of lowering unwanted catches and eliminating discards will likely be achieved through technical measures—gear modifications (e.g. grids) that increase selectivity. However, for some species it will also likely involve gear modifications that are inspired by their respective behavioural differences, for example, haddock tend to swim upwards while cod are less likely to, when entering a trawl. Here we test a raised fishing line trawl, where the distance between the fishing line and the groundgear was increased to 1 m. We show how raising the fishing line can have a positive impact on catches. Catches of cod, flatfish, skate and ray were reduced by 39, 67, and 80%, respectively. Alternatively, whiting and haddock catches increased by 87 and 37% respectively. Additionally, the raised fishing line trawl caught more fish during the day than the standard fishing line trawl. Under the landing obligation, using a raised fishing line trawl has the potential to delay when fishers need to stop fishing, i.e. when quotas are reached, especially for low-quota species. The results highlighted a straightforward and inexpensive option to help fishers contend with constraints under the LO.

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A Simple Groundgear Modification to Reduce Bycatch of Elasmobranchs in the Mediterranean Trawl Fishery

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The aim of this study was to reduce bycatch of relatively larger elasmobranchs in bottom trawl fishery without significant loss of target catch. The commercial trawl was modified only by cutting the rigging twine between fishing line and footrope in central 2.7 m length of groundgear which had a total length of 20.8m. The same trawl was alternatively used to make catch comparisons with and without this simple modification.

Eighteen pairs of hauls were made between January and May 2017, in Mersin Bay. Numbers of individuals and their total weights were obtained for ten commercial (red mullet (Mullus barbatus), brushtooth lizardfish (Saurida lessepsianus), common pandora (Pagellus erythrinus), common sole (Solea solea), bogue (Boops boops), goldband goatfish (Upeneus moluccensis), Randall's threadfin bream (Nemipterus randalli), striped piggy (Pomadasys stridens), por's goatfish (Upeneus pori), green tiger prawn (Penaeus semisulcatus)) and six bycatch species (guitarfish (Rhinobatos sp.), stingray (Dasyatis spp.), spiny butterfly ray (Gymnura altavela), dragonet (Callionymus lyra), lesser swimming crab (Charybdis longicollis), mantis shrimp (Squila mantis)). Differences in mean catch rate of all species between commercial and modified gears were compared in terms of total numbers and weights with Mann–Whitney U tests. Additionally, length data were collected for commercial species, and multi model inference were applied to describe paired catch comparison rate using SELNET. Confidence Intervals were estimated using double bootstrap method with 1000 iterations.

In terms of total weights and numbers of individuals for commercial species, no significant difference was found between the commercial and modified groundgears. The results were also similar for the length based comparisons except for common sole, for which catch comparison curve showed that modified gear captures significantly fewer individuals than the conventional between 17 and 22cm length classes. The mean catch of guitarfish was significantly reduced by 91% in the modified gear (1,15±0,57kg) compared to that of the commercial gear (0,02±0,2kg; $p<0.05$). For stingray, although the mean catch of conventional gear (1,09±0,58kg) was found to be 77% higher than that of the modified gear (0,14±0,12kg), the difference was not significant (p=0,31).

Modification made in this study provides laterally increased space for dorsa ventrally compressed specimens. However, release of specimens from this increased gap also depends on their preference of entrance height in trawl mouth. As seen in underwater recordings, guitarfish and stingray remain close to the seabed, which explains why their escape probability is increased in the modified trawl.

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Benefits of an inclined separator panel and two codends with different selectivity measures in the Irish Nephrops mixed fishery

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Gear options are needed to assist trawlers which target *Nephrops norvegicus* and a range of demersal fish species to reduce bycatch and address European Union landing obligation requirements. We demonstrated how this can be achieved by using inclined panels to separate fish species into an upper codend with 90 mm T90 mesh, and *Nephrops norvegicus* into a lower codend with 80 mm diamond-mesh. A nested mixture model was developed to compare proportional catch at length of key species retained in test or control trawls, and based on this, the conditional probability of retention in the upper or lower test trawl codends. Haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*) < minimum conservation reference size (MCRS) were substantially reduced in the test trawl compared with the control trawl. No significant difference was observed in haddock and *Nephrops* ≥ MCRS, nor were any reductions in cod (*Gadus morhua*), monkfish (*Lophius piscatorius*), or commercial flatfish species evident in the test trawl catch data. Effective separation of fish species into the upper codend and *Nephrops* into the lower codend facilitates alternative selectivity measures depending on landing obligation requirements. Additional benefits of this gear such as improved catch quality and reduced catch sorting times, but also the need for further incentives to encourage industry uptake are discussed.

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Trials of measures to reduce bycatch of whiting in the Irish Sea mixed fishery targeting Nephrops

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The western Irish Sea (Functional Unit 15, Division 7a) is an economically important area for Irish Nephrops trawlers. The Nephrops fishery accounts for the majority of whiting catches in Division 7a most of which are below the MCRS (≥ 27 cm). Given low quotas (46 t for 2018) and relatively high catch estimates (~217 t in 2016) whiting has major potential to choke the Nephrops fishery when phased in under the landing obligation on January 1st 2019.

BIM has carried out trials of a range of technical measures aimed at reducing whiting catches while maintaining the economic viability of the fishery. The results of trials of increased codend mesh size, large square mesh panels and rigid sorting grids have generally demonstrated reductions of whiting catches with varying effects on catches of Nephrops.

Catches of whiting less than 20cm have proven particularly difficult to reduce using the aforementioned measures. This finding has prompted more recent trials:

- To improve the efficiency of a SELTRA sorting box with 300 mm square mesh panels
- To increase codend mesh size selectivity by reducing codend circumference
- To reduce the quantity of whiting entering the trawl using counter-herding devices such as "floating" bridles and scaring ropes.

The relative pros and cons of the technical measures tested to date are presented.

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A new flexible grid to improve selectivity in the otter trawl fisheries targeting anglerfish

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Among all the selective devices tested all over the world, very few targeted the selection of anglerfish. Several trials were carried out on research and commercial vessels in France from 1993 to now, built first in aluminium, then polyurethane, articulated or not, in one or several pieces. All these grids were fitted in the bottom part of the extension of the trawl with an angle between 40 and 45°. Even if the results obtained were encouraging for small anglerfish, megrim and skates selectivity, all of them were subject to ergonomic and resistance problems, particularly when they were rolled up on the drums. Considering these difficulties, we have carried out new experiments within the CELSELEC project in 2015 and 2016. A new totally flexible rope grid has been developed after some preliminary experiments in flume tank and at sea. This presentation will sum up the evolution of the different types of grids tested since 1993 and detail the results obtained with the last prototype in 2016 on a commercial trawler, with very encouraging results nor for melgrim or monkfish, but also for gurnards or lesser spotted dogfish and other species. The handling and resistance problems were also solved.

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Combination of a sorting grid and a square mesh panel to optimize size selection in the North-East Arctic cod (Gadus morhua) and redfish (Sebastes spp.) trawl fisheries

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Sorting grids and square mesh panels are the two most-applied technical devices to supplement codend size- and species-selection in demersal trawls. In the Barents Sea gadoid fishery, the compulsory size-selectivity system comprises a mesh section with

a sorting grid followed by a diamond mesh codend. We tested the size-selective performance of a new sorting section that comprised a sorting grid combined with a square mesh panel as a potential alternative for the grid sections currently in use. The new sorting section was shorter and therefore more manoeuvreable than the existing sorting grid sections. The investigation was carried out on cod and the bycatch species redfish. The grid was found to contribute to the largest proportion of fish release, and the release through the square mesh panel was low. But, the results showed that the grid was successful at guiding fish not escaping through the grid to a second selection process in the panel. However, the square mesh panel did not result on the intended release efficiency except for the smallest sizes of fish, most likely because the guiding angle of the grid and the square meshes in the panel used did not provide a suitable escape path for the desired size range of fish. Therefore, optimizing the mesh size/shape in the panel and/or the guiding angle for the grid potentially could lead to the desired selectivity pattern in the new sorting section.

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Sequential codend improves quality of trawl-caught cod

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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 any form for catch damage was five times higher when using the dual sequential codend. Furthermore, cod caught in the sequential codend had significantly reduced probability of incurring specific catch damage, such as gear marks, poor exsanguination, ecchymosis, and skin abrasions. It was also investigated if the new codend concept effected the size selection in trawl.

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7.6 Topic session: Artificial lights with fishing gears

The luminous net VISIONET – a guiding swimway to the exit or a stressor?

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Fish are believed to rely largely on visual cues when orientating relative to fishing gears, artificial light are increasingly used to influence fish behavior, for example by making escape routes more visible when ambient light levels are low. We tested if a newly developed luminous netting, VISIONET, could change the vertical behavior of six commercially important species. We inserted an ascending V-shaped piece of VISIONET in the tapered section in front of the entrance of a divided codend. The intention was to trigger the optomotor response and guide fish into the upper compartment so they can escape through large meshes. However, results from experimental fishing showed that fish entered the lower compartment more frequently as a response to the presence of VISIONET. The behavioral reaction to VISIONET were largely similar to what has been observed when using green LED-lights, except for haddock, for which the response was opposite. Large *Nephrops* significantly increased their preference for the lower compartment when using VISIONET. Our results show that low intensity light is sufficient to alter the vertical behavior of both fish and *Nephrops*. Although optomotor response appear to be well functioning in parts of the catching process, it was not triggered by the VISIONET design. We need to improve our understanding of the mechanisms underlying the responses of fish to different light characteristics to use VISIONET more efficiently for bycatch mitigation in trawl fisheries.

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Some recent trials with illuminated grids

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We present the results of two sets of experimental trials that were carried out on the MRV Alba na Mara to investigate the effect that an illuminated grid may have on the behavioural reaction of fish in the extension section of a demersal trawl. The grid was made from 25mm thick HDPE and measured 1.2 x 0.75 m, it had a horizontal bar that divided the grid in half and vertical bars set 0.145 m apart. Two 5mm multi-strand side emitting fibre optic cables housed in 12mm clear PVC tubing were cable tied to the grid, one illuminating the upper half and the other illuminating the lower half. The cables could be illuminated by a light pod unit which houses a single green (530nm wavelength) LED and is powered by a 12V DC supply.

During the first set of trials the grid was mounted at a 60 degree angle near the start of the extension. A panel of 80mm diamond mesh netting was attached behind the central bar of the grid and fitted along the selvedges of the extension leading to two separate 80mm codends. Fish that went through the top half of the grid were retained in the upper codend and those that went through the bottom half were retained in the lower one. Four different lighting configurations were investigated: (i) all of the grid illuminated; (ii) top-half of grid illuminated; (iii) bottom-half of grid illuminated; and (iv) no illumination. Furthermore, the tows took place between midday and midnight ensuring that half of each days tows took place during daylight hours and half during the night.

During the second set of trials the grid was mounted horizontally in the panel that vertically separated the extension section. A circular metal ring was fitted at the beginning of the extension section to hold the netting open. The front end of the separator panel was fitted to a horizontal cross bar on the ring and the grid was installed into the panel, 12 meshes aft of the ring. In addition an 80mm diamond mesh guiding panel was fitted from the cross bar to either the top or bottom netting sheets a position 1.85 m ahead of the ring. When the guiding panel was attached to the top sheet, fish were directed into the lower half of the extension from where they could either swim up through the grid and to the upper codend or swim past the grid to the lower codend. Similarly, when the guiding panel was attached to the bottom sheet, fish were directed to the upper half of the extension from where they could swim down though the grid and onto the lower codend or past the grid to the upper codend. Four different configurations were tested during these trials: (i) illuminated grid in top sheet; (ii) non-illuminated grid in top sheet; (iii) illuminated grid in bottom sheet; and (iv) non-illuminated grid in bottom sheet. These tows all took place during daylight hours.

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Catching Northern Prawn without benthic contact

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Background The technical feasibility of using laser light for wild-fish harvesting has been explored by the authors in a series of experiments. The ability to incite avoidance behavior in fish using directed light was initially established in tank trials. Similar behavior was subsequently observed in sea trials. The catch rate of Northern Prawn (Pandalus borealis) has now been measured using a purpose-built experimental VirtualTrawl™ employing laser light to herd prawns off the bottom.

Method The VirtualTrawl replaces the conventional trawl by a rigid frame and a small tapered net that corresponds to the codend of a traditional trawl. Automated height control allows the frame to glide above the sea floor without contact, and target species are herded with directed laser beams, leaving the benthic ecosystem undisturbed. The experimental equipment can be commanded from the bridge and includes live video for observation and recording.

Fishing experiments were conducted in the coastal waters of NW Iceland. The reaction of Northern Prawn to the VirtualTrawl was observed with the laser light alternatively turned on and off. The instantaneous rate of catch was measured by counting prawns that entered the codend within the field of view of the underwater camera. A more accurate re-count was done using recorded video sequences. The height of the VirtualTrawl above the sea-floor was monitored using an acoustic altimeter attached to the frame.

Results A total of 596 samples were counted with lights on and 573 samples with lights off. The average catch rate was 7.08 prawns per second (σ=7.5) with lights on and 3.37

prawns per second (σ=6.15) with lights off. The difference in catch rate is significant (t-test, t = 9.83; p << 0.05). The catch was pure prawn with negligible bycatch.

When towing at close proximity (0.3 m) to the sea floor, the VirtualTrawl was observed to be without contact to the benthos in over 99% of the soundings, although results did vary with bottom topology.

Conclusions Fishing experiments conducted using an experimental VirtualTrawl established a twofold increase in the catch rate of Northern Prawn when lights of the VirtualTrawl were deployed. The prawn was caught without touching the seafloor. The results show conclusively that the lights herd the prawn off the bottom while having negligible ecological impact.

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Trawlight – Using artificial lights to modify fish behaviour in trawls

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Trials were undertaken to investigate the potential for artificial lights to modify fish behaviour during the fishing process. The work focuses on modifying selectivity in the SW of England otter trawler fishery. Sea trials were conducted between 14th October and 4th November 2017, aboard the chartered fishing vessel Elisabeth Veronique. The vessel was supplied with two identical wing trawls, which had the inclusion of a horizontal separator panel, starting directly above the footrope, and splitting each trawl into two separate codends. The two trawls were towed simultaneously as a twin rig, the only difference between the trawl, was that a string of lights was attached to one trawl. The lights were attached in two positions, on the footrope and on the headline. The effect of the lights on the catches in the four different codends was analysed using a series of pairwise comparisons using the SELNET software.

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Location, orientation, and economic performance of low-powered LED lights inside snow crab traps in eastern Canada

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This study investigated the effect of installing underwater Light-Emitting Diode (LED) lights in different locations and orientations inside baited traps targeting snow crab *Chionoecetes opilio* off the coast of Newfoundland and Labrador, Canada, as well as the economic performance associated with using lights in this fishery. Our results showed no significant differences in catch per unit effort (CPUE) for both legal and sublegal-sized crab among the different experimental treatments, however all of the experimental (illuminated) traps harvested significantly more crab than control traps (without lights). While longer soak time did not increase the CPUE for control trap, this variable significantly increased the catch rate for the illuminated trap. Proportion of legal-sized crab was 73% for both control and illuminated traps, and there were no significant differences in crab size distributions between pairwise comparisons. In terms of economic feasibility, investment of LED lights in the snow crab fishery will require additional variable costs for fishing enterprises, however our analysis suggests the financial break-event point is quickly reached. A profit of $206,000 CDN per vessel is predicted during the life cycle of a typical light (e.g. 14 years), compared to traditional capture methods (without lights). This gain was proportional with crab prices and allocated quota level. Our results suggest that fishing enterprises could increase their profitability by using LED lights in the snow crab fishery.

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7.7 Poster session

Designing dolphins' catch-reduction phrases in the stow net

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The capture of marine mammals has recently emerged as an international issue. The purpose of this study is to investigate the technology of countermeasures for the reduction of marine mammals in order to enable the export of fishery products with a high percentage of marine mammals to be counteracted in response to US imports of marine products produced in Korea after the promulgation of amendment of the US Marine Mammal Protection Act and to prevent the reduction of marine mammal resources in Korea.

Therefore, in Korea, the dolphin, especially the neophocaena phocaenoides, which is the highest, catches. To confirm two experiments were carried out to investigate the possibility of reducing the dolphins. Experiments on four dolphins (Tursiops truncates) showed that the rope was perceived and avoided regardless of the thickness, the color and the spacing of the rope. However, Beluga whale (Delphinapterus leucas) did not show avoidance response to the rope as a result of experiments.

There are two kinds of fishing gear: one is a stow net that escapes to the outside (upwards) through the device by providing an escaping device in front of the net when it becomes a catch. The other is a non-intrusive phrase that allows them (dolphins) to go back by fixing the rope from above to below, which can be a threat when the baulk enters the net.

The purpose of this study is to introduce the design of escape - type catch - reduction and catch - prevention catch - reduction catches and to prove the effect of catching whales using this catch. Therefore, we are going to build two kinds of stow net to check whether dolphins are allowed to enter.

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A study of discard survival in set-net fisheries

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A discard ban in the reformed European Common Fisheries Policy include the possibility of exempting species with proven high discard survival from landing obligation. A large number of the commercial Danish fishing fleet is gillnetters that are mostly fishing coastal. European plaice (Pleuronectes platessa) is a key species for the gillnetters in the North Sea, Skagerrak, and Kattegat. Discard survival in P. platessa from beam and otter trawls range from 0–68%, but survival data on plaice fished with set-nets (trammel and gillnets) is absent from the literature. To investigate discard survival of gillnetters a study, financed by European Fisheries Fund and the Ministry of Environment and Food of Denmark, was established as a cooperation between Aalborg University, Copenhagen University and Foreningen for Skånsomt Kystfiskeri. Experiments were conducted in 2017 and 2018 from smaller coastal commercial gillnetters. Methodology was developed to collect, assess and observe discard survival in P. platessa fished with set-nets. Injury assessments and reflex action mortality predictor (RAMP) tests performed on the fishing vessels immediately after capture, and at the end of the observation periods, revealed substantial recovery of minor catch-related trauma during the observation periods. At the end of the experiment, all fish were sacrificed and dissected to assess the level of long-term internal lesions sustained during capture. All plaice observed so far were alive at the end of the predetermined observation periods. In conclusion, our study document a high discard survival that might justify an exemption of set-nets fished P. platessa from the landing obligation imposed by the European Commission.

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Size selectivity of barrier traps for Gilt-head Sea Bream: A FISHSELECT application

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Lagoon fishery is one of the oldest fishing method and still being used to exploit coastal species in the northeastern Mediterranean. The fishery use barrier traps, made of cane, plastic or iron bars, to retain the species. There is no information about selectivity of the traps used in these fisheries.

We studied the size selectivity of different bar spacing (5mm-50mm) barrier traps for Gilthead Seabream (Sparus aurata) by using the fish morphology-based FISHSELECT methodology. Minimum landing size of the gilthead sea bream is 20 cm according to Turkish fisheries regulation. Optimum bar spacing for this size is estimated as 23 mm.

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Improved catch monitoring in purse-seine fisheries using acoustic methods

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Catch monitoring is important to ensure efficient and sustainable fisheries. One current challenge in the Northern European purse-seine fisheries is the lack of control of catch size. Catches that exceed vessel handling capacity or the allocated fishing quota need to be released. The weight of large catches may also cause the net to burst. In both cases non-retained fish mortality may be high.

We have used a Simrad SN90 multibeam sonar (Kongsberg Maritime) to monitor mackerel (*Scomber scombrus*), herring (*Clupea harengus*) and capelin (*Mallotus villosus*) schools during commercial purse seining. The sonar transducer was initially hull-mounted, but was later moved to the side of the scientific keel, about 8 meters below the surface. This significantly reduced signal attenuation from air bubbles. The acoustic volume backscattering strength from the schools was monitored during capture and used to estimate school density and behaviour. School density is required for estimating school biomass, while school density and behaviour are needed to ensure careful catch release. In the later catch stages, fish echoes were confused with echoes from the seine and air bubbles created by the vessel's propellers. The acoustic characteristics of the air bubbles and purse-seine backscatter were measured in controlled experiments to improve the extraction of school data inside the seine. This work gives some insight into the behaviour of schools captured by purse-seine and identifies challenges and future potential for purse-seine catch monitoring. School density and biomass can be measured more accurately once we have a better understanding of school internal organization during capture and accurate estimates of lateral target strength.

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Determining the effect of mesh size on scaling up of model net of tuna purse-seine in physical model testing

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To ensure efficient and sustainable purse-seine fisheries, it is necessary to understand well the fishing performance of a purse-seine, which can be related to many factors, such as mesh size, twine materials, leadline weight, fishing operations and the marine environment, etc. In this study, we tested two tuna purse-seine model nets with different mesh sizes to obtain the moving and drifting distance, spatial geometry, pursing 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 compared with 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 moving 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. 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 45 mm. In general, larger mesh nets increase sinking performance and decrease pursing tension. These results and experiences will form the crucial basis for the design and modification of purse-seine studies.

Identifying the design alternatives and flow interference of tuna purse-seine by numerical modelling approach

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Determinant attributes alteration and current-responsive dynamics of tuna purse-seine were numerically identified in perspectives of the vertical subsidence and global stress sensitivity. We rebuilt the submerged geometry of net using a mass-lumped model supported by hydrodynamic coefficients test on the prototype material, as well as a mesh lessening method allowing lower-quantity mesh for long operating-period and large dimensional fish gear by a simplified net of hydrodynamic force and gravity in equivalent proportion to prototype. Uneven pressure distribution across the operational period offered implications of rational netting layout that those highly stress-sensitive areas, for bunt at shooting and lower region close to lead line at pursing, were supposed to make use of thicker twine and smaller sized mesh. Four categories of shooing with current intervention made not identical sinking reactions. Load distributions were mutually complementary responding to any two kinds of current direction opposite based on a revealed rule that convex sections of net circle to which current heading were under high load. Shooting speed up will remarkably promote more balanced sinking, whereas reduced hanging ratio were preferable alternative for faster sinking. Despite its superiority of large sized mesh in reduced water resistance, extensive usage should be taken conservatively. We evaluated two options of different proportions of large-meshed panels to overall net and suggested that, by contrast to high risk of strands vulnerability as to mesh size doubled for 15 strips, mesh size doubled for 5 strips would be a balance in the selection of low mesh density and low mesh pressure.

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Understanding and predicting size selection of greater forkbeard (Phycis blennoides) for bottom trawl codends: a simulation-based approach

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The greater forkbeard, *Phycis blennoides* (Brünnich, 1768), is a gadiform species, which has economical value and its population is dwelling in a 60–800 m depth range throughout the Atlantic and the Mediterranean. The greater forkbeard is an important food fish in the Mediterranean. Found mud and sand bottoms it feeds mainly on crustaceans. The landings of greater forkbeard are mainly bycatch from bottom trawl fisheries. The general character of the fishery for this species makes the fishery difficult to manage in a single-species context. For this reason, several experimental studies have been carried to assess to codend size selectivity for greater forkbeard in bottom trawls.

However there are very limited experimental-based data on the size selection of greater forkbeard in trawl codends. These data needs to be supported by theoretical works, which try to understand and explain the experimental obtained results for managing the exploitation of the greater forkbeard stocks. The main objective of this study is to establishment a theoretical–based framework for understanding and predicting size selection of greater forkbeard in codends with different mesh configurations. For this aim, we used the fish morphology and computer–based simulation method FISHSELECT and we demonstrate how results for the size selection of greater forkbeard obtained from experimental fishing can be understood based on morphological characteristics of the species and mesh geometry. Results reported in this work will contribute to the knowledge of the understanding and predicting size selection of greater forkbeard in codends with different mesh configurations, with the aim of generating sufficient information to improve future stock management and sustainable fisheries.

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Quantifying bell-shaped size selectivity in shrimp trawl fisheries: effect of codend design

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Often trawlers targeting shrimp use a Nordmöre sorting grid ahead of a small-mesh codend. The purpose is to avoid bycatch while shrimps are efficiently caught. However, small fish can pass through the grid to enter the codend and risking being retained. This makes the size selection processes in a trawl fishery targeting shrimps complex, and the size dependent curve often adopt a bell-shaped signature. In this study we quantified the bell-shaped size selection pattern for the standard Nordmøre grid used together with each of three different codend designs. *1) the baseline with a 35 mm diamond mesh codend, 2) a 35 mm square mesh codend and 3) a "hour-glass" section comprising two 9 mm grids inserted between the Nordmöre grid and the 35 mm diamond mesh codend.* Results were obtained for Deepwater shrimp (Pandalus borealis) and four bycatch species based on fishing trials in the Northeast Barents Sea. The size selectivity for the bycatch species showed the characteristic bell-shaped size selection pattern expected with low retention probability of very small fish and bigger fish, while certain sizes of juveniles had high retention probability. Our results identified which size ranges of the different bycatch species that for the different codends would result in high risk of capture and thereby provided guidance on which size ranges that should be avoid to fish on with the different codends.

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Experimental fishery and utilization of mesopelagic fish species and krill in the North East Atlantic – NEAFC RA 1 Reykjanes ridge area.

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Extensive mesopelagic acoustic scattering layers (SLs) were found over the North-East Atlantic NEAFC RA1 Reykjanes Ridge area in 2016 and 2017. 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 analyses 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 analysed for unwanted substances such as dioxins, PCBs, PAH, pesticides, and heavy metals, showing values far lower than limiting values, suggesting that mesopelagic fish is suitable for human consumption.

Behavioural Responses of Krill and Cod to Artificial Light in Laboratory experiments

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Most fish and crustaceans respond to light, and artificial light sources may therefore be an efficient stimulus to manipulate behaviours in aquatic animals. It has been hypothesized that the catch efficiency of pots could be increased if prey, for example krill, can be attracted into the pots providing a visual stimulus and a source of live bait. To find which light characteristics are most attractive to krill, we tested the effects of light intensity and wavelength composition on Northern krill's (*Meganyctiphanes norvegica*) behavioural response to an artificial light source. The most attractive individual wavelength was 530 nm (green light), while broadband (425 - 750 nm) white light was an equally attractive light source. The intensity of the emitted light did not appear to have a direct effect on attraction to the light source, however it did significantly increase swimming activity among the observed krill. The most promising light stimuli for krill were tested to determine whether they would have a repulsive or attractive effect on cod (*Gadus morhua*); These light stimuli appeared to have a slightly repulsive, but non-significant, effect on cod. However, we suggest that a swarm of krill attracted to an artificial light source may produce a more effective visual stimulus to foraging cod.

Using artificial lights to illuminate gillnets as a strategy for reducing the bycatch of sea turtles and other marine species

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Bycatch in gillnet fisheries is a major issue for protected marine species, including sea turtles, seabirds, sharks, and marine mammals. Altering the visual cues associated with such fisheries has in recent years been examined as a potential bycatch reduction strategy.

Our work has focused on illuminating gillnets with artificial LED (light-emitting diodes) lightsticks as a way to reduce sea turtle and other marine megafauna bycatch. In Mexico, in collaboration with NGOs and local fishers, we tested the effects of nets illuminated by different wavelengths (short, mid, long) on the catch rates of sea turtles, target fish, and subsequent market value. In our experiments, we found that sea turtle interactions were reduced significantly by 40% - 60% with no change in target fish catch and no change in catch value.

Subsequently, we have initiated collaborations to further test net illumination in specific fisheries. In Northern Peru, we tested the effects of illuminating a coastal bottom-set gillnet fishery. Results show a 64% decrease in sea turtle bycatch with no change to the target catch. In addition, we saw a 74% decline in seabird bycatch. In Western Borneo, Indonesia, we tested net illumination in a coastal drift gillnet fishery and have found a 61% decrease in sea turtle bycatch with a slight increase in target and catch value.

With these studies, net illumination has been shown to reduce the bycatch of sea turtles, as well as seabirds, with no impact on the catch of target species. This suggests that net illumination may be an effective multi-taxa BRT. This finding has broad implications for bycatch mitigation in net fisheries given LED's relatively low cost, the global ubiquity of net fisheries, and the limited number of bycatch solutions. Additional net illumination trials are underway in Pakistan, Ghana, the Adriatic, and in NC (USA).

Shedding light on Swedish shrimp potting

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With the introduction of the EU's landing obligation there is an increasing demand for the development of both highly selective and sustainable fishing gear. In search of a low impact and selective alternative to current shrimp fishing methods, both in terms of bycatch reduction and catch rate, pots for Northern shrimp (*Pandalus borealis*) were evaluated within the Swedish coastal fisheries. Our aim was to analyse the catches and bycatches using different pot designs and alternative attractants. As an alternative attractant to herring, green, white, and ultraviolet (UV) coloured LED lights were tested.

Our main objectives were to:

- Evaluate how different pot designs and light attractants affect the catch rate and composition of shrimp and bycatch species.
- Analyse how the different pot designs and attractants affect the shrimp size distribution.
- Analyse how the different pot designs and attractants affect the behaviour of shrimps and bycatch inside the pot, through underwater video recordings.

We show how pots with the larger oval side entrances caught significantly more shrimp compared with pots with plastic funnel entrances and conventional top entrances. Catch rate was about three times higher than in conventional pot types used in US and Canada. In terms of bycatch, there was no difference between pot designs.

The use of lights as an alternative to herring as attractant resulted in a three time increase in shrimp catch. However light attractants also affected the bycatch rate. Green light resulted in large amounts of gadoids in the bycatch, white light resulted in fewer gadoids than green light, but UV light was found to be the most selective light with the best shrimp catch/bycatch ratio.

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Effects of population density on catch rates of snow crab traps using artificial light in the Barents Sea

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Since its introduction as a new commercial fishery in 2012, snow crab has quickly become an important species for the Norwegian seafood industry. Landings in 2016 were 5,300 metric tons accounting for approximately USD $40 million. Finding a solution to improve the catching efficiency of the existing trap design has the potential to significantly improve the profitability of fishing enterprises. Recent studies in Canada have shown that adding a low-powered light emitting diode (LED) light inside a baited trap significantly improved Catch per unit of effort (CPUE) of snow crab. In this study, we compared the catch rate of baited and illuminated traps in the Barents Sea during different fishing seasons in which we attached either a purple or a white LED light inside the baited trap. Results showed that crab population density in the Barents Sea was very low, with catch rates dependent on the fishing season, soak time, and fishing location. Mean CPUE was 1.2 and 2.3 crab per trap for June 2017 and February 2018, respectively. Population densities were higher in the west than the east side of the Norwegian water (e. g., border with Russian water). Although, the traps equipped with purple and white LED light produced a higher mean CPUE than traditional baited traps, no significant difference was statistically detected. Mean CPUE for the baited traps, purple light traps, and white light traps were 1.95, 2.22, and 2.1, respectively. The results also indicated that CPUE increased for both illuminated traps and baited traps with increasing soak time. However, longer soak times disproportionally benefited the illuminated traps compared to baited traps. Results also showed that snow crab captured in February tended to be larger (mean = 110.9 mm CW) compared to snow crab captured in June (mean = 106.8 mm CW). However, no significant differences in CW between baited and illuminated traps were found.

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LED lights to reduce bycatch in trawls: does phototaxis come into play?

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Several factors affect species behaviour inside trawls. For this reason, gear designs which aim at exploiting behaviour to reduce bycatch often obtain unexpected results.

This is particularly true when Light Emitting Diodes (LED) are used as behavioural stimulation due to the general lack in understanding on how species react to artificial lights. Using as an example a trial conducted on the *Nephrops* (*Nephrops norvegicus*) directed mixed trawl fishery in Skagerrak, we discuss the advantages and limits of the catch-comparison method in testing LED lights as bycatch reduction devices. In two separate experiments, we tested LED lights in the lower and upper netting panel in the tapered trawl section to improve fish' vertical separation from *Nephrops* in a horizontally divided codend. The experimental questions were if: i) phototactic responses could affect species separation; and ii) if either positive or negative phototaxis could be efficient at leading fish into the upper compartment. We obtained significant changes in vertical separation, but no clear species-specific phototactic response. Neither of the light positions improved fish separation from *Nephrops*. More information is needed to determine if the type of lights and their position in this experiment triggered a behavioural response, which was not useful to separate fish from *Nephrops*, or if phototaxis is simply not exploitable in the trawl to achieve species separation due to the amount of other stimuli involved.

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Using Artificial Illumination to Reduce Bycatch in Two US West Coast Trawl Fisheries

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Along the eastern North Pacific, the Pacific hake (*Merluccius productus*) midwater trawl fishery and ocean shrimp (*Pandalus jordani*) otter trawl fishery contribute substantially to the overall economic value of commercial fisheries in the region. However, bycatch of Chinook salmon (*Oncorhynchus tshawytscha*) in the Pacific hake fishery and eulachon (*Thaleichthys pacificus*) bycatch in the ocean shrimp trawl fishery can be an issue affecting each fishery as US Endangered Species Act (ESA) listed Chinook salmon and eulachon are caught at times. In this presentation, we will present detailed results from our research in the Pacific hake trawl fishery and ocean shrimp trawl fishery where we tested the efficacy of artificial illumination (e.g. LEDs) as a technique to reduce Chinook salmon and eulachon bycatch. Catch data for other roundfish and flatfish encountered will also be presented. In general, findings among our studies were similar in that the presence of artificial illumination appears to enhance fish optomotor response and their ability to perceive escape areas in and around the trawl gear that they would not be able to perceive as well under dark conditions. As ESA listed Chinook salmon and eulachon face many uncertainties in their ESA recovery, our research findings contribute new data on how artificial illumination can affect their catches (and other fish) and contribute to their conservation. Lastly, while our research has implications along the eastern North Pacific, our findings may also have potential applications in other trawl fisheries nationally and internationally; for example, the Icelandic pelagic mackerel (*Scomber scombrus*) fishery where Atlantic salmon (*Salmo salar*) bycatch can occur, and northern prawn (*P. borealis*) trawl fisheries in the North Atlantic where marine fish occur as bycatch.

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How artificial lights affect bycatches of fish and the Deepwater shrimp during trawling in the Barents Sea

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The Nordmöre grid, as used in Norway with 19 mm bar spacing, will reduce a large proportion of the bycatch of fish species. The bycatch is therefore small-sized fish species and juveniles that are able to pass through the grid and enter the codend, along with the targeted Deepwater shrimp (*Pandalus borealis*). The bycatch of fish not only leads to additional sorting work onboard, but it clearly has negative impact on the ecosystem due to increased fish mortality. A minor proportion of small fish and juveniles will escape through the outlet above the grid, without making contact with the grid itself. We investigated if introduction of Led lamps could promote this behavior could potentially reduce bycatch in shrimp trawl fisheries. We conducted experimental fishing trials over two periods to assess the size selective properties of the 19 mm bar spaced Nordmöre grid with and without LED lamps. In the first study we placed 5 green LED lamps around the escape outlet. Adding green LED-lamps small haddock were significantly discouraged from seeking the escape outlet. For the other bycatch species, results indicated a similar trend but they were not as clear and were not statistically significant. In the second study we attached 4 green LED lamps in the lower part of the Nordmöre grid. Adding LED lamps, we found for the four bycatch species investigated that 50-99 % of small fish passed through the Nordmöre grid. The addition of green LEDs to the Nordmöre grid did not significantly affect the escape probability and the size selectivity of any of the investigated species. In both studies very few shrimps were found to escape through the escape outlet independent of the presence of the green LED lamps mounted on the grid.

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Establishing baseline understanding of Antarctic krill (Euphausia superba) response to LED light exposure

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In this study, we wanted to investigate if Antarctic krill (*Euphausia superba*) modify its behavior upon exposure to LED light stimulation. To evaluate if any detectable response under laboratory conditions is representative of the response of krill in its natural environment, we used two methods during February 2018;

A controlled experiment of live krill onboard a fishing vessel was performed on individuals collected off the South Orkney Islands. The experimental tanks had chambers of different light levels to quantify preference of krill for a dark vs. light zone.

During the same time period and area, a mooring equipped with sensors was constructed and anchored to the seafloor to record krill behavioral response to LED light in their natural environment. The rig contained an upward pointing powerful LED light source programmed to switch on and off every other hour, and an echosounder storing data continuously for the presence and abundance of krill within the water column above the transducer.

Results from this study, shows that krill is positive phototactic. Detailed knowledge of this behavioral response might have relevance for the future development of krill fishing technology both to optimize the harvest and to reduce potential amount of bycatch.

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Assessing the impact of buffer towing on the catch quality and size selectivity of Northeast Atlantic cod (Gadus morhua) caught with a bottom trawl

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The dense aggregations of Northeast Atlantic cod (*Gadus morhua*) in the Barents Sea have led to a new fishing practice termed "buffer towing." In this fishery, many trawlers redeploy the trawl directly after taking the catch onboard in an attempt to secure a continuous supply of fish and avoid any unnecessary stops during processing. If the approximate desired amount of fish is caught or exceeded before the catch from the previous haul is processed, the trawl is lifted off the seabed and towed at a given depth at low speed, usually ~1–2 knots, until the production capacity of the onboard factory is restored. Both researchers and fishers onboard trawlers believe that buffer towing has a negative impact on fish quality, as indicated by increased frequency of gear marks and dead fish, poorer exsanguination, ecchymosis, skin abrasion, fillet gaping, and fillet redness. The aim of this study was to document the effects of buffer towing on fish quality. The quality was assessed using two different indices, one for whole cod and one for cod fillets. The results proved that buffer towing has a negative impact on fish quality. Specifically, cod subjected to buffer towing, in contrast to direct haul-back, had an increased relative probability of 371% for poor exsanguination and an increased relative probability of 209% for fillet redness. Furthermore, combining scores of the different quality categories within the indices (e.g. gear marks, ecchymosis, poor exsanguination, and skin abrasion) proved a significant reduction the quality of cod subjected to buffer towing. Furthermore, calculating size selection applying a new analytical method demonstrated a significant size selection for cod during buffer towing where cod measuring up to at least 42 cm in length were proven to escape. Specifically, at least 60% of cod measuring 20 cm were estimated to escape, whereas, for cod measuring 30 and 40 cm, at least 53 and 45% were estimated to escape during buffer towing, respectively.

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The PhysFish project – investigating the role of animal physiology in fisheries induced evolution

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Evidence is accumulating showing that intensive commercial fishing is not only depleting fish stocks, but is also acting as a selective force causing evolutionary changes to fish populations. A wide body of research suggests indeed that size-selective harvesting is altering growth rates, body size, and fecundity in wild fish populations. While these effects have serious consequences for the viability of marine fish communities, there are a range of traits besides body size which could also affect catchability by commercial fishing gears – and therefore the fisheries-induced evolution (FIE) – but which have not been investigated. In the PhysFish project, we investigate the mechanisms of fishing selection, focusing on individual variability of physiological traits, to improve our understanding of FIE. Specifically, we focus on the linkages between individual variability of key physiological traits, such as energy demand and swim performance, and the likelihood of encounter with fishing gear, capture and post-release survival. Using a multi-level experimental approach, conducting field and controlled laboratory studies on wild, fisheries targeted species or surrogate species, the main aims of the PhysFish project are to determine:

- if individual differences in physiological traits explain movement and habitat use patterns that might in turn correlate with differential encounter and capture rates with fishing gear;
- if escaped or discarded fish differ in their ability to recover and survive based on their individual physiological phenotype;
- the effects of environmental plasticity under different warming scenarios (increased temperatures and hypoxic conditions) on fishing selection;
- the transgenerational effects of intensive and selective harvesting.

Results from this project provide important biological information that can contribute to improve fish stock assessments and predictions, and the forecasting of FIE.

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Estimating available selectivity of jellyfish reduction device equipped on small trawl

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In the coastal waters of Japan, jellyfish *Aurelia aurita* are found in summer season. Sometimes, a problem arises for fishers whereby large quantities of jellyfish are caught in trawlnets. This can degrade freshness of the fish and can distort or damage the nets. We have developed a jellyfish reduction device to solve these problems. Our trial jellyfish reduction device was constructed with a grid, funnel-net, and escape-vent. The grid consists of a frame made from iron and vertical PVC bars of 13 mm diameter with 30 mm bar spacing. The bottom of the grid was spaced at width 0.85m and height 0.1m. The grid was installed in front of the codend. The escape-vent was cut out from the top of the net where the grid was installed. We carried out fishing experiments in the coastal area of Yamaguchi Prefecture in Japan during June, July, and August of 2015 and 2016. In this experiment, we chartered the commercial small trawl vessel *Dai-San-Kaikomaru* (2.9t) and conducted twenty tows using the jellyfish reduction device. In this study, we analysed catch data obtained from the fishing experiments to estimate the effect of excluding jellyfish when catching the target species, of which large numbers of the following were caught: sea bream *Pagrus major*, cinnamon flounder *Pseudorhombus cinnamoneus*, and whiskered velvet shrimp *Metapenaeopsis barbata*. In this analysis, we attempted to construct a numerical model to estimate available size selectivity of the grid including the funnel-net of the jellyfish reduction device. Numerical models were used to calculate probabilities of species encounters with grid and funnel-net. Equation parameters were calculated using the maximum likelihood method. For sea bream, we adopted a model unaffected by grid selectivity but affected by funnel-net selectivity. For this species, we confirmed a reduced catch rate to TL 0–75mm, but catch rate later increased following a size increase. For cinnamon flounder, we adopted a model affected by both grid and funnel-net. We presumed that size selection was affected by swimming position within the net. For whiskered velvet shrimp, we adopted an equation affected by funnel-net size selectivity. The resulting exclusion rates for jellyfish were 46–86%. This was also influenced by the height at which the grid was towed.

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Size selection in conical pots: A study of the effect of soaking time in the Norwegian snow crab fishery in the Barents Sea

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Conical Snow crab pots are regarded a selective fishing gear with low degree of bycatch. SINTEF has performed sea trials in the Barents Sea to investigate the size selective properties of this type of gear and the effect of soaking time. Our results show that conical pots reach their full size selective potential only when they have had sufficient soaking time.

To our knowledge, the selective properties for the conical snow crab pots used in the Barents Sea has never been scientifically investigated. To study the selective potential of the pots, we used the paired-gear method, where we compared test pots with 140 mm diamond mesh size and control pots with 52 mm diamond mesh size. In addition, we carried out fall through experiments to establishing maximum selectivity limits for the 140 mm mesh size pots. In Norwegian waters, the minimum legal size for snow crab is 100mm carapace width, and a diamond mesh of 140 mm complies well with this regulation. However, the selectivity of the pots depends, not only on the selective properties of the meshes in the pots but also, on the fraction of crabs that are able to contact the meshes in the pot. Our results demonstrate a positive correlation between soak time and mesh contact, and show that under the fishing conditions in the Barents Sea, the selective properties of the pots vary significantly with soaking time. After 5-6 days of soaking time, 10-15% of the crab have still not contacted the meshes in the pot. It is first after 9-14 days of soaking time that 100% of the crabs in the pot have been able to contact the diamond meshes in the pot, and the selective potential of the pot is fully achieved.

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

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

8.1 Introduction

A WGFTFB topic group (TG) of experts was formed in 2018 to evaluate the use of artificial light as a fisheries selectivity tool. The first meeting of this TG was in Hirtshals, Denmark at the 2018 ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) annual meeting. The goals of this first meeting 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.

8.1.1 Background and Objectives

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 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 this 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 ongoing 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.

8.1.2 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.

8.2 2018 Topic Group Meeting Overview

The topic group met June 7-8 (Thursday - Friday) for approximately three hours each day. The first day included introductions, with each person sharing their involvement in research using artificial light. This was followed by each person filling out a card to indicate their reason for joining the topic group, and indicating an experimental, technological, and analytical challenge that they have been confronted with in doing this research. This was followed by a series of six keynote presentations related to the six fundamental principles of conducting research using artificial light to affect behaviour (see 'Keynote Presentations', 8.3.2). The primary focus of the second day was on workshops to discuss some of the common challenges highlighted in the cards that were filled out the first day (see 'Workshop Discussions', 8.3.3).

8.2.1 2018 Topic Group Participants

There were 46 TG participants, representing 17 countries. Participants were primarily conducting research applying artificial lights to trawl gear, but were also involved with studies pertaining to gillnets, pots, jigging, purse-seine, and a laser trawl (see table below). The lights were being used to affect behaviour of fish (e.g. cod, haddock, salmon), invertebrates (e.g. Norway lobster, shrimp, snow crab, squid), marine mammals and turtles, and seabirds. The mode that participants have been using the lights included lights as lures, lights to substitute mechanical components of the trawl, lights as bycatch reduction devices (BRDs; e.g. separating species), and light to illuminate BRDs. The motivation for joining the TG for nearly all of the participants was that they were doing work in that field currently.

NAME	FISHERY TYPE	SPECIES OF INTEREST	RESEARCH INTEREST
Adnan Tokaç		Fish	Effects of lights on fish schools
Anne Christine Utne Palm	Passive gears	Fish	Fish behaviour related to vision
Barbara Koeck		Cod	Ecophysiology and behavioural ecology
Chris Rillahan	Trawl	Squid, fish	Lights in trawls to separate squid from fish
Damien Grelon	Pots, trawls	Snowcrab	Lights as lures in pots or as BRD in trawls
Dan Watson	Trawl		Development of lights for fishing gears applications

Elsa Cuende	Trawl	Fish	Behavioural stimulation to increase contact with square mesh panel
Emma Jones	Trawl	Fish	BRDs in trawls based on fish behaviour
Enis Noyan Kostak		Fish, crustaceans	Meshes selectivity
Erika Andersson	Trawl	Roundfish and flatfish	Use of behaviour for species separation
Geir Gudmundsson	Laser trawl	Shrimp	Laser beam to catch shrimps without bottom contact
Halla Jonsdottir	Laser trawl	Shrimp	Laser beam to catch shrimps without bottom contact
Haraldur Einarsson	Passive gears, laser trawl	Fish, shrimp	Lights as lures and as a substitute of mechanical components of the trawl
Iñigo Onandia			
Isabella Kratzer	Gillnets	Marine mammals	BRDs for gillnets fisheries
Jérôme Chladek	Pots	Cod	Red lights to observe fish natural behaviour
John Wang	Gillnets	Marine turtles	Lights as BRDs in gillnets fisheries
Junita Karlsen	Trawl	Fish, Norway lobster	Lights to guide fish for catch separation and use of escape routes
Khanh Nguyen	Pots	Snowcrab	Lights as lures
Lauren Fields		Marine mammals	Conservation
Lotte Kindt-Larsen	Gillnets, pots	Marine mammals, seabirds, cod	Lights as BRDs in gillnets or as lures in cod pots
Ludvig Krag	Trawl	Fish, Norway lobster	Lights as BRDs in trawls
Luisa Barros		Cod and Haddock	Laboratory studies; behavioural ecology
Marie-Claude Côté-Laurin	Pots, trawls	Snowcrab	Lights as lures in pots or as BRD in trawls
Mark Lomeli	Trawl	Fish, Chinook salmon	Lights as BRDs in trawls
Martin Oliver	Trawl	Fish, Norway lobster	Lights as BRDs in trawls
Mike Breen	Purse-seine, trawl	Fish	Species behavioural interaction with fishing gears
Michael Osmond	Gillnets	Marine turtles, marine mammals	Application of lights as BRDs

Noëlle Yochum	Trawl	Fish, salmon	Lights to encourage exit out BRDs (escape portals)
Odd-Børre Humborstad	Pots	Snowcrab and cod	Lights as lures
Paul Michael Petersen			Laser systems and LEDs
Paul Winger	Pots, shrimp trawl	Snowcrab, fish	Lights as lures in pots or as BRD in trawls
Pascal Larnaud	Trawl	Fish	Behavioural stimulation to increase contact with square mesh panel
Pedro Sá	Pots, trawls		Producer of the glowing net
Peter Ljungberg	Passive gears		Lights as lures or for bycatch reduction
Pieke Molenaar	Trawl	Fish, shrimps	BRDs in trawls based on fish behaviour
Pyungkwan Kim	Jigging	Squid	Lights as lures
Ron Douglas		Human	Human eye: biology and diseases
Ronald Kröger		Vertebrates	Vision: optical lenses
Rónan Cosgrove	Trawl	Fish, Norway lobster	Lights as BRDs in trawls
Subong Park	Jigging	Squid	Lights as lures
Svein Løkkeborg	Passive gears		Lights as lures
Terje Jørgensen	Trawl	Fish	Lights as BRDs in trawls
Thomas St-Cyr Leroux	Pots, trawls	Snowcrab	Lights as lures in pots or as BRD in trawls
Torfi Thorhallsson	Laser trawl	Shrimp	Laser beam to catch shrimps without bottom contact
Valentina Melli	Trawl	Fish, Norway lobster	Lights as BRDs in trawls

8.2.1.1 List of participants

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8.3 2018 Topic Group Accomplishments

The large number of contributions (see 'Presentations and Posters in Plenary', 8.3.1) as well as participants in the TG (see '2018 Topic Group Participants', 8.2.1) demonstrate the growing interest of 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, which is followed up through e-mail communication in-between meetings with all members of the WGFTFB both inside and outside the TG that have expressed their interest in being part of this community. In addition, according to the goals of this first meeting (see 'Introduction', 8.1), common challenges have been identified and discussed in workshop discussion groups (see 'Workshop Discussions', 8.3.3). Among the resources that are being built-up and provided to the community during the duration of the TG are keynote speakers during the meetings (see 'Keynote Presentations', 8.3.2), a literature library with a reference list (see 'Literature Library', 8.4.1), and a database of studies that will be used both to look for patterns in the effect of light and to create guidelines for conducting this research (see 'Examination of Research Using Artificial Light', 8.4.2).

8.3.1 Presentations and Posters in Plenary

There were 13 contributed papers focusing on artificial light in the plenary. Of these, five (see table below) were oral presentations in the 'Light' Topic Session (see section 8.6 for abstracts):

Title	Presenter
The luminous net VISIONET- a guiding swimway to the exit or a stressor?	Junita Karlsen
Some recent trials with illuminated grids	Barry O'Neill
Catching northern prawn without benthic contact	Torfi Thorhallsson
Trawlight- using artificial lights to modify fish behaviour in trawls	Tom Catchpole
Location, orientation, and economic performance of low-powered LED lights inside snow crab traps in eastern Canada	Khanh Nguyen

The presented studies focused on the use of different light sources (e.g. luminous net material, LED light using fiber optic cables, laser, and point LED-lights) to influence the behavior of marine animals during the capturing process. The studies focused on bycatch mitigation, catch efficiency, selectivity, reducing sea bottom impact, and economic analysis of implementing the lights in the fisheries.

The open session discussion for the 'Light' Topic Session included comments regarding the environmental implications of adopting lights commercially with respect to marine litter (e.g. thousands of plastic lights and batteries in the water for pot fisheries). This included follow up discussion about luminous pigments compared to lights that require batteries, and how that might be accomplished. Another topic of conversation was in regard to how effective lights are as a bycatch reduction tool, and if results are promising enough to move forward.

The remaining eight contributions were presented as posters at the poster session (see section 7.7 for abstracts):

Title	Presenter
Using artificial illumination to reduce bycatch in two US west coast trawl fisheries	Mark J.M. Lomeli, W. Waldo Wakefield, Scott D. Groth, Matthew T.O. Blume, Bent Herrmann
LED lights to reduce bycatch in trawls: does phototaxis come into play?	Valentina Melli, Ludvig A. Krag, Bent Herrmann, Junita D. Karlsen
How artificial lights affect bycatches of fish and the deepwater shrimp during trawling in the Barents Sea	Roger B. Larsen, Bent Herrmann, Manu Sistiaga, Jesse Brinkhof, Ivan Tatone, Lise Langård and Jure Brčić

Using artificial lights (LEDs) to illuminate gillnets as a strategy for reducing the bycatch of sea turtles and other marine species	John Wang, J. Barkan, F. Carvalho, S. Fisler, J. Mangel, J. Alfaro-Shigueto, S. Pingo, A. Jimenez, Y. Swimmer, Dwi Ariyoga Gautama, W. Teguh, C. Ngesti Handyani
Establishing baseline understanding of Antarctic krill (*Euhausia superba*) response to LED light exposure	Bjørn A. Krafft, Ludvig A. Krag
Behavioural Responses of Krill and Cod to Artificial Light in Laboratory experiments	A.C. Utne-Palm, M. Breen, S. Løkkeborg, and O-B. Humborstad
Effects of population density on catch rates of snow crab traps using artificial light in the Barents Sea	Khanh Q. Nguyen, Odd-Børre Humborstad, Svein Løkkeborg, and Paul D. Winger
Shedding light on Swedish shrimp potting	Peter Ljungberg, René Bouwmeester

All studies used light sources to study the response of either fish, crustaceans, or sea turtles. Five of the studies used artificial light with the aim of reducing bycatch in trawl (four studies) and gillnet (one study) fisheries. The remaining three studies used artificial light with the aim of increasing catch rates in pot fisheries.

8.3.2 Keynote Presentations

Working with artificial light in fisheries requires a multidisciplinary approach. The previous Artificial Light TG (2012-2014) identified five areas of expertise involved, creating five ‘pillars’ onto which studies are based (see ‘Keynote 1’, 8.3.2.1). The current TG identified an additional 6th pillar needed to address common challenges in creating optimal experimental design, using appropriate analysis, and interpret fish responses objectively. The latter was also addressed in the workshop discussion (see ‘Analytical challenges’, 8.3.3.3).

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: Behavior – Response to light stimuli

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

Pillar 6: Design, analysis, and interpretation

It is necessary to understand each of these disciplines when using artificial light as a stimulus to manipulate the behavior of marine animals for bycatch mitigation. For this reason, keynotes speakers representing different pillars will be invited each year to speak during the TG session, and in the course of the three years of the TG, the aim is to cover all the pillars at least once. In 2018, there were six invited keynote speakers, of which half were experts from outside the WGFTFB, covering pillars 1, 2, 3, and 6.

8.3.2.1 Keynote 1

Use of artificial light in fishing, what we have learned from the previous ICES TG (Mike Breen* and Anne Christine Utne-Palm)

Abstract

The ICES/FAO Topic Group on the Use of Artificial Light as a Stimulus in Fisheries recognized that the successful application and further development of artificial lights in fish capture will be dependent on a multidisciplinary approach involving five areas of expertise (Figure 1). Among various areas of review and discussion addressed the "TG Light", the most pertinent findings for the new TG on the Use of Artificial Light to Promote Selectivity were: what each of these fives disciplines provides, as well as how they should best be combined, to address the common challenge of manipulating marine animal behaviour using artificial light as a stimulus.

Engineering: Modern LED light technology gives us the unique possibility to design durable, low energy underwater light which can emit light of any desired wavelength and form. This has opened the possibility of fine-tuning of artificial light stimuli to almost any form we want. Thus, the remaining challenge is to find out what stimuli would be the best. This is a great challenge given that there are many physical and biological factors involved between the emitted light stimuli, the organism's eye and the response of the organism.

Physics/Optics: Between the light and organisms eye it is the optical properties of the water, which alters the light stimuli through scattering, absorption and polarization.

Biology: Once the light has reaching the fish eye the lens will affect what will be transmitted further on to the retina, where the species visual pigments will determine which part of the light stimuli will be detectable and to what degree.

Behaviour: Once detected by the retina and transported by the optical nerve to the brain, the species behavioural response can be, repel or herding, attract (guiding) or indifferent – and its response can be dependent on many things like; life history, age, hunger level, earlier experiences etc..

Gear Technology: Finally, once the process of stimulation and behavioural manipulation is understood, this can be applied to modify a capture process to selectively modify the catch be possibly attracting some species, while repelling unwanted catch. In presenting these findings, we will also share our experiences, and lessons learned, when applying the TG Lights recommendations to develop a fish pot to selectively target cod.

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Key points

- The light emitted by the light source does not have the same characteristics as the light received by the retina of the fish eye (e.g. attenuation, scattering, absorption, polarization).
- Differences in visual capabilities between species can be utilized.
- Choose wavelength and light intensity according to the sensitivity of the given species for the given wavelengths.

Discussion/questions

- What are the costs of collecting species-specific information about the visual range of the main commercial species? There are three ways, with the genetic method being the most affordable. However, it is not cheap or quick.
- Can we conclude when it is more appropriate to use white lights as opposed to green light? No, it is a trade-off between intensities and the distance at which species should be able to detect the light.

8.3.2.2 Keynote 2 (Pillar 2)

An idiot's guide to light and its measurements (Mike Breen)

Abstract

To a biologist studying the behaviour of fish and other aquatic animals, light is a stimulus that can have immediate and profound effects upon the behaviour of an individual. This stimulus is detected primarily by the eye, where photons of light energize the visual pigments in the retinal photoreceptors (rod and cone cells), which - after initiating a complex cascade of biochemical reactions - results in an electrical impulse being transmitted, via the optic nerve, to the optical centre of the brain. To understand how a light stimulus can be modified to manipulate the behaviour of a target species, we must first be able to accurately and consistently describe the nature of the light arriving at the fish's eye. To do this, we must enter the world of physics and optics, and ask: "what is light?" However, the physical definitions of light are complex, with a myriad of confusing metrics and units to describe it, including: radiance, irradiance, Joules, Watts, luminance, lux, lumens and, of course, the foot candle! This presentation will attempt to provide a concise and understandable explanation of the key characteristics of light (intensity, frequency/wavelength and polarization) and the units used to measure them. It will highlight the most useful units for biologists studying the behaviour of fish (i.e. Radiometric), as well as which units to avoid (i.e. Photometric). Finally, the principles of measuring light in the laboratory and in the field will be described, with guidance on common mistakes to avoid.

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Key points

- What is light? Light is characterized by photons, which are packages of energy, but also have the property of a wave characterized by a wavelength, directionality, polarization.
- How to measure light? Never use lux or any other photometric measures as these relate to human and not fish perception. Use radiometric units. E.g. non-directional scalar irradiance, which is a measure of light power (photos/sec) at a specific point in space and time: power^{-area} (Wm^{-2}). This can be measured using spectro-radiometers.
- Consider context when measuring light, e.g.:
  - how the characteristics of artificial light source change due to attenuation
  - how the artificial light source contrast with ambient light

Discussion/questions

No time for questions.

8.3.2.3 Keynote 3 (Pillar 1)

LED technology: the future of lighting (Paul Michael Petersen*)

Abstract

In the talk the basic physics of LEDs will be discussed. Furthermore, the talk focuses on the quality of LED lighting and why it is important to test the LED lighting. LED lighting has developed tremendously in recent years. The efficiency of LED's has doubled every third year and today LEDs are more efficient than any other conventional lighting source. In addition to the energy savings LED's have a number of other advantages: small, compact, and long lifetimes up to 20.000 - 100.000 hours.

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Key points

- White LED light is made from blue diodes with phosphorescent materials.
- LED lights are using RGB-technology, i.e. it is the combination of the intensity of red, green and blue that determines the colour.
- LED sources does not fail suddenly, but degrade slowly. The wavelength spectrum and efficiency of the light source must therefore be measured every time before it is used in experiments.
- Use spectral irradiance, i.e. power/area (W/m^2/nm) when measuring light in studies with fish.

Discussion/questions

- Are LED lights potentially damaging for the species eye? Yes, if the beam is very concentrated and it hits the retina it's harmful. To prevent that we can defuse the angle.
- How much more efficient are LED lights respect to sodium lights? They are approximately the same in terms of brightness, but LED lights are superior in colour rendering and twice more efficient in terms of energy consumption.

8.3.2.4 Keynote 4 (Pillar 3)

The eyes of fish inhabiting different environments (Ron Douglas*)

Abstract

The level of sunlight underwater, as well as its spectral content, depends on depth, time of day and geographical location. The bioluminescence generated by many species further adds to the diversity of the underwater light environment. Not surprisingly, the visual systems of different fish are very varied.

Two fundamental properties of vision are the ability to gather the maximum number of photons, enabling vision at low light levels (sensitivity), and the ability to resolve fine spatial detail (acuity). High absolute sensitivity is provided by retinal rods, whose outputs converge onto few ganglion cells. High spatial acuity, on the other hand, is mediated via relatively insensitive cones.

The retinae of animals inhabiting low light level environments are dominated by rods, which are often either enlarged or occur in multiple banks. The eyes of such species also show various optical adaptations to enhance photon capture.

Species living in higher light levels possess a greater proportion of cones. However, the structure of their retinae is rarely, if ever, uniform across its entire surface. Areas of

increased cone and ganglion cell density provide regions associated with higher resolution due to finer sampling of the visual field and less convergence of photoreceptor output. However, even if it were desirable to have the entire retina composed of tightly packed cones linked to individual ganglion cells to maximize visual acuity throughout the visual field, this would not be energetically sustainable and would require an unreasonably large optic nerve and excessive central processing. Thus, such retinal specializations cover only some of the retina subtending just a small part of the visual field. These specialised regions are positioned so as to sample visual space mostly appropriately for any given species. From the density of cells within such regions and their position, it is possible to estimate the spatial acuity of a given species and its 'preferred' direction of gaze.

Another basic visual attribute of an object or environment is its colour. This is also detected by cones. Different cones contain visual pigments maximally sensitive in different regions of the spectrum. The spectral sensitivity of the cones and the number of spectral cone types an animal has determines the wavelengths it perceives. Thus, while deep-sea fish have only a single spectral type of photoreceptor, maximally sensitive at short wavelengths, species inhabiting brightly lit coral reefs may have four different cones types spanning the spectrum, while coastal species often have only two.

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Key points

- Never, ever use lux when measuring light for a fish perspective.
- Rods gives sensitivity, cones gives resolution (≈ pixels).
- Cons are expensive to run and so the area of high cone density is limited. Thus, it is only possible for the retina to sample a particular area of the visual field. Therefore, different species look in different directions. The retina is adapted to the habitat fish live in, e.g. flatfish will look up (i.e. the retina samples from the visual field above the fish).
- The spatial resolution (pattern disruption) differs between species.

Discussion/questions

No time for questions.

8.3.2.5 Keynote 5 (Pillar 3)

The biology of underwater vision (Ronald H. H. Kröger*)

Abstract

The underwater visual environment is highly variable, changing with depth, water type, weather condition, season and so forth. Even non-visual factors, such as temperature and osmolality, play important roles. Evolutionary optimization has led to a multitude of different visual adaptations in fish, but an animal cannot invest in a more powerful visual system if the costs exceed the returns obtained. Visual performance is therefore limited by various internal and external factors. Importantly, underwater vision is a short-range sense, with visual distance being limited to about 50 m even in the clearest open-ocean water and to much shorter distances in most coastal waters. Furthermore, visual needs and conditions change during the lifetime of a fish and the visual system adapts to these changes. The adaptive fine-tuning occurs on various timescales, from minutes to months. This means that different species and even different age groups of the same species have different visual capabilities. Additionally, fish of

the same species and age (size) living in different environments may have somewhat different visual capabilities, just as we perceive white as white if illuminated by the reddish light of a candle only if our eyes had time to adapt. Specific visual capabilities may make it possible to specifically target species and/or developmental stages by using suitable visual stimulation. However, it is difficult to make predictions because of the large diversity of fish visual systems and their adaptive plasticity. Testing a variety of solutions, with the available knowledge of the visual system and habitat of the targeted fish population in mind, may therefore be necessary.

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Key points

- Think of fish vision from the fish's perspective rather than from a human's.
- The eyes of fish are diverse, each species is different.
- Eyes develop as fish grows (larvaevs.adults). Take into consideration that bigger fish have higher resolution.
- Fish live in a constantly changing environment, thus their vision have a high degree of plasticity.
- Different wavelengths are focused at different distances from the optical system. Multifocal lenses can see several colours focused on the retina at the same time. Such lenses are found in many vertebrates. However, humans are the exemption.
- Light and dark adaptive states are achieved by pigment migration through the retina.
- Visual speed is temperature dependent.

Discussion/questions

No time for questions.

8.3.2.6 Keynote 6 (Pillar 6)

Value and limits of the catch-comparison method to test the effect of LED lights on fish behavior in trawls (Valentina Melli*and Junita D. Karlsen)

Abstract

Several factors affect species behaviour inside trawls. For this reason, gear designs which aim at exploiting behaviour to reduce bycatch often obtain unexpected results. This is particularly true when Light Emitting Diodes (LED) are used as behavioural stimulation due to the general lack in understanding on how species react to artificial lights. While expectations and experimental designs would benefit from studying how the different physical parameters of artificial lights affect species responses in laboratory conditions, catch-comparison sea trials with twin-rig trawls are necessary to investigate if lights can be efficient bycatch reduction devices. By using this method, it is possible to investigate species responses to the LED lights during the fishing process, under the summed effect of all the stimuli involved and the variable conditions typical of fishing activities. Using as an example a trial conducted on the *Nephrops* (*Nephrops norvegicus*) directed mixed trawl fishery in the Skagerrak Sea, involving the application of LED lights to improve species vertical separation into two compartments, we discuss the advantages and limits of the catch-comparison method in testing the efficacy of LED lights as bycatch reduction devices.

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Key points

- There are a lot of unknowns when designing a study using artificial light, including what is the best light colour to use, which light intensity work best, how many lights will give the response we aim at, and what will be the best position.
- What we do know is the catch-comparison method. Using a trawler with a twin-rig, there will for the two gears towed in parallel be the same:
  - catch composition
  - environmental conditions
  - technical conditions, except for the use of light

  Thus, any differences in fish responses between the two gears will be due to the only variable that is different, i.e. the artificial light.
- When interpreting fish responses, it is suggested to distinguish between reactions, which can be defined as objective observations of fish responses, and behavior, which imply a causal explanation behind the fish response.

Discussion/questions

The use of laboratory experiments versus field experiments was discussed. The suite and interaction of stressors the fish experience during fisheries cannot be reproduced in the lab. A combined approach of the two methods can be beneficial, i.e. stepwise test of the different stressors in the lab to understand the mechanisms behind fish responses alternated with feedback on the fish response during fishing in field experiments.

8.3.3 Workshop Discussions

One TG goal was to collectively identify and address common experimental, technological, and analytical challenges. To do this, on the first day of the TG meeting, each participant identified a challenge related to these three themes (written on cards). That evening, the TG conveners met to synthesize the information and select, for each of the three themes, a common challenge presented by the participants. On the second day, participants were randomly divided into three equal groups. Each group discussed the three questions, with one discussion lead and rapporteur assigned to each question. The three discussions were:

1. Experimental Challenge: What environmental parameters should be measured/ data collected? How can these be measured? (John Wang, USA, discussion lead; Valentina Melli, Denmark, rapporteur)
2. Technological Challenge: What are the best ways to observe behaviour in a dark environment? What are some existing techniques/ experimental design? (Dan Watson, UK, discussion lead; Martin Oliver, Ireland, rapporteur)
3. Analytical Challenge: How do we describe responses to light/ behaviour objectively? Create a list of behaviours and define them. (Mike Breen, Norway, discussion lead; Paul Winger, Canada, rapporteur)

8.3.3.1 Experimental Challenge Summary

What environmental parameters should be measured/ data collected? How can these be measured?

For this discussion, each participant was asked to briefly describe their primary research focus with respect to fishery, environmental conditions, and target species (see table below). The discussion included researchers with substantial experience in this field and those who had never worked with artificial lights in this capacity. In addition to the research listed below, other areas of expertise among the participants included conducting behavioural laboratory experiments with fish (cod, haddock), producing a 'glowing net' for snow crab and fish, and fish and human vision (ecophysiology).

Fishery Type	**Species**	**Specifics**
Gillnet	Marine mammals	Coastal
	Marine turtles	Mainly daytime activities
Pots	Cod	Coastal/deep waters
		Both day and night-time
	Snow crab	Deep waters
		Both day and night-time
		Extended soak periods
Demersal trawl	Fish	Coastal/deep waters
		Both day and night-time
Nephrops/ shrimp trawl	*Nephrops*/ Shrimp	Coastal/deep waters
		Both day and night-time
		Muddy bottoms - High turbidity
Laser trawl	Shrimp	Deep water
	Fish	Night-time
		Variable turbidity
Purse-seine	Fish	Day and night activities Observed higher survivability during daytime activities
Jigging	Squid	Pelagic
		Night-time
		Powerful light as lures
Other areas of expertise		
Laboratory experiments	Fish (Cod, haddock)	Behavioural ecology
Glowing net producer	Snow crabs, fish	Promising results with passive gears Investigation of potential application for active gears
Vision	Fish, Human	Ecophysiology

The discussion focused on identifying environmental parameters that the participants wish they could and that they had measured, and comparing the tools used to do this. Several environmental parameters were identified as important to measure when applying artificial lights to fishing gear and/or in general when studying species behavioural interactions with gear components (see table below). The majority of these parameters were consistently identified by each of the three groups. One notable insight was that different behaviour states will influence how the animal is affected by these environmental parameters. For example, an animal's stress level in a trawl is substantially different during the early stages of the catching process (e.g. at the trawl mouth) compared to inside the extension and codend where exhaustion and crowding can facilitate a 'panic' reaction. It was also noted that not all trawls are the same, and that the application of lights in different part of the trawls should not be compared as equals. For example, the level of turbidity can vary strongly throughout the trawl. Participants also pointed out that there are variables like vessel noise that can impact behaviour and need to be considered in addition to environmental parameters. Lastly, it was highlighted that it is important to understand the variables that influence the background/ contrast for the artificial light (e.g. ambient light).

Environmental parameter	**Comments**
Temperature	
Depth	
Turbidity	Interacts with light in 3 ways: absorption, scattering, and transmission
Light level - underwater	Both in the area with artificial lights and ambient light level (e.g. for an animal in a trawl, must consider ambient light level for pre-fishing activities, ambient light level at the headline, and artificial light at the point of interest)
Ambient light level - surface	Maybe more useful and comparable than "time of the day", "weather conditions", or "position"
Water colour	Phytoplankton abundance (for example)
	This is important because it affects the light spectrum and this information is not carried by turbidity measurements
Salinity	Together with turbidity affects laser beams
Precipitation	Prior and during experiment
Sediment	The composition of the sediment (size of particles) determines the level of light scattering (this is particularly important with active gear because it determines the extent of the sand cloud generated)
Water current	Intensity and direction
	It affects gear dynamics
Time of the day/ geographic coordinates	
Moon phase	Has a strong influence on species behaviour and contributes to nocturnal light level
Season	Affects prey availability, hunger, level of activity, etc.
Weather condition	Affects gear dynamics
Sounds and vibrations	Additional stimuli that can affect the behavioural response observed

The discussion on tools to measure environmental parameters focused on the main parameters of interest: turbidity and light level. The groups highlighted that the priority is to identify a viable method to measure these two parameters to improve comparability among studies. Additional discussion topics are detailed in the table below.

Environmental Parameter	Tool/Method	Limits and Challenges	Suggestions/Comments
Temperature, depth, salinity	CTDs (Star Oddi, etc.)		
Turbidity	Secchi disc	Maintaining a stable angle of the camera while fishing	Black and White extra sensitive cameras (ideal in turbid conditions)
	Cameras/GoPro and objects of known distance	Sand cloud in the trawl prevents video observation	Low deep red light, not perceived by many of the species of interest
	Scatterometer (e.g. Wet lab)	Getting in loco measurements while fishing	See reference: Hannah, R. W., and Blume, M. T. (2016). Variation in the Effective Range of a Stereo-Video Lander in Relation to Near-Seafloor Water Clarity, Ambient Light and Fish Length. Marine and Coastal Fisheries, 8(1), 62-69.
Light level	MK9 tags (Wildlife Computers) calibrated with a PAR sensor	Flat surface needed; several tags needed to detect light from different directions	
		Ambient light level dominant with respect to values produced by commonly used LED lights	
		Difficult to determine significant differences between gears	
	Portable PAR sensor	Not sensitive enough to detect differences between gears	
		Doesn’t provide any information on the spectral quality of the light	
	Spectrophotometer	Not many options applicable to active fishing gears	Viable option for passive fisheries

For this 'experimental challenge' discussion, the groups concluded that, currently, we do not know what variables are critical. For this reason, we have to measure as many environmental parameters as possible. Questions remain regarding whether environmental parameters should be selected according to the target/bycatch species, or whether they are all important across species. If the latter is true, there are remaining questions as to whether this is too many data to process and whether it can all be processed meaningfully. The discussion, for all three groups, built up to a final question: how does one incorporate these environmental data in the analyses? The recommendation from this discussion was to revisit in 2019 and follow up on these unanswered questions.

8.3.3.2 Technological Challenge Summary

What are the best ways to observe behaviour in a dark environment? What are some existing techniques/ experimental design?

Fishery Type	Species	Case Study	Comments
Demersal	*Nephrops*	Cameras mounted in trawls	Muddy sediment
	Haddock		Low light
	Whiting		Poor visibility
	Cod		Challenging conditions
	Cod	Cod put in cage and subjected to wind-farm noise to observe reaction	
	Krill	Using cameras to assess krill interaction with nets in crystal clear Antarctic waters	
Other		Acoustic tagging for fish movement studies	
	Snow Crab	Observing snow crab reactions	Lights in different orientations and colours with different efficiencies
	Mixed fishery	Inclined panels and grids (with and without lights), assessing fish reactions	
	Seal	Seal predation of gillnets	
		Fish orientation in gears	Still flash photography with and without additional lights
	Cod/Krill	Cod eating krill in pots	Cod unaffected by light, whereas krill attracted
	Giant squid	Light (as bait) used to cause interaction for observation	

For this discussion, the groups were asked a series of questions, focused on: (1) case studies/ motivation; (2) technology-in-gear insights; (3) broad technology insights; and

(4) computer vision and footage analysis. Group discussions were transcribed on post-it notes, aggregated, grouped, and synthesized.

Case Studies/ Motivation

Each group discussion began with participants describing the experiments they had done related to using artificial light, what the focus of their research was, what they tried to achieve, and what technology was used to accomplish the research. A summary is provided in the table below.

Technology-in-Gear Insights

Participants were subsequently asked about their experiences deploying various observation technologies in fishing gear. This included a description of the types of observations they were trying to achieve (see table below). It was noted that technology purchased "off-the-shelf" could be far more expensive than custom-built gear depending on access to suppliers/producers.

Gear Type	Technology	Comments
Gillnets	Go-Pro Camera	Limited range of observations, meaning no clear way of observing massive gears (e.g. 1.5 meter visual coverage over a 2km gillnet)
Traps	Didson	Can be used to differentiate species over longer range (TBC)
	Aris	Can be used to differentiate species over longer range (TBC)
	Go-Pro	100s meters lead-in netting to trap so difficult to properly cover with a camera
Demersal trawl	Go-Pro Camera	What vibrations are being sent through the gear and affecting the observation technologies?
	Acoustic	Sediment can block vision of sensors
	Cameras	Ability to see which parts of the gear, BRD, mechanisms are actually affecting fish behaviour, better enabling tweaking of gears.
		How should the cameras be mounted?
		Enables observation of how mounted gear technologies (e.g. lights) perform in the field.

Wider Technology Insights

Additional comments made by participants about the use of technology to observe behaviour in fishing gear over all groups were aggregated (table below). Some additional insights include that it is important to consider the vision of the fish. [Note: the book "Light in Water" was recommended.] In particular, it is important to consider how camera lights affect behaviour. [Quote from a participant: "Putting a camera with lights into fishing gear is like driving into the Savannah with a flashing light and the stereo on full blast. Only things left are the stupid, the blind and the dead."]

Technology	Comments from Participants
Cameras/GoPro	Fisheye lenses can be useful but poor focus makes it hard to judge distances beyond 1m.
	Standard cameras can also be applied as back-ups to other trial devices.
	Vibration is an issue for GoPros.
	Most GoPros use modified casings for increased depth, batteries, memory and easier mounting.
	Cameras can cause eddies due to their presence, affecting fish swimming and reaction.
	GoPros can be used with IR by altering lens filter.
	Technology is advancing battery life and low-light cameras.
	Fish can react to cameras, do they affect fish behaviour mid-experiment?
	When filming at night, without lights, can't use cams below 100m.
	Calibration can be done in lab facilities before going out into the wild.
	First tows can be completed without caring about catch to ensure camera set up properly. Testing in environmental variables (e.g. saltwater) important.
CTD (Conductivity, Temperature, Depth) sensors	Live feed CTDs available.
	Also retrieval CTDs which are cheaper, smaller and easy to use (Star Oddi, etc.).
Real-time controllable, pointable lights	Useful as it's possible to turn lights on/off and direct them.
SWARM	Expensive £100k+. Long-range acoustic camera.
	Deployed in Antarctic for 1 year to watch krill.
Acoustic Camera	Can be deployed in multiple planes to view in 3D (better in 2D though).
	Good for static gears, not so good for dynamic.
	Bulky recording, limited battery/memory, expensive.
	Sediment can cause issues for optical and acoustic.
Low-Level White Lights	Real-time controllable.
	Can be used strategically to choose between influencing and observation of animals during experiments.
Flash Photography	Used for instantaneous capture of species distribution with "minimal" impact/disruption.
	Can fish react faster than strobe?
RFID	Useful for logging beginning and end locations of animal.
	Not useful for tracking route through gear.

	Two tags can cancel each other out, in particular if fish hold station near antenna meaning the system will not work correctly. Cameras can be used to validate results.
Echosounders, LI-DAR and Acoustic	Will LIDAR interact with species?
	What can LIDAR see through?
	Can LIDAR be used to recognize scale pattern?
	Can fish/organisms/porpoises/whales respond to the Didson? Frequency = 2000KHz
	Identifying fish with similar tails/physical characteristics can be really hard (e.g. rockfishvs.shad).
	Sometimes having to identify 6 different species of flatfish at once (difficult with these techs). Difficult to identify different species.
	How stable should the platform/mounting be for effective use of these techs?
	Didson Case Study: Salmon escapement in Alaska pollock fishery.
	Didson is quite large, not made for dynamic gear, expensive.
	Can these techs filter anything (e.g. sediment)?
	No lights required for Didson use.
Multibeam Sonar	
Acoustic Tags	Useful if light is too attractive to fish.
	Can be used to track fish motion around gears.
	Can knock-on effects of acoustic (e.g. sub-frequencies) cause reaction in animals?
Catch Comparison	Irish Sea trials using catch comparison backed up by video footage.
	Compartments to collect outcomes of trials.
	Use cameras to see if specific BRDs perform, counted after experiments (length, frequencies and weights).
	Impossible to know how fish are moving during trawl/experiment. Impossible to know which part of the gear/BRD is being effective.
	Process include counting, subsampling and weighing.
Red Lights	Requires low-light cameras.
	Light penetration is low. Ok for grids.
Surface light	Ambient illumination with cameras (limited to 100m range in water column).

Computer Vision and Footage Analysis

The discussion also included post-experiment analysis, with a particular focus on computer vision software (see table below). These programs were seen to lower the barrier to efficient analysis, especially given the often vast quantities of data that need to be parsed after an experiment is completed using cameras.

Technique	Comments
Image J	Computer vision software
Bait Cams + VLC	A huge amount of work to watch the resulting footage
VidSync	Computer vision software
Noldus – Observer XT	Able to mark individuals to track movement
IFREMER – Julien Simon has created a computer vision system	15 animal can be tracked even in trawl video (noisy background imagery due to meshes)
Student for post-film analysis!	6 weeks of footage means a lot of follow-up work and terrabytes of storage may be required to capture the footage

For this 'technological challenge' discussion, the groups looked at barriers, motivations, and frustrations related to technology. Topics of the discussion included what equipment has been used, how to process the data collected, and how to use existing light in the environment to avoid using artificial light to illuminate the camera field of view. With the latter point, the group discussed how to avoid secondary effects of the experiment. For example, it is important to consider differential light perception among species. Namely, how the artificial light affects the bycatch species could be different from how it affects the target species. An example of this "chain of effects" was discussed: cod predation on krill in pots. In this case, cod ignored the presence of lights, but the krill were strongly affected, in turn affecting cod presence (increase). As evidenced by the tables generated (above), there is an incredible range of ways to observe behaviour, but 'best practices' are not yet known. The recommendation from this discussion was to revisit this topic in 2019.

8.3.3.3 Analytical Challenge Summary

How do we describe responses to light/ behaviour objectively? Create a list of behaviours and define them.

For this discussion, the groups considered qualitative versus quantitative descriptions of behaviour. While both can certainly be objective, the groups recognized there has been a trend toward increasingly quantifying animal behaviour during the capture process. In this context, the groups discussed how early observations of fish behaviour during capture, particularly in trawls, were initially qualitative (1980's), followed by the use of count data (1990's) and later advanced image analysis and statistical techniques (2000's). The value of today's quantitative methods is the ability it gives researchers to evaluate the variability of behavioural expression, between and within individuals. But this requires high resolution observation tools that do not modify the behaviour being observed, for example low-light sensitive cameras and high frequency sonars (or "acoustic cameras"); which was the subject of another discussion topic.

The need to avoid "anthropomorphism" was repeatedly highlighted. This is when one erroneously attributes human characteristics of behaviour to the animals being observed. It was recognized that fish are fundamentally different from humans – especially with regard to vision. Thus one should avoid terms such as "fear", "panic", or "anxiety" to describe the behaviour observed.

To further explore how to objectively describe behaviour, while avoiding "anthropomorphism", the question was asked: "what is behaviour?" This led to interesting discussions about what is practically observable by researchers (e.g. movement) versus what is not (e.g. increased heart rate). From this it was concluded that what one can most objectively describe are "activities" (e.g. swimming, including speed and direction) and how frequently these occur. The groups discussed how some behaviours are voluntary in nature (e.g. swimming, feeding), while others are autonomous reflexes (e.g. fast start, dorsal light reflex). In the end, the groups concluded that behaviour is the integrated expression of the status of the whole animal (i.e. its motivations, its perception of the world around it and its state of well-being); it is essentially "all of life".

More than objectively "describing behaviour", the groups also briefly discussed "why do fish do what they do?" The four classical behavioural/ethological questions of Niko Tinbergen were briefly reviewed: 1) what are the stimuli that cause the observed behaviour, 2) how does the behaviour change over the lifetime of the animal, 3) what is the adaptive function of the behaviour, and 4) how did the behaviour evolve over time? As fish capture researchers, it was recognized that we tend to focus only on the first two questions. While a better understanding of question three would give a more informed basis on which to begin to utilize/manipulate the animal's behaviour during the capture process; for example, by understanding why an animal is seemingly attracted by artificial light and thus being able to refine and optimize the stimulus we present.

One person aptly pointed out – "you need to know your animal". The point being, it takes time and effort (i.e. watching lots of video!) to learn the full range of behavioural responses that an animal/species can express, in any particular context, including their limits of perception (vision, hearing), limits of locomotion (speed, endurance), etc. Underpinning this is the need to understand the role of environment on the animal and how it modulates behaviour. Extrinsic factors such as temperature, turbidity, ambient light level, depth and the presence of conspecifics were discussed. The importance of intrinsic factors was recognized, such as fish size, hunger level and past experience. All of these things can modulate behavioural expression. For example, water temperature may not affect the detection distance of an approaching trawler (i.e. the distance at which a fish first hears an approaching trawler), but it could affect its reaction distance (i.e. the distance at which it chooses to respond), as well as the speed and distance it could swim in response to that auditory stimulus.

Finally, the groups discussed the fundamental differences between capture methods. The groups were quick to recognize that the stimuli perceived, and the behaviours, exhibited during capture by a bottom trawl, for example, are fundamentally different from those associated with luring a fish into a baited pot/trap.

In summary, when describing behaviour, one should try to objectively document the observed activities of the animal (including autonomous reflexes and cognitive behaviours), in context with the spectrum of stimuli the animal is potentially exposed to, as well as any likely modulating factors (both intrinsic and extrinsic).

8.4 Progress toward ToRs and Recommendations

8.4.1 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). The collected literature is uploaded onto the Sharepoint site of WGFTFB under the folder 'Working documents' and subfolder 'Light TG' under the meeting folder of the given year. 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 8.3.2). The TG community is notified about recent additions to the literature library. The library forms the basis for doing systematic reviews described in the next section (8.4.2).

8.4.2 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), reports and peer reviewed publications will be added to that database so that systematic reviews of the research can be made (ToR 1). This includes identifying 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, once the database has been finalized, the organization of it, along with summaries from TG workshop discussions, will be used to develop guidelines for conducting future research studies (ToR 3). The database will also be used to identify needed research and fisheries that might benefit from the application of artificial light (ToR 4).

8.5 Plan for 2019

At the 2019 ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) meeting in Shanghai, China, the 'Light' Topic Group of experts will meet for the second year. The goals of this meeting will be to: (*i*) welcome new community members; (*ii*) identify work on using artificial light for bycatch mitigation that was not previously presented at the 2018 meeting and new projects, and discuss ongoing research; (*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*) continue discussions of common challenges when using light as a selectivity tool; and (*v*) begin to explore the database of combined studies.

9 Topic Group: Factsheets on fishing gear selectivity and catch comparison trials (Facts)

9.1 Introduction

A WGFTFB topic group convened by Barry O'Neill (Denmark) and Jordan Feekings (Denmark) was formed and met on 6 and 7 June 2018 in Hirtshals, Denmark to develop a series of factsheets on fishing gear selectivity and catch comparison trials

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.

9.2 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 by-catch and discard issues that are being faced by the fishing industry.

9.3 Participants:

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9.4 Existing factsheets.

The group discussed the different types of factsheets that have been produced in recent years and in particular considered those associated with the EU funded Horizon 2020 project DISCARDLESS; those produced by SLU in Sweden; BIM in Ireland; and IMR in Norway. The participants were also aware of other factsheets (Belgium, France) in other countries but these were not discussed.

The factsheets could be simply classified as being of either 1 or 2 pages of A4. They were all of a more or less common format and had very strong graphical appearance, relying very much on figures and tables to describe the gear changes and explain the results. The main difference between the 1 and 2 page factsheets was the large increase of textual information that can be provided in the 2 page sheets.

The work being carried out by the 'GearingUp' project was examined. The main output from the GearingUp project is an interactive online tool which aims to collect information on different gear selectivity related trials. The current version is very standardized and does not have the possibility to incorporate any graphics, tabulated results and/or figures. While the GearingUp tool has good search facilities, it was thought that at present the output was very formulaic and that it is not possible to individualise or tailor it for specific circumstances. However, if this project succeeds in getting further funding it intends to incorporate graphics, in which case it is possible that its output could converge more with the other types of factsheets above.

It was decided, in order to 'futureproof' any possible link with the GearingUp project, factsheets developed as part of this topic group should endeavour to store the factsheet data in a spreadsheet format and in categories that are compatible with the GearingUp database. It is not thought that this would entail much additional effort to complete and indeed could be a useful checklist for factsheets.

9.5 Format and content.

The group agreed to follow the 1 page of A4 type of format that has been used in the DISCARDLESS project, and by SLU in Sweden, BIM in Ireland and ILVO in Belgium. These factsheets have a more or less similar format, and generally provide a brief description of the

i) the aim of the trials

ii) the target species

iii) where the trials took place and on what vessel

iv) a description of the gear modification/trialled and

v) the results

They have a strong reliance on visual content, using graphics, figures and tables and do not attempt to provide detailed descriptions of the gears, trials or results, but instead aim to highlight possible solutions/approaches and provide contact details (e-mail, web link, etc) where further details/information can be found.

The specific style and format the factsheets should have was briefly discussed. They could all have a uniform style and format; a similar style with perhaps different background colours for different institute/countries; or they could all be different except perhaps a constraint on size of 1 page of A4.

There was also a discussion to extend the remit of the factsheets to include the development of technologies and techniques that address bycatch and discard issues including those that improve discard survival. Up to now most factsheets have dealt exclusively with fishing gear selectivity and catch comparison trials, however this does not cover the full range of possible solutions that can be used to reduce discarding and the capture of bycatch.

It was also discussed whether there should be some method to classify the different factsheets based on the validity of the work. For example, a traffic light system, similar to what is used in ICES for the classification of a stocks status, could be used to denote whether the results have been published in scientific peer-reviewed journals (green), national reports (orange), or undocumented or anecdotal findings (red).

9.6 Producing factsheets.

As a trial to test the viability of producing factsheets on an annual basis, the participants decided to assemble some examples of trials and developments from their own fisheries. The PowerPoint factsheet template from the Discardless project was used, and during the course of a morning seventeen factsheets were prepared. Ten of these are on trawl gear selection or catch comparison trials, and the remainder are on gillnets, creels, suction dredges, purse-seines and discard survival (see in Annex 5).

Except for some minor editing after the meeting, all of these factsheets were produced during the topic group, demonstrating the feasibility of producing such factsheets on an annual basis at the WGFTFB.

It was proposed that the production of factsheets could be a rolling term of reference for WGFTFB. Two ways that this could be accomplished were that: (i) factsheets are prepared beforehand and submitted perhaps with or as part of the national reports or (ii) they are produced at the WGFTFB. With both these approaches there would be a need for a small group to edit the factsheets, to ensure they complied with whatever guidelines, style and format is agreed by the WGFTFB.

9.7 Dissemination and reach.

There is no point in producing these factsheets if fishers and gear manufacturers are not aware of them and they are not easily accessible. Hence, they need to be promoted, web based and available from a range of platforms (computers, mobile phones, tablets, etc). It was suggested that perhaps ICES could host them, but there were concerns that many fishers would not naturally go to and might be reluctant to use the ICES website. One of the attractive things with the GearingUp project and tool was that there were no obvious affiliations to any management body or scientific institute.

Language is also a major issue. Ideally factsheets would be available in as many languages as possible, however, there are going to be limitations and it was thought that in the first instance they should be produced in English and the language of the country/institute producing them. The FAO have also expressed an interest in translating them into Spanish and perhaps French which would further increase their reach.

It was also agreed that the factsheets would have a much greater impact if their geographical coverage was greater. To date, the majority of factsheets we are aware of are mainly from ICES countries, particularly European ones, but given that WGFTFB is a joint working group of ICES and the FAO there is clearly the potential to include factsheets from countries worldwide and develop a global repository.

9.8 Recommendations

The topic group recommends that a comprehensive trial run be held to produce factsheets for the 2019 WGFTFB meeting.

It is proposed that prior to the 2019 WGFTFB meeting:

- 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.

It is proposed that during the 2019 WGFTFB meeting:

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

10 Topic Group: "Contact Probability of Selective Devices" (Contact)

TG chairs: Daniel Stepputtis, Bent Herrmann

10.1 Summary

The main purpose of this topic group was to increase the awareness of successful contact between fish and selectivity device (as basis to make the selectivity device working) and to discuss the work related to contact probability. The topic group met three times during WGFTFB (2015, 2016 and 2018), whereas in 2018, the work of the topic group was summarized. During the two meetings of the topic group in 2015 and 2016, a number of examples were given, were contact probability was a) investigated and estimated and b) played an important role in the functioning of successful selectivity devices or c) was a likely reason that a developed selectivity device/concept did not worked as desired. Therefore, a large fraction of the topic group meeting was spent to show and discuss intensively different devices/concepts/underwater video recordings etc. The topic group participants stated during and after the meeting that especially these intensive (and mostly informal) discussions made the topic group meeting a success. This is impressively shown in the number of scientific, peer reviewed papers dealing with contact probability, which were published by topic group members in recent years (see chapter 10.5).

As basis for further discussions, a definition of "contact" (including "effective contact" and "qualitative contact") was developed (see chapter 10.4)

The main aim of the final report of the topic group is to provide an overview of studies that have explicit considered contact probability with selection devices to researchers and gear technologists (see chapter 10.5).

The topic group was officially suspended after the ICES WGFTFB-meeting in 2018.

10.2 Terms of reference

1) Summarize current and past work in relation to contact probability

2) Discuss and describe methods (experimental and statistical) to investigate and quantify contact probability

3) Investigate and make recommendations on how to improve contact probability in selective devices, including

> 3a) Identification of gears and selective devices with suboptimal contact probability (preferably based on current gear trials from group members)
>
> 3b) Discussion on potential causes and solutions
>
> 3c) Recommendations on experimental/theoretical work to understand and improve the contact probability

10.3 Narrative

Over the past decades, numerous selective devices have been developed and tested. Many of them did not fulfil expectations and even those that are now being used can probably be improved.

A key factor influencing the effectiveness of selectivity devices is the probability of a given specimen to contact the specific selection device. Nevertheless, this factor was often not sufficiently considered when developing selective devices prior to the establishment of the topic group. Additionally, few selectivity studies have quantified the contact probability of these devices although it underpins how they perform and how they can be improved (see also Figure 10.1)

Consequently, it was highly relevant for the further development of sustainable fisheries, especially in the light of discard ban, single and multispecies selectivity and potentially also for balanced harvesting - in a wider sense to foster the discussions and exchange of knowledge regarding contact probability. Therefore, a WGFTFB topic group of experts was established in 2015 to investigate, understand and improve the contact probability of specific selective devices (e.g. grids, netting). One aim of the TG was to **document** and evaluate current and past work regarding the influence and improvement of contact probability. This included studies from a wide range of scientific fields, such as selectivity, behaviour, hydrodynamics and gear design. Special attention was given to investigating how to improve the performance of gears and selective devices with suboptimal selective properties. Additionally, this topic group aimed to increase the awareness of successful contact between fish and selectivity device (as basis to make the selectivity device working) and to discuss the work related to contact probability. Therefore, a large fraction of the topic group meeting was spent to show and discuss intensively different devices/concepts/underwater video recordings etc., as well as to discuss past, ongoing or future studies and new methodologies.

During the first two topic group meetings (Lisboa, 2015; Mexico, 2016), the participants presented a large number of examples, were contact probability was a) investigated and estimated and b) played an important role in the functioning of successful selectivity devices or c) was a likely reason that a developed selectivity device/concept did not worked as desired.

The topic group participants stated during and after the meeting that especially these intensive (and mostly informal) discussions made the topic group meeting a success and influenced future scientific work related to selectivity devices. This is impressively shown in the number of scientific, peer reviewed papers dealing with contact probability, which were published by topic group members in recent years (see chapter 10.5).

The objective of the final meeting in 2018 was to summarize and document the work of the group.

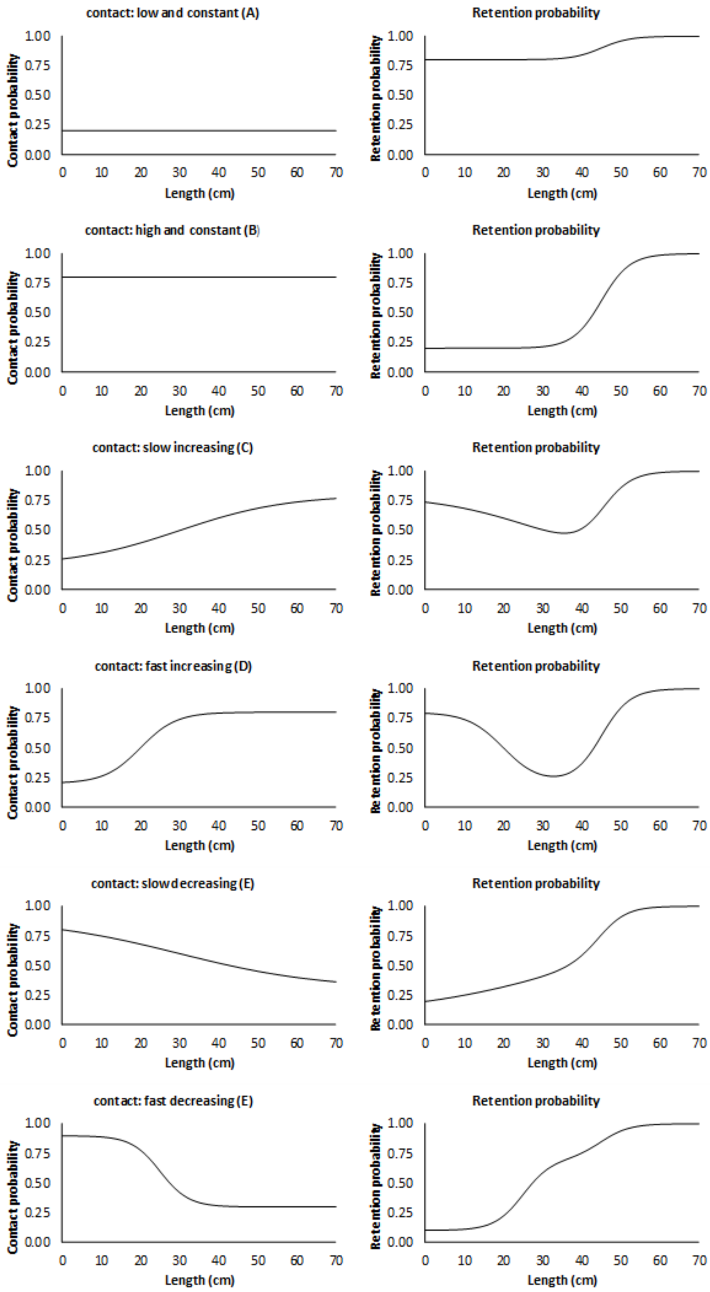

Figure 10.1: Schematic presentation of the influence of contact probability (left column) on the retention probability/selectivity curve of selective devices (right column). The retention probability is the combination of a (theoretical) standard sigmoid selectivity curve of the selection device with the given contact probability. Please, note the significant influence of contact probability on the shape of the final retention probability. Figure is prepared by Bent Herrmann.

10.4 "contact" concept

During the discussions, it became clear that there is no agreed understanding of the general concept and definition of "contact" (including "effective contact" and "qualitative contact"). Therefore, this TG tried to set a basis and common understanding when developing proper definitions.

The **contact** is the probability of a given specimen to contact the specific selection device and leads to a size dependent escape probability through the selection device (e.g.

grid, net) which is relevant and for which we can estimate the value. With this definition, a fish that makes physical contact with the device but does it with a very poor orientation for escapement through the device will be accounted as not making contact (contact = 0).

This basic definition did lead to the discussion about specific examples for reason for lack of contact. For example:

a) Fish get in (physical) contact with the grid, but due to some reasons (not selective properties of the selection device) it is not able use the device, e.g. due to

a. wrong orientation to the selective device, e.g. sliding along a grid

b. High water flow, reducing the time of escapement trials

b) Fish try to use the selective device but is able to swim out and in (and out and in and out and in)

Both examples show that the basic definition (and the methods we use to calculate contact does not take into account the complex structure of processes which can result in the final contact probability (e.g. in-out-in-(out) is measured as binomial event). Therefore, an improved knowledge of contributing processes can lead to a better understanding of the entire process as basis for the improvement of the gear. Additionally, this process can be potentially influenced by a number of parameters which are seldom taken into account in gear selectivity investigations. These parameters include:

1. Gear related

a. Design of gear / selection device

b. Movement of codend/selection device (e.g. important for T90 vs. T0)

2. Fishing process

a. Depth

b. Catch volume

c. Water flow

3. Environment

a. seasonal effects (see below abstract from O'Neill et al.)

b. temperature

c. biology of fish (e.g. condition, maturity status)

d. Turbidity

e. Light

4. Behaviour of specimen in relation to the gear

10.5 Overview of studies considering contact probability

The main aim of the final report of the topic group is to provide an overview of studies that have explicit considered contact probability with selection devices to researchers and gear technologists (see reference list in chapter 10.6).

The table lists studies that

1. deals with similar questions/problems before, such
    a. selection devices (grid, square mesh panels, other net panels, upper/lower codend, outlets)
    b. use of guidance/stimulation (guiding panels, mechanical stimulation, optical stimulation)
    c. species-specific contact probability
    d. contact probability in relation to fishery type and fishing area
2. used different experimental methods for collecting information on contact probability for selection devices, such as
    a. single cover experiments
    b. multi cover experiments
    c. paired experiments (with control, without control)
    d. combination of covered and paired methods
3. have used different approaches for modelling/quantifying contact probability for selection devices, such as
    a. Structural modelling with length independent contact and contact size selectivity
    b. Structural modelling of length dependent contact and contact selectivity
    c. Modelling contact alone

Additionally, few summary plots were given (Figure 10.2 – Figure 10.3). In Figure 10.2, the number of studies that explicity considered contact probability is given for different years. It can be seen that after initial discussions about this topic group (at WGFTFB-meeting 2014) and the first meeting in 2015, the number of studies increased significantly in 2016.

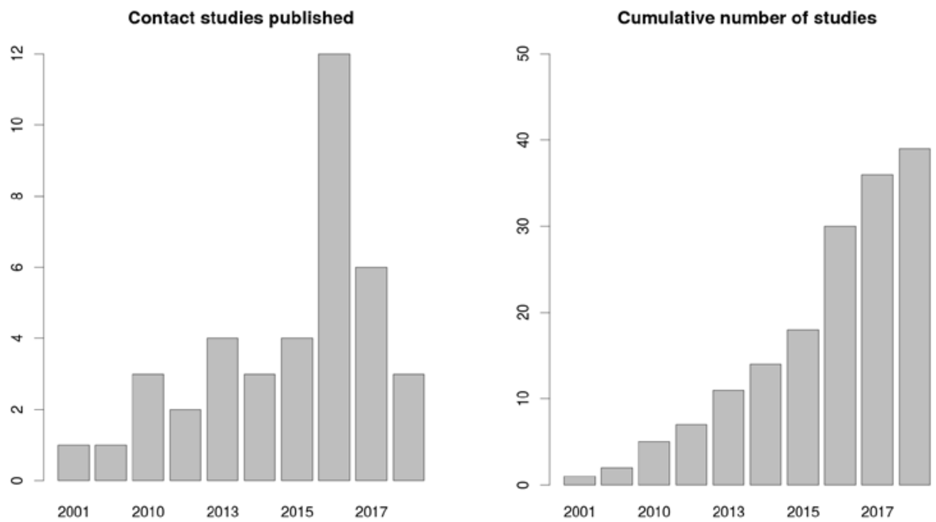

Figure 10.2: number of studies that have explicit considered contact probability with selection devices in different years.

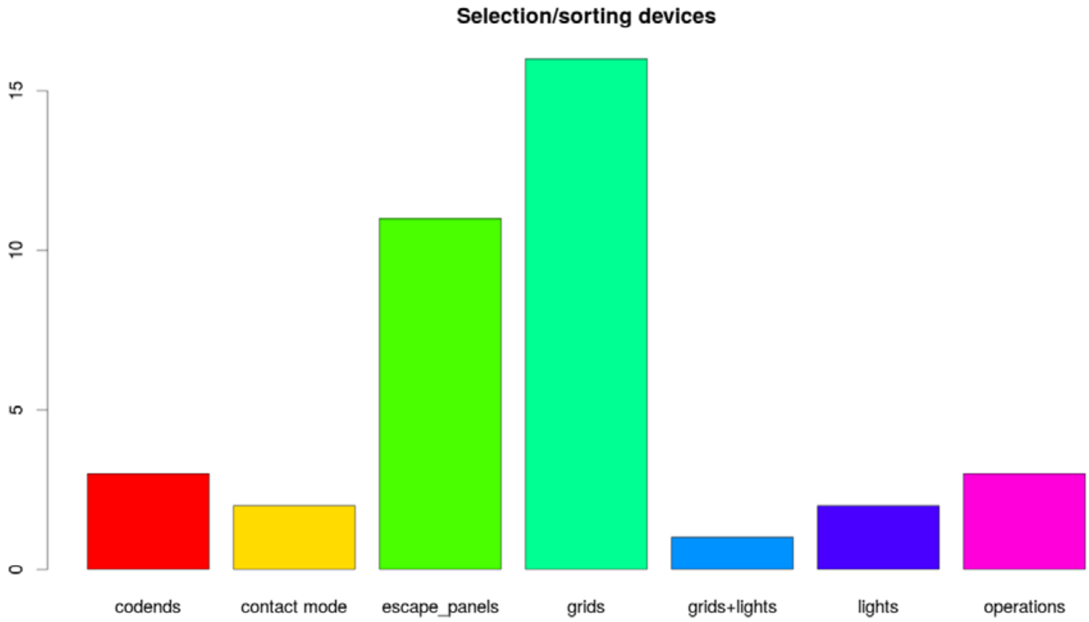

Figure 10.3: number of studies that have explicit considered contact probability with selection devices categorized regarding the type of selection device.

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10.1 Future work and recommendations

The work of this topic group was discontinued after the 2018 meeting of ICES WGFTFB.

10.2 Annex: Individual Presentations

A summary of presentation, given during the TG-meeting in 2015 and 2016 will be given. Due to the different strategy for presentations and discussions in both years, the abstracts will be given for presentation in 2015 and summary slides for presentation given in 2016.

10.2.1 Individual Presentations 2015

Can square mesh panels inserted in front of the codend improve size and species selectivity in Mediterranean trawl fishery?

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The size selection of Trachurus trachurus (Atlantic horse mackerel), Merluccius merluccius (european hake), Mullus barbatus (red mullet), Trisopterus minutus (poor cod), Illex coindetti (broadtail shortfin squid) and Parapaeneus longirostris (deep-water rose shrimp) has been evaluated for a typical Mediterranean bottom-trawlnet equipped with the 50 mm square mesh panel placed in front of the 50 mm diamond mesh codend. The purpose of this study was to investigate if a square mesh panel mounted in the upper panel in front of the codend could improve size and species selectivity in the fishery. The results showed very poor release efficiency through the square mesh panel. When the selectivity of the experimental gear was compared with the estimated selectivity for the "codend alone" setup, no significant difference in selectivity between the two setups was found. The low release efficiency of the square mesh panel was caused by the lack of fish making contact with the panel during their drift toward the codend. Insufficient contact with the selection device was thus found to represent a major challenge for obtaining improved size selection by integrating a square mesh panel in the upper panel ahead of the codend.

Contact efficiency for lateral square mesh panels in a Spanish otter trawl: Does the lateral position enhance the fish contact probability?

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Square Mesh Panels (SMP) are often integrated into trawl sections ahead of a diamond mesh codend in an attempt to improve release efficiency of undersized individuals of some species. Often these release panels are integrated in the upper panel of the trawl.

This is the case for some trawl mixed fisheries in western European Atlantic waters, where a diamond mesh codend with 70 mm mesh size can be applied conditioned that a SMP with at least 100 mm mesh size is integrated into the upper panel ahead of the codend. One of the main purposes of this SMP configuration is to avoid catches of undersized hake for which the 70 mm diamond mesh codend is known to have insufficient release potential. The main requirement for these SMP's to work efficiently it that a large fraction of fish i) notice the presence of the selection device in the top panel, and ii) react to the presence of the SMP altering their swimming direction upwards to encounter it. However, experimental fishing studies testing the mentioned SMP configuration has shown very low release efficiency for different species, such as hake (Merluccius merluccius). Some of those studies have shown that most of the hake simply do not make contact with the square mesh panel in this position during their drift towards the codend. Based on these poor results we designed and tested a new selective device named SLEP (Side Long Escapement Panels). The novelty of the new gear design is the position of the SMPs as they are fitted into the lateral sides of the aft part of the belly section. This position for the SMP's was selected based on informations provided by fishers collaborating in the design stage, who in their normal fishing activities observed that a large proportion of fish meshed in the netting when they pull the gear up are found in the sides of the gear. Such observations indirectly indicate that many fish come into contact with the netting at the position the SLEP was finally positioned. Contrary to inserting SMP´s in the top panel, the effectiveness of this device does not rely on changes in fish swimming direction under the presence of the SMP's, but on using the longitudinal swimming path towards the codend expected in normal catch process. The SLEP concept is completed by the insertion of two net pieces forming an V-shaped panel in the belly section, with the aim of guiding fish to the sides to increase the fish contact likelihood with SLEP further.

SLEP was mounted and tested in a Demersal Otter Trawl commonly used in the trawl fishery operating in Divisions VIIIc-West and IXa-North (OTB_DEF_55), targeting a mixed of demersal species including Anglerfish (Lophius spp.), Hake, Megrim (Lepidorhombus boscii) and Nephrops (Nephrops novergicus). The fishery is known to present high discard rates, estimated to be between 30%-60% of the total catch. By species, the high discard values for Hake juveniles have been identified as a key factor causing the failure of this species recovery plan (COM (2011) 260; UE 2005). The experimental sea trials were carried out from May 21th to 25th onboard the vessel "Nuevo San Cibrán", a 27.9m, 490HP otter trawler; chosen for being a representative vessel of the fishery. Two 5m long PE netting covers with 40mm mesh size were attached to the sides of the belly where to retain all fish escaping trough SLEP, while the codend selectivity was avoided by using a small mesh cover. The sea trials resulted in 13 valid hauls, and the two compartment collected data were analized using a structural model implemented in SELNET. Based on the data collected we quantified the contact probability, the fraction of individual fish which during their drift towards the codend came into contact with the square mesh panels. The analysis revealed that 81% Hake, 61% Norwegian lobster , 26% Four-spot Megrim and 38% Blackmouth catshark (Galeus melastomus) contacted SLEP. Thus the contact probability for the square mesh panels when integrated in the side panels by far exceeded that found by others when integrated in the top panel. This study was carried within the project "Desarrollo y experimentación en campaña de un arte selectivo para la pesquería de arrastre de litoral Cantábrico noroeste" funded by the Spanish Ministerio de Medio Ambiente y Medio Rural y Marino.

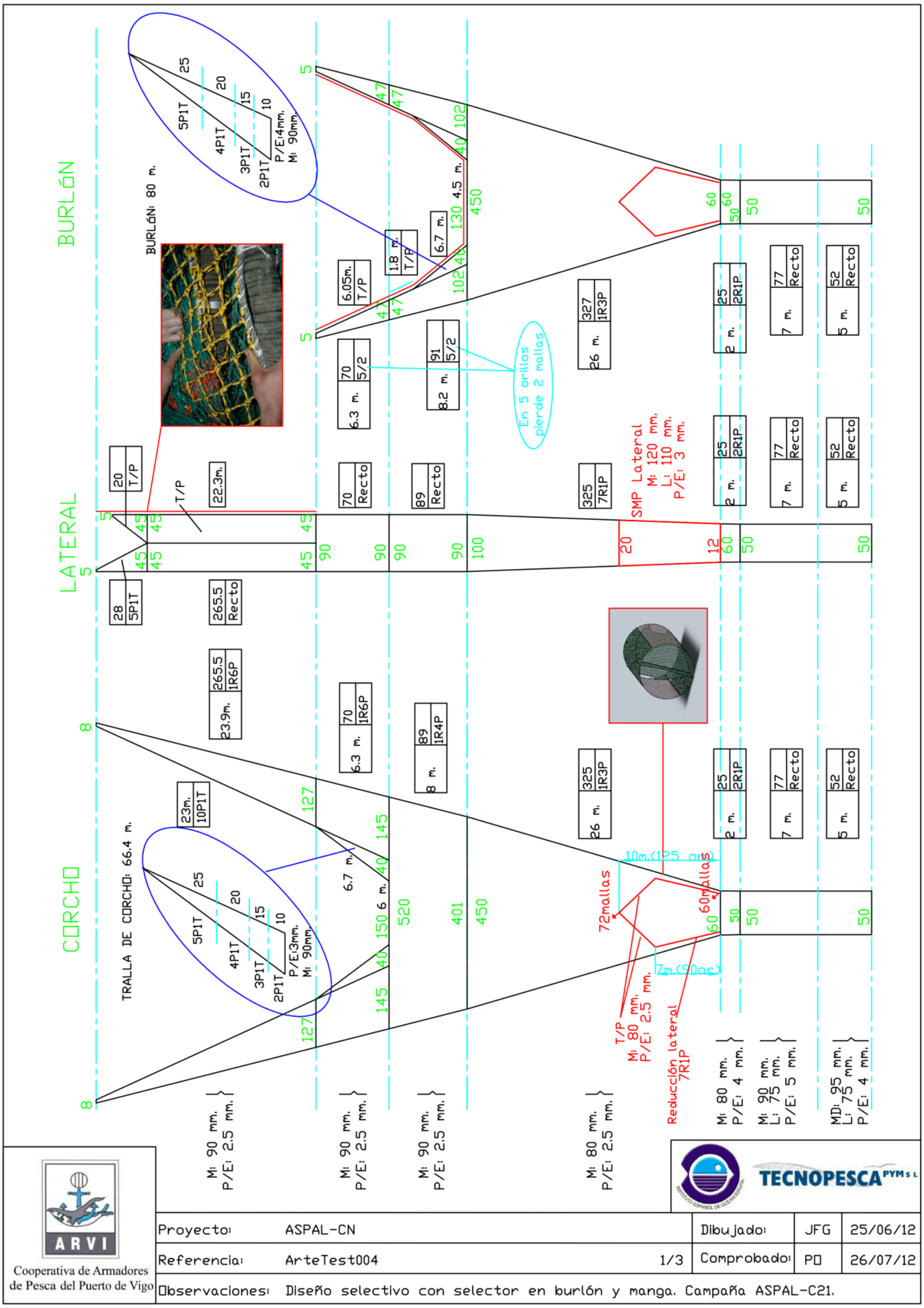

Figure 10.4: drawing of net including of SLEP

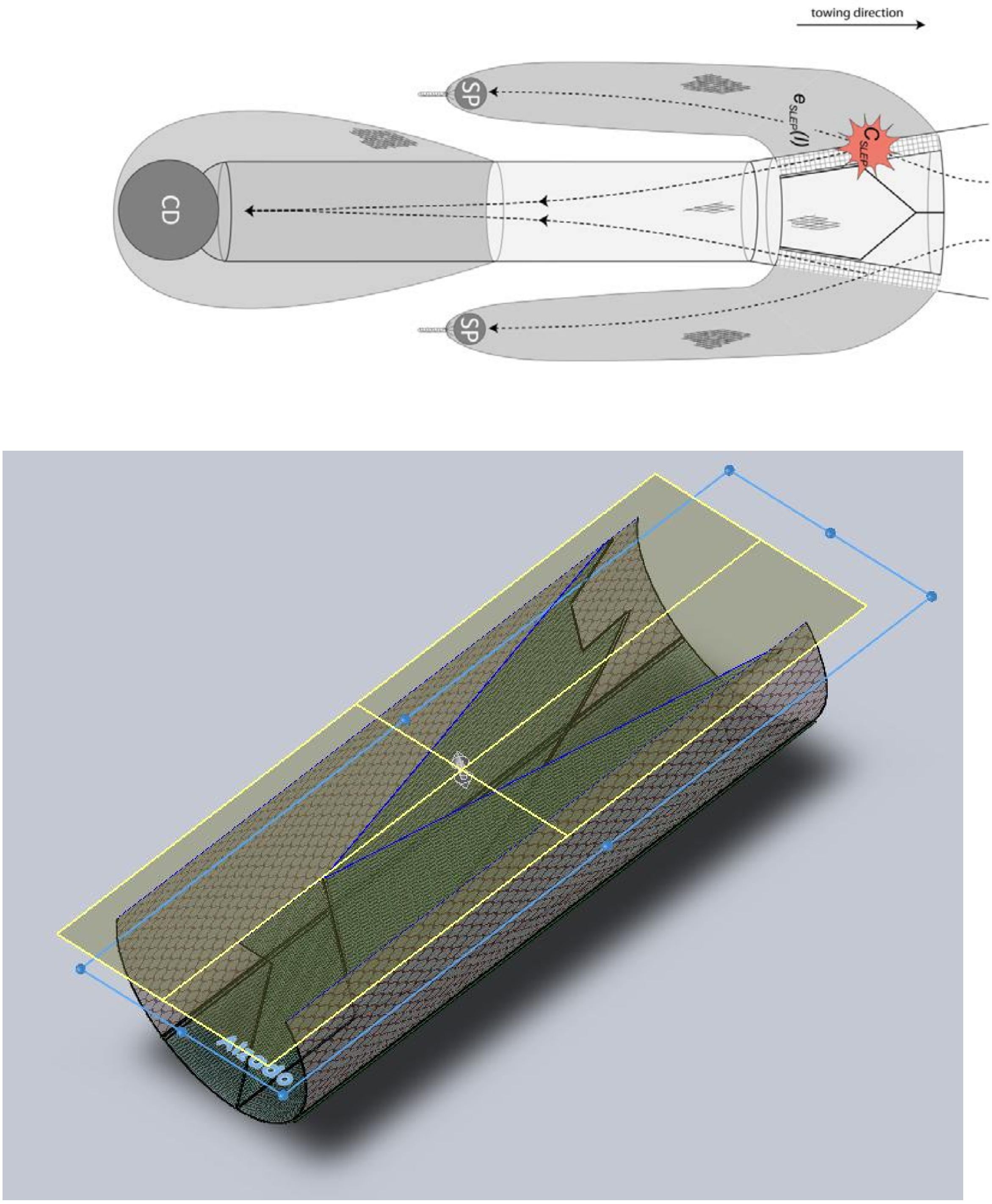

Figure 10.5: schematic drawings of SLEP

Contact probability of square mesh panels: Evidence of a seasonal effect for haddock.

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A recent meta-analysis of haddock selectivity developed a structural model of the dual process of square mesh panel and codend selectivity. The model takes into account the codend selection, panel selection and the contact probability of haddock with the codend. Individual-haul estimates of the 50% retention length (l50) and the selection range (SR) from 40 sets of trials were related to explanatory variables such as mesh size, twine thickness, panel position etc. The results show that panel contact probability has a seasonal component and is greatest during November and January and least between May and July, periods which broadly coincide with peak and poor haddock condition.

Here we explore these results further and consider the implications these may have for fisheries management.

Improving escape panel selectivity by active stimulation of fish behavior

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The efficiency of escape panels inserted in trawls relies on fish actively attempting to escape through the panel. Several studies however indicate that most fish drift towards the codend, passing beneath the escape panel through which they easily could have escaped, without making contact with the panel. For such panels to be efficient, the contact probability needs to be improved. In this study, we investigate to what extent we can improve the panel efficiency by actively stimulating the escape behaviour of fish. We compare the performance of two identical panel sections using the covered codend method in a twin trawl system, one with and one without a stimulation device. We took full advantage of the experimental setup using a new coupled analysis method to explicitly quantify the improvements in contact probability and release efficiency for the escape panel. The results demonstrate that active stimulation can significantly improve the contact probability and release efficiency for cod (Gadus morhua), hake (Merluccius merluccius), saithe (Pollachius virens), whereas no effect was found for plaice (Pleuronectes platessa) and Norway lobster (Nephrops norvgicus).

Could T90 be the solution for size selectivity in the Belgian beam trawl fishery?

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In an effort to improve the selectivity of beam trawls targeting flatfish, codend size selectivity of three flatfish and two roundfish species were compared testing 80 mm diamond-shaped mesh (T0), versus 80 mm mesh turned 90^{0} (T90). The results demonstrate that the T90 codend significantly increased size selectivity for the two roundfish investigated, whiting (Merlangius merlangus) and pouting (Trisopterus luscus), and significantly decreased size selectivity of the three flatfish, sole (Solea solea), plaice (Pleuronectes platessa), and dab (Limanda limanda). Models that considered contact probability, the fraction of fish that make sufficient contact with meshes required for size based selection, provided the best model for four of the species with T90, and one species with T0. Lack of adequate contact with the T90 meshes could be a result of the combined effects of increased flow through the T90 codend due to T90 meshes remaining more open than T0 meshes during towing, and the relative high towing speeds of beam trawls. The advantages of using a T90 codend in a beam trawl are discussed for the Belgian beam trawl fishery.

T0 T90

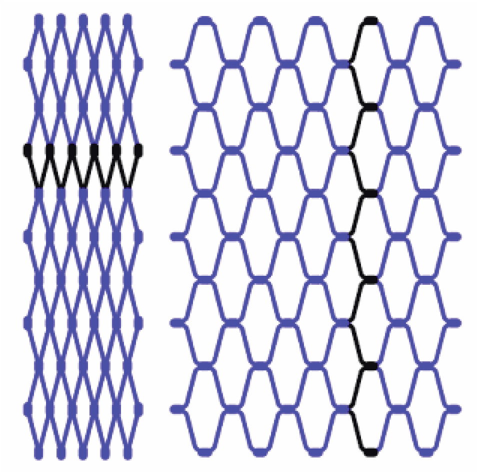

Figure 10. 6: T0 (left) and T90 (right) netting

Table 10.1: Overview of catch data

	Sole		Plaice		Dab		Whiting		Pouting	
Codend	T0	T90	T0	T90	T0	T90	T0	T90	T0	T90
No. of hauls	15	15	15	15	15	15	14	13	14	14
No. in codend	783	911	473	580	764	779	1007	131	361	129
No. in cover	1159	1043	134	52	353	227	102	788	74	327
Min. length (cm)	8	4	9	7	6	6	12	11	9	9
Max. length (cm)	39	39	42	51	39	35	40	41	30	29

Table 10.2: AIC values for fit of models.

		Logit	Probit	Gom-pertz	Richard	CLogit	CProbit	CGom-pertz	CRichard
Sole	T0	2197.08	2204.22	2247.56	2177.55	2164.19	2161.49	**2157.47**	2160.08
	T90	1938.38	1965.01	2073.15	1922.54	1890.78	1898.08	**1874.92**	1877.66
Plaice	T0	**439.98**	443.33	444.93	441.12	441.65	445.33	443.98	443.12
	T90	189.34	191.33	215.41	186.78	183.95	185.50	**183.88**	185.74
Dab	T0	1108.15	1116.82	**1106.87**	1108.24	1110.15	1118.82	1108.25	1110.20
	T90	469.95	478.57	557.47	442.51	436.58	**435.33**	440.30	437.74
Whit-ing	T0	**611.48**	612.05	611.67	613.43	613.43	614.05	613.45	615.43
	T90	**568.19**	569.99	579.38	569.95	569.46	568.39	569.24	570.89
Pouting	T0	**315.01**	315.28	315.25	317.01	317.01	317.28	317.12	319.01
	T90	391.49	393.15	395.97	393.44	393.38	394.68	**391.46**	393.48

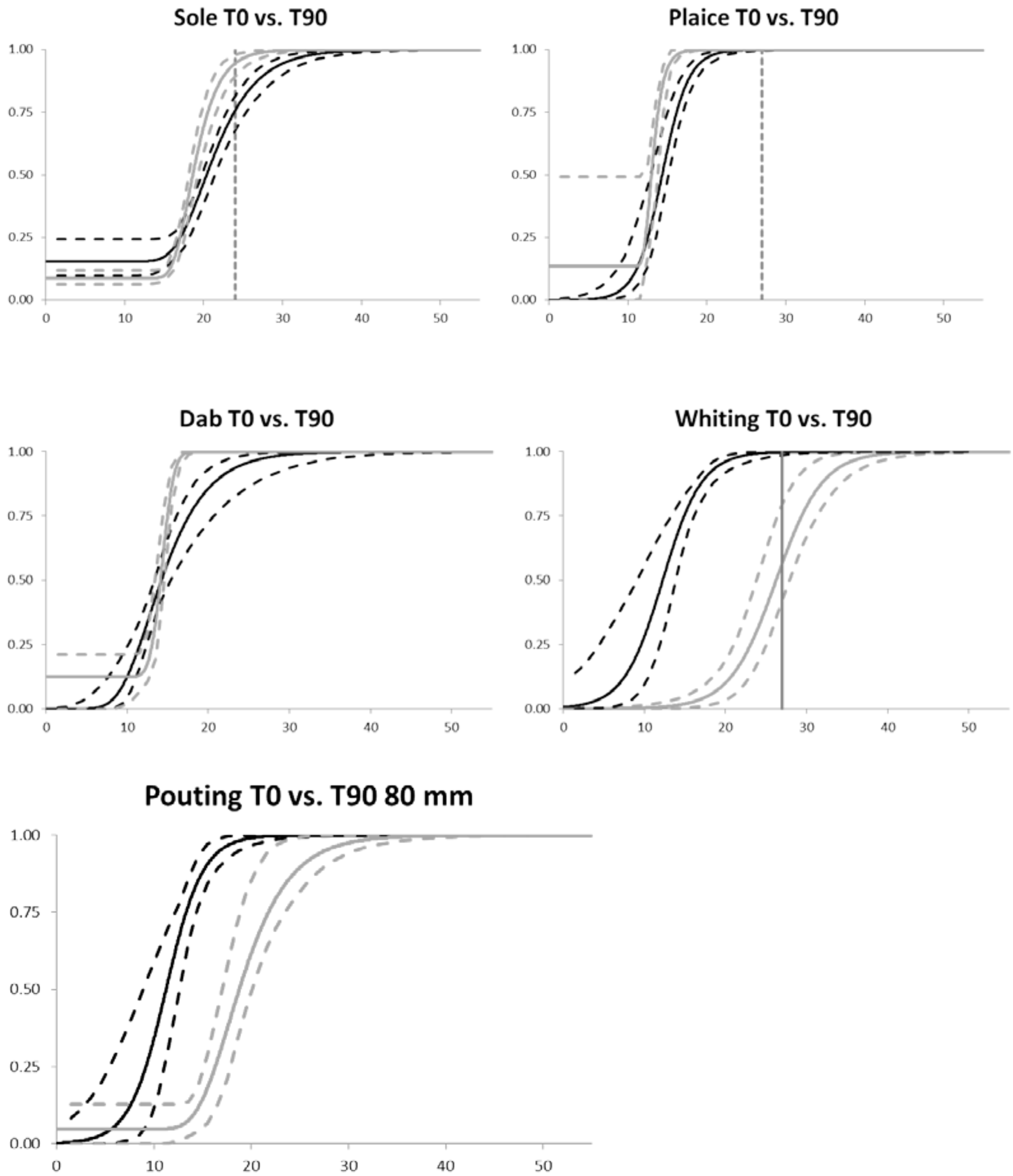

Figure 10.7: Comparison of selection curves for T0 (black) and T90 (grey) codends. Stippled curves represent 95% confidence bands for the selection curves

Table 10.3: Results for selected models. Values in () represent 95% confidence limits. * not applicable; ** undefined – see text

	Sole		Plaice		Dab	
Codend	T0	T90	T0	T90	T0	T90
Model	CGompertz	CGompertz	Logit	CGompertz	Gompertz	CProbit
L50 (cm)	20.4 (19.8-21.4)	18.6 (18.1-19.3)	14.3 (12.9-15.1)	13.0 (12.0-14.3)	14.2 (13.3-15.4)	14.1 (13.4-14.6)
SR (cm)	6.8 (5.3-8.6)	3.5 (2.7-4.4)	3.7 (2.8-5.2)	1.6 (**-2.1)	6.1 (4.3-9.9)	1.9 (1.2-2.5)
C	84.5 (75.8-90.2)	91.2 (87.8-93.6)	*	86.4 (50.9-100.0)	*	87.6 (78.8-100.0)
L501 (cm)	21.3 (20.6-22.5)	18.9 (18.4-19.6)	*	13.2 (12.5-14.5)	*	14.3 (13.5-14.8)
SR1 (cm)	5.9 (4.6-7.0)	3.3 (2.5-4.2)	*	1.4 (0.1-1.8)	*	1.6 (1.0-2.2)
nP-	29.2 (20.3-38.2)	30.7 (19.9-41.4)	76.2 (65.4-87.8)	90.1 (87.4-94.1)	65.7 (57.7-72.9)	75.1 (71.5-78.4)
nP+	89.0 (81.9-96.1)	99.0 (95.0-100.0)	100.0 (100.0-100.0)	100.0 (100.0-100.0)	91.5 (70.0-100.0)	100.0 (100.0-100.0)
p-value	0.001	0.258	0.757	1.000	0.030	1.000
Deviance	56.83	34.60	21.61	9.25	42.36	8.37
DOF	28	30	27	29	27	26

	Whiting		Pouting	
Codend	T0	T90	T0	T90
Model	Logit	Logit	Logit	CGompertz
L50 (cm)	12.3 (9.0-13.8)	26.2 (23.8-27.9)	11.2 (8.8-12.6)	18.7 (17.0-20.1)
SR (cm)	5.3 (3.5-9.0)	6.3 (4.1-8.3)	4.1 (2.2-6.8)	5.5 (2.3-7.0)
C	*	*	*	95.2 (87.3-100.0)
L501 (cm)	*	*	*	19.0 (17.1-20.3)
SR1 (cm)	*	*	*	5.3 (2.2-6.8)
nP-	90.3 (86.3-93.0)	9.1 (4.1-16.3)	*	*
nP+	100.0 (100.0-100.0)	70.5 (55.4-94.3)	*	*
p-value	0.999	0.016	0.991	0.333
Deviance	7.54	41.29	7.49	20.00
DOF	24	24	19	18

Conclusion

Our analysis indicates that a T90 codend can increase the selectivity of roundfish, something that is desired within the fishery, and decrease the selectivity of flatfish, which is a conflicting point. Sole, a flatfish, was shown to have a lower selectivity with T90, which is a result that is likely in favor of fishers targeting sole, but these results conflict with management goals seeking a decrease in the discards of flatfish, particularly plaice. Therefore, a T90 codend is not the panacea for beam trawl selectivity, but it does function to improve selectivity for roundfish. Additionally, though plaice selectivity is decreased, the end result is the same for both T0 and T90, 100% of fish under MLS being retained.

The Dutch flatfish fishery is the major beam trawl nation in Europe. Many of the Dutch vessels have changed to pulse trawling with reduced catches of plaice (Van Marlen et al., 2014 – Fish Res). Catches of plaice may be further reduced by the T90, as pulse gear still catches the plaice. So, then there is a combination of the selectivity of the gear stimulus (tickler vs.pulse) and the codend (T0 vs. T90). In the light of the landing obligation this could seriously improve selectivity, especially of plaice.

Questioning the effectiveness of implemented technical measures under the EU landings obligation: the Basque Otter Bottom Trawl fishery case study

Nekane Alzorriz[1*, 2], Luis Arrregi[2], Bent Herrmann[3], Manu Sistiaga[4], Jan Jaap Poos[5]

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Three experiments were carried out on board two commercial trawlers in the Bay of Biscay area for the period 2011-2013 to study the effectiveness of the implemented top square mesh panel (SMP) selective device. "Fall-through" experiments with netting and fish demonstrate the potential size selection of the SMP for hake (Merluccius merluccius), red mullet (Mullus surmulletus) and bib (Trisopterus spp.), which should enable escape of immature and undersized fish. However this was contrasted by the results from the experimental fishing with the SMP which showed very limited escapement through the SMP also for immature and undersized fish. Analysis of the data collected during the experimental fishing showed that the poor escape effectiveness of the SMP was caused by that only a very small fraction of the fish entering the trawl did attempt to escape through the SMP during their drift towards the codend. This attempt probability was quantified by the "SMP contact probability" (CSMP) whereas the size selective potential for the SMP was described by the parameter L50SMP. The analysis resulted in L50SMP values above the length-at-maturity, documenting that the panel have the potential to function well regarding release of immature fish. However, the CSMP values for all three species suggest that the panel contribution to the selectivity is small, as on average less than 15% of the bib and less than 4% of the hake and red mullet were predicted to attempt to escape through the device. For all three species, the release potential for the diamond mesh codend, quantified by the parameter L50codend, was found to be significantly lower than the length-at-maturity and the minimum landing size (MLS), resulting in an average retention of 45 % of the undersized hake and underweight red mullet entering the gear. Overall the results show that the studied fishery remains somewhat unselective in the face of the EU landings obligation.

Some do, some don't, and some do hesitate: estimating species contact-probability with grids. The Portuguese experience

Aida Campos[1] and Paulo Fonseca[1*]

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The use of selective gears has proven to successfully reduce, in many situations, the amounts of bycatch otherwise discarded. In some cases, survival rates were found to be high for individuals escaping through these devices, thus justifying the adoption of gear-based management measures in a number of fisheries.

Different types of sorting devices have long been used to sort out bycatch taking advantage of the differences in behaviour and/or size between species, such as escape windows, sorting panels or sorting grid systems. The latter in particular, provide escapement while ensuring higher survival rates for escapees. However, a key factor influencing the effectiveness of these devices is the probability of a given individual to contact the specific selection device. Few selectivity studies have quantified this probability for the species in study.

In this presentation, we will show a few examples on how escape behavioural responses can be elicited by the use of sorting grid systems, and the probability of contact with the grids estimated, for a number of species captured in Portuguese bottom-trawl fisheries.

Performance of a new double grid design: quantification of grid contacts

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The flexigrid is a double grid design and is one of the mandatory selection devices used in the northeast Arctic cod and haddock fishery. The aim of this study was to investigate the selective performance of a new 4-panel flexigrid design for this fishery. Specifically, we wanted to evaluate if this new design increases the chances for a fish to make contact with at least one of the two grids in the design. Therefore, in addition to the selectivity parameters L50 and SR, we quantified the parameter "grid contact" for both grids independently and combined for both the mandatory 2-panel and the new 4-panel designs.

In a direct comparison carried out using a twin trawl, the 4-panel flexigrid design showed higher L50 values and lowers SR values than the 2-panel design. Underwater recordings revealed that the cause for this difference between the designs may be that the 4-panel section holds a more correct shape than the 2-panel section while fishing. The mean values estimated for the grid contact were always higher for the new design. The results also showed that undersized cod escapes mostly through the lower grid of the section whereas haddock utilizes in general the upper grid. This is in good agreement with the behavioral differences expected between these two species.

French experience to improve the contact probability of selective devices

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** Presenting author*

This presentation will summarize several French studies carried out to improve the probability of contact of fish and Nephrops with various selective devices or meshes in trawlnets. The following trials will be presented:

- Combination of a semi-rigid grid with a square mesh panel tested in the Channel and North Sea, which increased the contact of whiting with the square mesh panel.
- The influence of a "float" on the escape of fish, in interaction with a square mesh panel or cylinder.
- The implementation of a separator panel in a Nephrops trawl, which allows to separate Nephrops from fish but also to increase the contact either with the net or the selective devices.

Some short video footages will be screened for these three devices.

Guide fish to the selective device as a measure to improve the contact probability. Experiences with Argentine hake (Merluccius hubbsi) *(* presentation not given due to logistic reasons)*

Aníbal Aubone[1,2] and Julio García[1*]

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**Presenting author*

This presentation will show some results in contact probability on hake (Merluccius hubbsi) selective devices tested in the Argentine Sea. Contact probability is defined as the proportion of the fish that encounter the selective device. Trials were carried out with the following devices:

DEJUPA: single sorting grid device with a guide funnel. FLEXIGRID: double sorting grid and a guide panel over the second one. ARSEL: a single sorting grid turned upside down compared to DEJUPA and with a lifting panel. SMD: Square mesh device, is a square mesh window in the upper panel, with lifting-guiding panel. The data were collected with a three-compartment setup, and the devices own selectivity was considered.

ARSEL and SMD showed none strictly increasing retention. This situation is postulated to be necessarily correlated to a variation in the probability of a fish contact the selective device. Both DEJUPA and FLEXIGRID showed a logistic retention relationship. This is associated with a practically constant contact probability. A simple theoretical model helps to explain these results of retention (observed), correlated to the variation or not in the contact probability. We model the contact probability as a function of length. Both retention function of the fishing gear and contact probability are estimated. The estimation is considered suitable under the knowledge of the low escape reaction of the argentine hake against the selective device. We conclude the importance of the high contact probability in the selective device in order to obtain a more knife edge selectivity of the fishing gear.

Size selection of redfish (Sebastes spp.) in a double grid system: quantifying the escapement through individual grids and comparisons with former grid trials in Norway.

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Rigid sorting grids have been mandatory in the northern gadoid fisheries since 1997. Over the last years, the Norwegian fleet has reported problems related to the sorting capacity of the sorting grids as fish accumulates before the grid section. Currently the commercial fleet seek simple, practical solutions to improve the water flow through the system and help the fish move faster through the grid section and finally to the codend.

At present we have limited information on how increasing water flow can affect selectivity of various species of fish through grids, i.e. how increased flow can affect contact rate. In an attempt to improve the release efficiency for undersized fish in a rigid grid system, we tested a new double steel grid system consisting of first a lower grid followed by an upper grid. The grid system was inserted in a 4-panel section. The trials were made during February-March 2015 along fishing grounds in the Barents Sea using a conventional bottom trawl. We concentrated this study on a typical bycatch species in the cod and haddock directed fishery, i.e. redfish (Sebastes spp.). Redfish were available in most of the hauls and had a good length distribution for selectivity studies. Therefore, all fish from the codend and the upper and lower retainer bags were length measured (nearest cm). The data were modelled in the SELNET software including quantification of the probability for the fish making contact with each of the two grids. The results showed that most of the redfish escaping did it through the second (upper) grid. The release efficiency of the first (lower) grid was significantly smaller. The low efficiency of the first grid was caused by that a significant smaller fraction of the redfish entering the grid zone was making contact with it compared to with the second grid. It was estimated that 80% of the redfish did make contact with at least one of the two grids. Further, the release efficiency for redfish in the new double grid system was compared to earlier results obtained with the grid systems used in the fishery today. However this comparison did reveal that the new double grid system did not increase size selection of redfish compared the existing grid systems. Moreover we found that that existing Sort-V single grid system released significantly more redfish than the new double grid system.

Understanding and quantifying the size selection of Brown Shrimps (Crangon crangon) in Trawls based on net-frame experiments in laboratory.

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b: SINTEF Fisheries and Aquaculture, Fishing Gear Technology, Willemoesvej 2, 9850 Hirtshals, Denmark

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Very little is known about the size selectivity process of Brown shrimps (Crangon crangon) in trawl codends. Due to limitations in shrimp swimming ability compared to the towing speed it could be expected that their contact with the codend meshes is a complex process. It may involve many different shrimp orientations, so called contact modes, making the size selection complicated. In an attempt to learn more about the size selection of Brown shrimps and to enable predicting it, we carried out a series of laboratory experiments with netting frames. We collected a set of artificial size selection data for shrimps for a range of meshes with different size and openness for each of 14 different potential modes of contact. Supported by underwater recordings, and assuming different contributions from the different contact modes and mesh openness's, it was possible to reproduce accurately size selection curves obtained during experimental fishing. Based on this we were able to identify the modes of contact most likely defining codend size selection. Specifically we found that three very different modes of contact probably are the most important and that is unlikely that any of the shrimps are able to make contact with meshes optimal for escapement. These findings confirm that the codend size selection of Brown shrimps is more complex than previously found for many fish species having better swimming capability. Our findings enable predictions, based on our laboratory experiments, of size selection for other codend mesh sizes than tested at sea. Our approach could potentially be applied for other species as well.

abstracts for presentations submitted to TG contact, but given in plenary session

Size selectivity of selective devices unveiled by contact probability: separator panels (grid and window) of trawl and tooth space of dredge

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This presentation will explain several examples of size selectivity of selective devices that I studied with contact probability model. First, grid separator has size selectivity on grid bar space, similar to mesh size. In Nordmøre grid separator fishing experiments carried out in the Inland Sea of Japan, some of shrimp whose body size was enough small to pass through the bar space, escaped out through the fish outlet. This suggested that only a part of shrimp contacted the grid bar space, which was defined as encounter probability (Tokai et al. 1996). And the available selection of the grid with fish outlet was expressed as pr(l) + 1-p, with contact probability p and retention curve of the grid bar space for l-length shrimp, r(l). Second, in a square mesh top window tested by Aberdeen Marine Laboratory, the contact selection curves of the window

panel for haddock and whiting were estimated with using probability parameter of fish contacting the window panel, and then the available selection curve (Zuur et al. 2001). Third, in the windows fishing experiments with three positions of window panel: top, sides and top & sides, higher contact probabilities were provided in top and top & sides for blackthroat seaperch and in sides and top & sides for white-spotted conger (Tokai unpublished). This suggested that the fish behavior contributed to contact probability and that gear modification can improve contact probability. Fourth, the net-mouth available selection of dredge with tooth was modelled with contact probability of a clam against the tooth and tooth space contact selection curve (Mituhasi et al. 2005), for analysing the data of paired-gear test with a control dredge of 12-mm tooth spacing and four test dredges of tooth spacing 16, 20, 24 and 35 mm, based on the SELECT method. In the SELECT process, the plots of the proportion of clams caught in the test dredge to the total catch were U-shaped (Kim et al. 2005). Finally, a BRD which comprised a pair of net panels and escape vents between the panels was attached at the net mouth of small beam trawl, and the available size selection was expressed with parameters of contact probability and contact selection curve for each panel (Kajikawa et al. 2013). The equation expressing the available selection looked complicated. But no contact of animals against the panel veiled the contact selection. No retention in contact selection, e.g. too small body compared with mesh size, veiled the contact probability.

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Kim IO, Mituhasi T, Jo Th, Park CD, Tokai T (2005) Effect of tooth spacing on the contact selection and net-mouth available selection of a dredge for Venus clam Gomphina melanaegis. Fish Sci, 71, 713-720.

Kajikawa Y, Tokai T, Hu F (2013) Modelling of available size selectivity of the SURF-BRD for shrimp beam trawl. Fish Sci, 79, 879-894. DOI: 10.1007/s12562-013-0668-8

New approaches to by-catch reduction in bottom trawling for shrimps Pandalus borealis

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Currently, there is a great interest in improving bycatch reduction in the Norwegian shrimp fisheries and joint efforts by the fishing fleet, the Directorate of Fisheries and science started recently. The aim is to reduce bycatches well below today’s strict regulations on legal numbers of fish counted as bycatch.

Despite the compulsory Nordmöre grid (since 1991/1993) removes large quantities of fish during the catch process, the 19.0 mm bar distance allow small juveniles and slim fish in general to enter the codend, i.e. they are retained as part of the catch. Typically juveniles smaller than 15-16 cm from important species like cod, haddock, redfish, etc. are likely to be retained whenever they occur along the fishing ground.

As a first attempt in Norway we tried a setup with green Lindgren-Pitman Electralume LED lamps along the fishing line during trials in February 2015. We attached 16 (and 20) of these LED lamps along the 52 m fishing line. We managed to get only 6 valid hauls (30 min. tows) with small shrimp catches and rather few retained fish and the interpretation of them should therefore be done with caution. For the 3 comparisons pooled numbers showed a 27% reduction by numbers of the most important and abundant bycatch species, but we found a discouraging reduction close to 9% of shrimps (by weight).

10.2.2 Individual Presentations 2016

Below, summary slides of selected presentations are collected

Roger B. Larsen (The Arctic University of Norway; Norway)

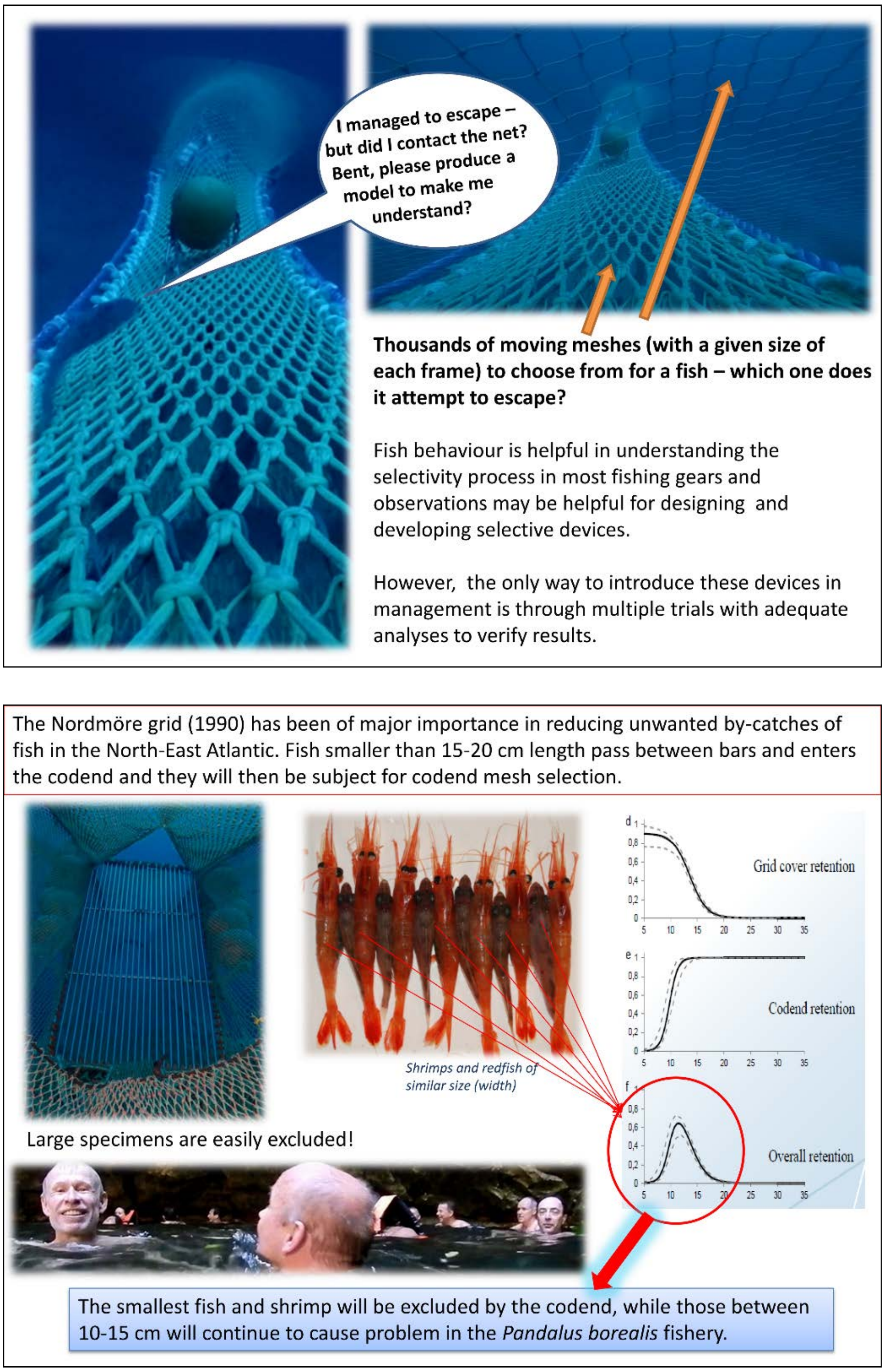


Figure 10.8: summary of presentation, given by Roger B. Larsen: Norwegian selectivity experiments (e.g. grid systems) and Contact probability as a driving factor for success

Bart Verschueren (ILVO; Belgium)

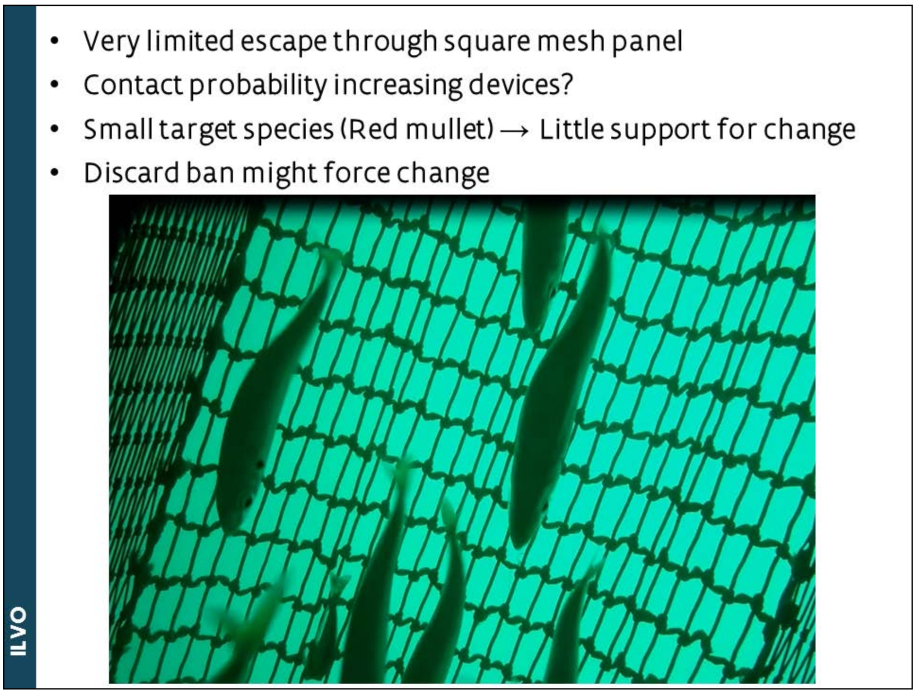


Figure 10.9: summary of presentation, given by Bart Verschueren: The efficiency of square mesh panels in Flyshooting Fishery, intensive discussion about underwater recordings (see picture).

Juan Santos (Thuenen-Institute of Baltic Sea Fisheries; Germany)

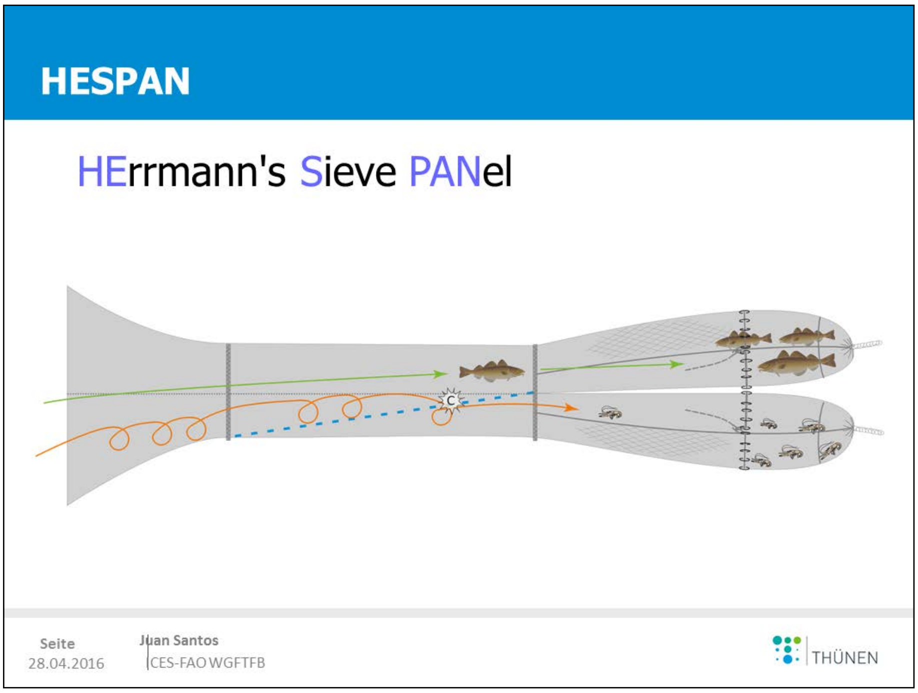


Figure 10.10: summary of presentation, given by Juan Santos (slide 1): Schematic drawing of a selection device to separate Nephrops from fish (HESPAN).

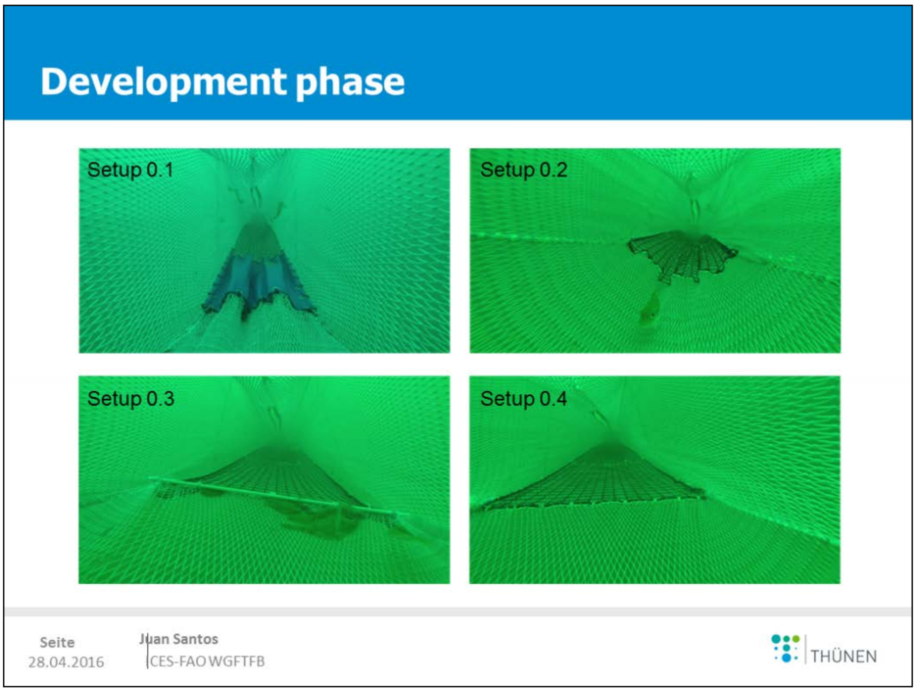


Figure 10.11: summary of presentation, given by Juan Santos (slide 2): Different HESPAN-setups tested (underwater recordings).

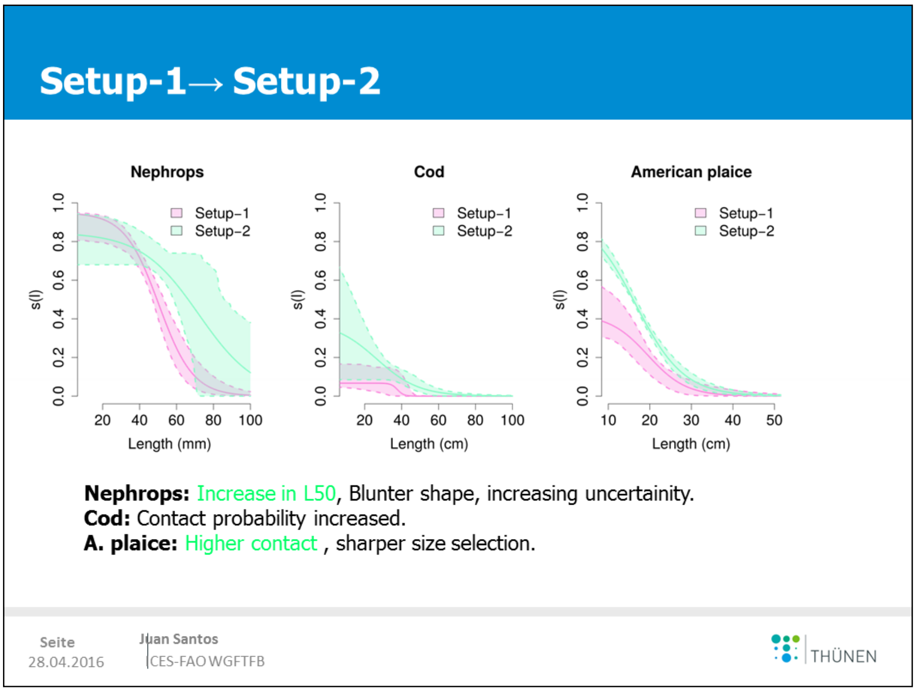


Figure 10.12: summary of presentation, given by Juan Santos (slide 3): example for results, obtained with different HESPAN designs.

Julio Garcia (INIDEP; Argentinia)

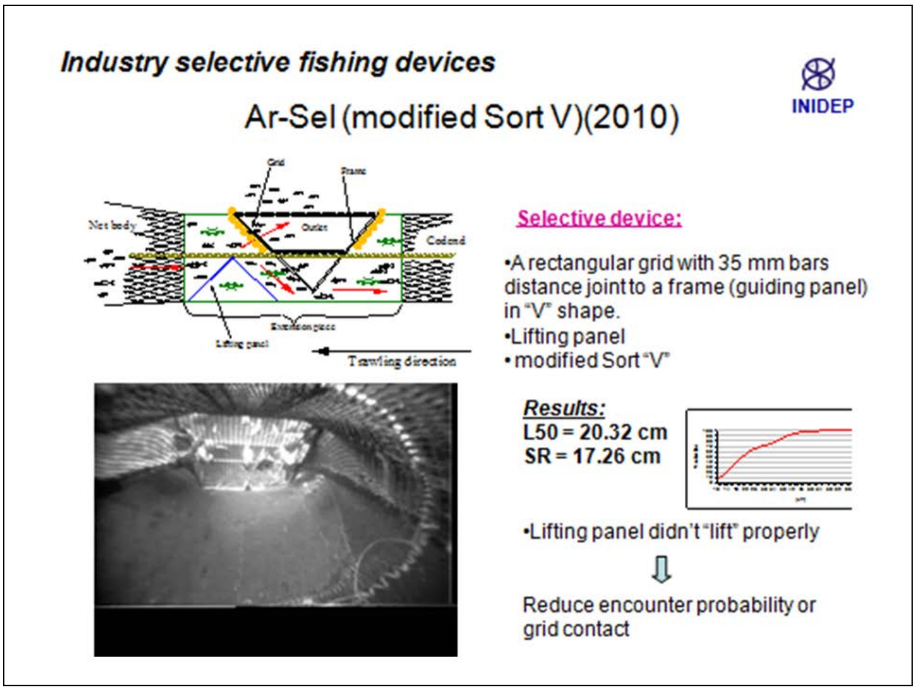


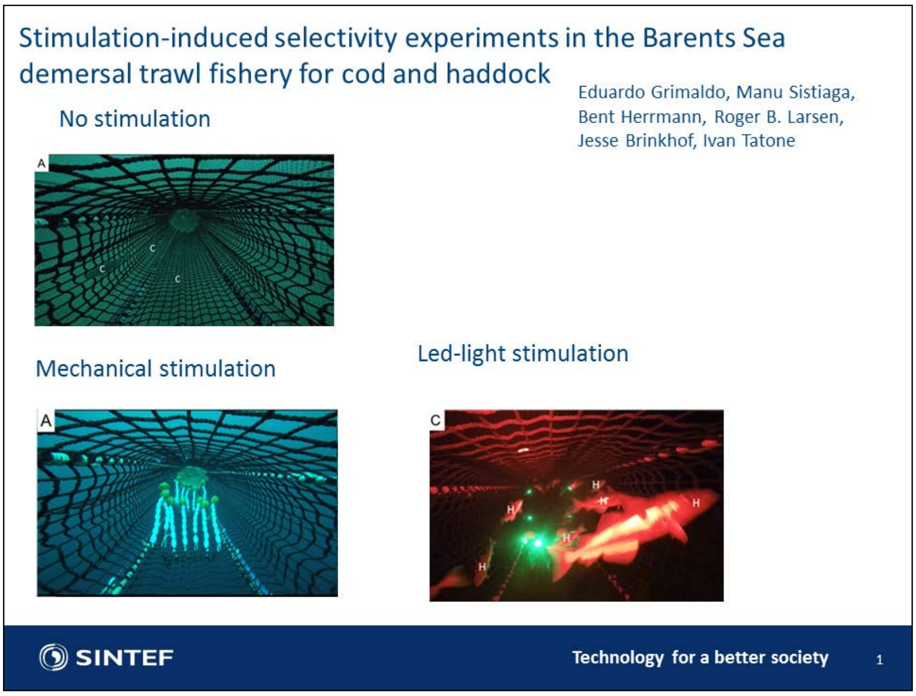
Figure 10.13: summary of presentation, given by Julio Garcia: experiments regarding grid-based selectivity systems.

Pieke Molenaar (IMARES, Netherlands)

Figure 10.14: summary of presentation, given by Pieke Molenaar (topic 1): selective devices for the Dutch Nephrops fishery.

Figure 10.15: summary of presentation, given by Pieke Molenaar (topic 2): selective devices for the Sole and brown shrimp fishery.

Bent Herrmann (SINTEF; Denmark)



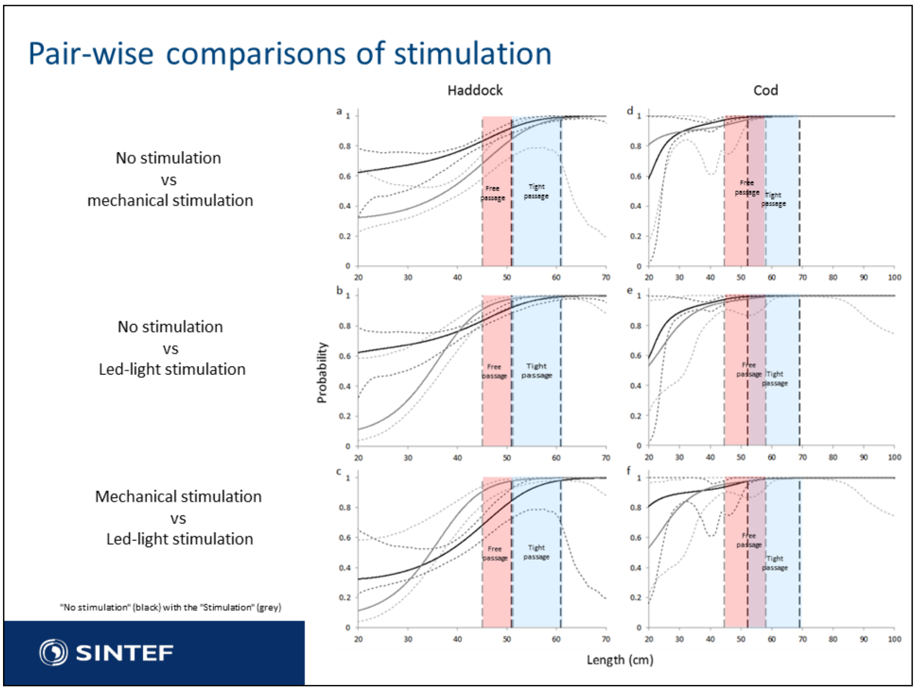


Figure 10.16: summary of presentation, given by Bent Herrmann (SINTEF; Denmark): Stim-ulation-induced selectivity.

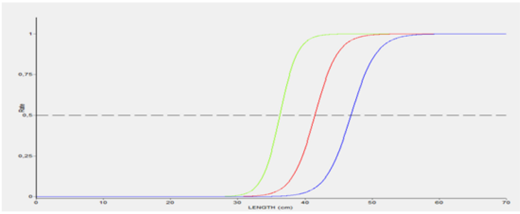
Iñigo Onandia and Luis Arregi (AZTI; Spain)

Summary for ToR on Contact Probability

- There are 2 trawl fisheries in the Basque Country with the following operational parameters:

Fishery	Footrope length (m)	Floatline heith (m)	Wingspread (m)	Towing speed (knots)	Codend mesh size (mm)
Single trawl	80-100	1.8-2.4	22-26	4	70 + SMP
Pair Trawl	200	30	100	2	100

- From 2009 to 2012 the mandatory SMP has been tested in the Single trawl fishery. Results for hake show low escapement rate < 4% (Alzorriz *et al*. 2016).
- Since 2015 we have started working to improve selectivity on pair trawl.
- Work started with a fall-through experiment (70-80-90 mm nominal mesh) to identify the most suitable mesh size in relation with MCRS for hake (27 cm).



2

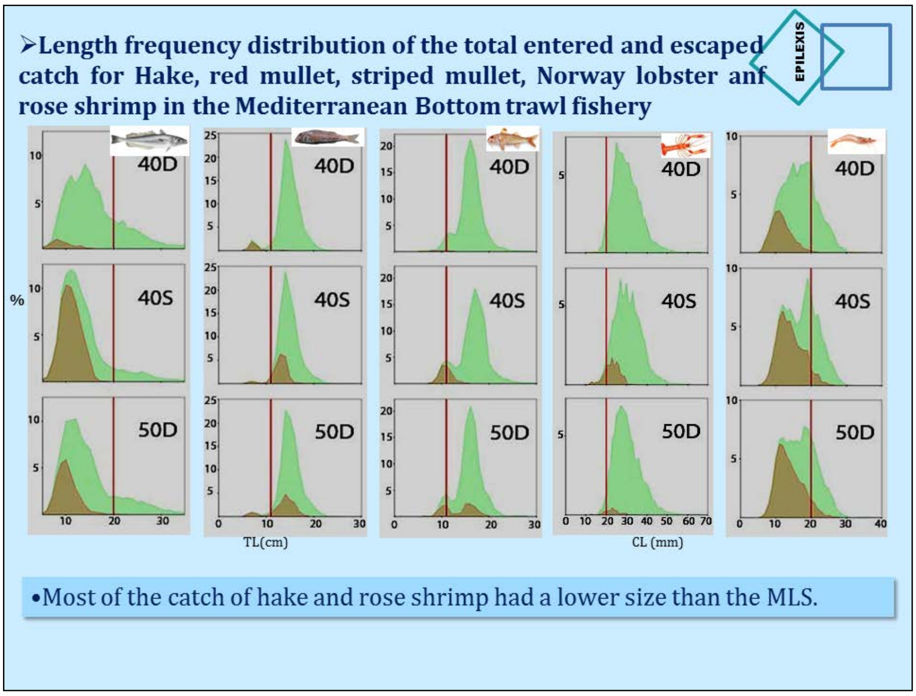
Summary for ToR on Contact Probability

- From this experiment 76 mm mesh size has been identified, nevertheless 86 mm mesh size was selected to improve contact probability.
- Several cruises have been performed and some good results achieved on escapement through the SMP for Choke Species.
- Underwater footage reveals that in the pair trawler fishery the gear remains stopped quite long during the hauling back, and is in this moment where part of the hake selection occurs. The fish escaped through the SMP and retained by a cover could also enter again into the gear, resulting in an underestimation of the escapes.
- In addition, in two of the tows SMP was set in the lower panel of the trawl showing the highest escapement rate observed during the cruises. This matches up with the underwater video observations where hake vertical distribution inside the trawl is higher in the lower part of the gear.

3

Figure 10.17: summary of presentation, given by Iñigo Onandia and Luis Arregi: Discard re-duction experiments on the Basque trawler fleet.

Chryssi Mytilineou (HCMR; Greece)



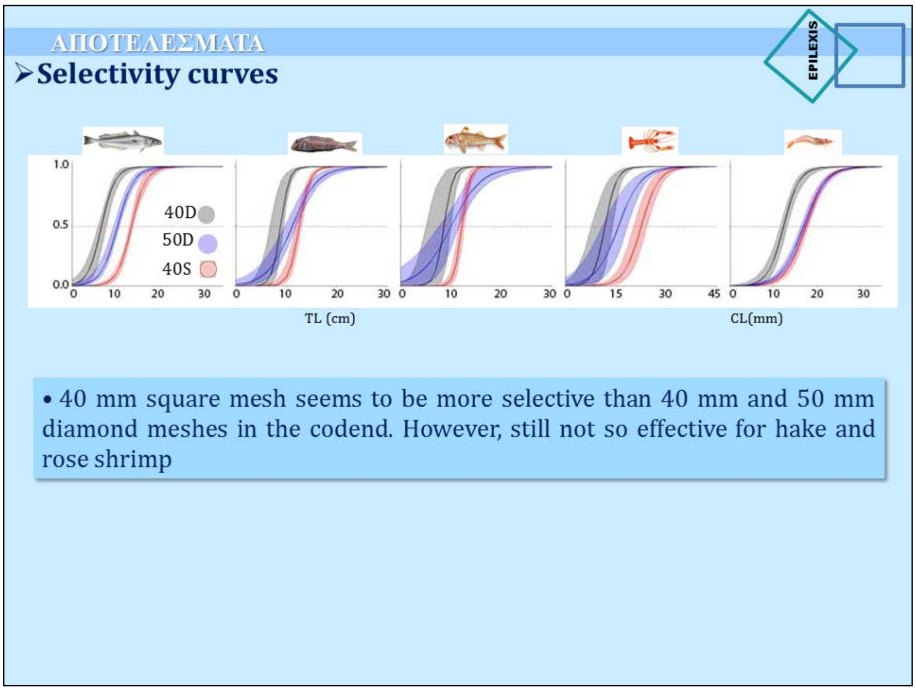
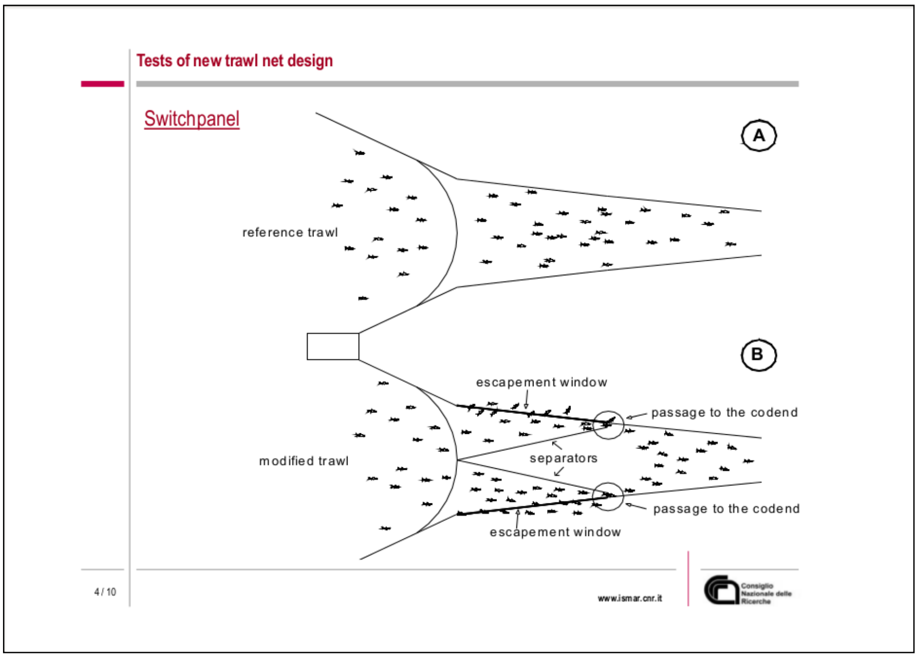


Figure 10.18: summary of presentation, given by Chryssi Mytilineou: Greece selectivity ex-periments in the Mediterranean Sea.

Antonello Sala (CNR; Italy)



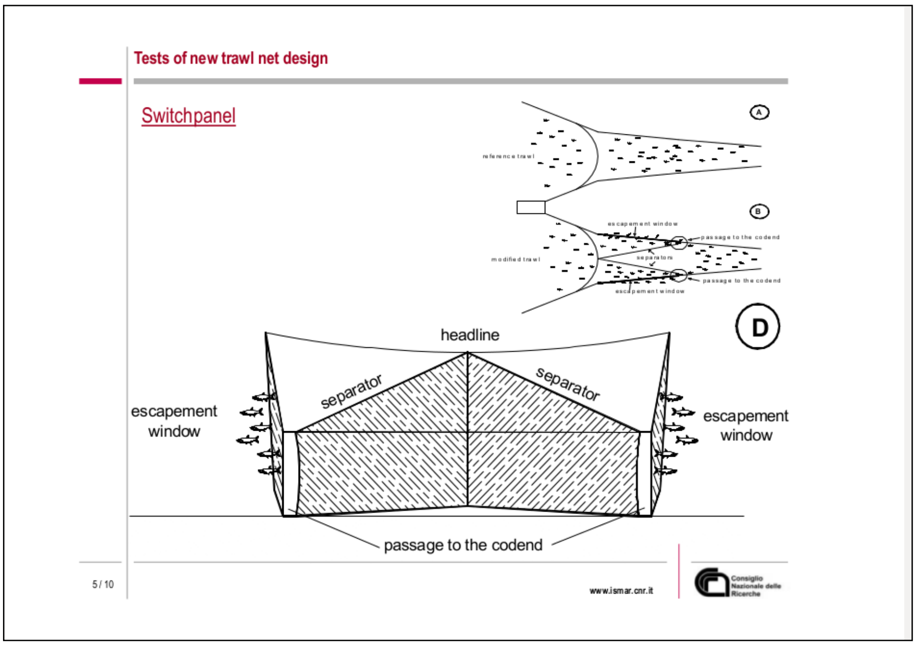


Figure 10.19: summary of presentation, given by Antonello Sala: Tests of a new trawlnet design (which guides the fish to the side panels) – preliminary results of sea trials in the Mediterranean Sea.

11 Topic Group: Evaluation of trawl groundgear for efficiency, bycatch and impact on the seabed (groundgear)

11.1 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 that are usually in contact with the seabed during bottom trawling, which was initiated during the 2017 WGFTFB meeting in Nelson, New Zealand.

The topic group was to evaluate current and past work on trawl groundgear regarding its 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 and drag, gear design, operating strategies, and technologies for reducing fuel consumption and greenhouse gas emission, as well as species and size selectivity attributable to groundgear, and behaviour of fish and other animals near groundgear.

11.2 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 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 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 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.

11.3 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.

11.4 Participants

The Topic Group met on June 7 and 8, 2018 with the following twenty participants (listed in a random order), seventeen of them were new to the group. Co-chair Antonello Sala was not able to participate the meeting in person.

First name	Last name	Country	Institution/affiliation	E-mail
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11.5 The accomplishment:

The Groundgear topic group decided that it 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.

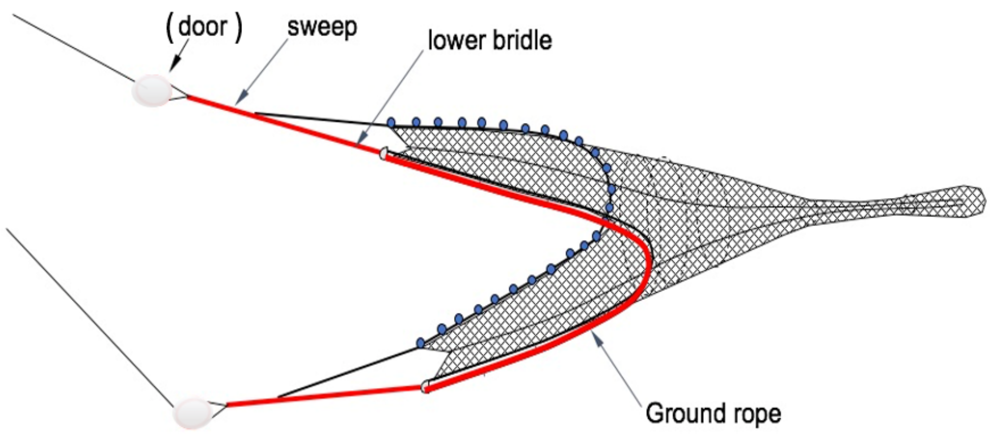
The Groundgear topic group defined "groundgear" as the bottom-tending components between wing-ends. The scope of the topic group on "Groundgear" (and its report), however, will include both groundgear and bottom-contacting cables connecting the trawl and the doors, including, but not limited to:

- Groundrope (footrope), fishing line and tickler chains.
- Sweeps and lower bridles and other cables attached.
- (Trawl doors – will not be included as they were covered by a recent topic group).
- Center weights and sleds of twin-, triple- or multi-rigs.

The components covered by the "groundgear" topic group is shown (in red) in Figure 11.1.

Figure 11.1 A typical bottom trawl with the "groundgear" highlighted in red.

The Groundgear topic group defined the scope of this topic group, and reaffirmed the Term of References of it:



- 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 bottom trawls. 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 minimal unwanted bycatch.

11.6 The work plan

Members of the topic group 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 (in factsheet-style) 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 will meet to produce the final report of this topic group for the 2019 FAO-sponsored WGFTFB meeting.

11.7 Final report

A final report from the Groundgear topic group will be provided at the ICES-FAO WGFTFB meeting in April 2019. Publication of the report (or part of it) in FAO Fisheries Report or in a peer-reviewed journal is envisaged. The preliminary table of content for the report may include:

- Definition and extent of a groundgear, including commonly used names (and rigging):
  - ✓ Grasrope
  - ✓ Cookie
  - ✓ Bobbin gear
  - ✓ Rock-hopper gear
  - ✓ Rollergear
  - ✓ Brushgear
  - ✓ Plategear

- Types of commonly used groundgears (illustrated):
  - ✓ Rope, wire, lead line
  - ✓ Chain (drop, straight, loops)
  - ✓ Discs (rubber, plastics)
  - ✓ Bobbins (steel, rubber, plastic)
  - ✓ Chafing skirt
  - ✓ Combinations of these types
  - ✓ Components, i.e. referring to drawings/ "fact sheets"

The report will also include the elements influencing the performance of the groundgear:

- 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)
- Plategear/Semicircular spreading groundgear
- Aligned gears
- Experimental/others

Members of the 2017 and 2018 Groundgear topic group (and the whole WGFTFB family) will be asked to add information relevant to the ToR. We will produce a template for collecting information on typical groundgears being used and drawings (with explanations) would be appreciated. The "factsheet" template will be provided to WGFTFB members via the current FTFB e-mail list.

12 National Reports

12.1 Introduction

Participants were asked prior to the meeting to prepare summaries of current and expected research related to the activities of the WG within the country as the group have done for many years. Fifteen National reports were received where thirteen was within ICES member country's: Belgium, Canada, Denmark, France, Germany, Iceland, Ireland, Netherlands, Norway, Spain, Sweden, United Kingdom and the United States of America. Then were two countries outside the membership of ICES delivering national report: Italy and Japan. The full text of these reports is inserted below, by country and institutes. The activity is clearly on a very broad range of research areas where towed and static gears are under inspection from many different perspectives. The contents of the individual national reports were not discussed by the group, and such they do not necessarily reflect the views of the WGFTFB.

12.2 Belgium

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

Heleen.Lenoir@ilvo.vlaanderen.be,

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Duration: 2017 – 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 will be tested to reduce choke species and other bycatch species in the net. Light or mechanical stimuli in the opening of the net could be used. The selectivity of the net will be improved through the use of panels, different net materials and mesh sizes and shapes. The project will test what adaptations have an influence on the survival of the catch. The effects of the volume caught, the haul duration, organization on deck will be examined.

The innovations found most promising by the sector and ILVO, will be tested and further developed on board of commercial vessels. Evaluation will be done by means of self-sampling by the crew, followed by an extensive catch analysis by ILVO. In addition, the potential of certain innovations can also be investigated on board of research vessels.

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 fishers, shipowners and the Rederscentrale.

V-Pulse Sole ('developing and testing a cheap and light pulse gear for coastal day fisheries')

Maarten.soetaert@ilvo.vlaanderen.be,

Heleen.Lenoir@ilvo.vlaanderen.be,
Els.vanderperren@ilvo.vlaanderen.be

Duration: 2018 – 2020

The aim of this project is to develop a cheaper and lighter 4m pulse gear to target Dover sole (*Solea solea* L.) and which is interchangeable with a 9m pulse beam for Brown shrimp (*Crangon crangon* L.). This is necessary because the existing systems are too expensive and heavy for the smaller coastal fishing vessels going out daily. The idea is to have a winch and control panel that is compatible with both pulse trawls, which would allow the fishers to easily switch between pulse trawling for shrimp and pulse trawling for sole depending on the season by just changing beams. The first year of the project focuses on the development and optimalisation of the new pulse trawl for sole, based on the same modular system (LFish) as the recently constructed pulse trawls for shrimp on the O81. Additionally, a mobile winch and controller will be provided enabling us to have a 'mobile' prototype that can more easily be moved and tested on several vessels to allow different fishers to know the technology. Each vessel will fish for 3 to 12 months with the pulse trawl, comparing its performance with that of a conventional beam trawl at the other side of the boat.

eBRP ('Development path for the Electrified Benthos Release Panel')

Maarten.soetaert@ilvo.vlaanderen.be,
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Els.vanderperren@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 that a better rigging as well as electrifying the BRP allows to prevent sole from escaping. On one hand, the escapement of sole could be reduced with 10-20% by keeping the BRP stretched, which shows that a conventional BRP merits renewed attention. On the other hand, elaborate trials with an electrified 200 mm electrified BRP (eBRP) proved that this eBRP can release 20-50% of the benthos and debris caught without losing commercial sized sole. Additionally, also the bycatch of undersized fish of several species was reduced by this new development, which illustrates the promising potential of electric stimulation in the net to promote selectivity.

12.3 Canada

Fisheries and Marine Institute

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

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 fall of 2018.

Helical Rope

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

Feb 2018 – Dec 2018

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. See presentation at the 2018 FTFB meeting for more information.

Emerging Fishery – Porcupine Crab

Contact Person: Scott Grant Scott.Grant@mi.mun.ca

April 2016 – March 2019

In 2016, a two week study was conducted aboard a 30.5 m commercial gillnet fishing vessel (*FV Arluk I*) in NAFO Division 0B. The primary focus was to collect information on the distribution Porcupine Crab (*Neolithodes grimaldii*) using a towed benthic camera sled. Water depths were very deep, ranging from 400 to 1400 m. A total of 22km were transected. Video analysis is currently underway.

Invasive Green Crab – Optimizing Capture Efficiency:

Contact Person: Brett Favaro, Brett.Favaro@mi.mun.ca

April 2016 – Dec 2018

European green crab (Carcinus maenas) is a notorious invader on the east and west coasts of Canada. In 2016, we completed a two-year study using stationary underwater video cameras attached to Fukui traps to study parameters critical to informing the design of an optimal removal program, including rate of crab accumulation in traps, length of time to saturation, the mechanism of saturation, and whether there are differences in these parameters across distinct populations.

LED Lights – snow crab pots

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

Jan 2016 – March 2019

This project is investigated the potential benefits of adding small low-powered LED lights (Lindgren-Pitman) to snow crab traps. Laboratory experiments were completed to investigate the behaviour of snow crab toward various colours of lights. Sea trials demonstrated that that CPUE of baited traps could be enhanced by as much as 77% depending on the colour and soak time utilized. Location and orientation of the lights did not appear to be important. See recent manuscript in Aquac. and Fish. for more information.

Baited Cod Pots

Contact Person: Philip Walsh, Philip.Walsh@mi.mun.ca

April 2016 – March 2018

A two-year study was recently completed to improve baited pots for Atlantic cod. We documented the catch rate and length selectivity for five different pot designs. Our findings showed that all designs were effective at catching cod, but that the modified NL pot with 4 entrances caught the most per deployment. This design caught 2.4 times as many fish per deployment as the standard NL pot, demonstrating that modest modifications to potting gear can have a substantial impact on catch rates. We also found that increasing mesh size was highly effective at reducing the number of undersized fish caught in the Norwegian cod pot design.

Biodegradable Gillnets

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

April 2017 – March 2019

A small pilot study in ongoing to evaluate the performance of biodegradable gillnets in cold Newfoundland waters. This longitudinal study is monitoring the change in breaking strength over time for traditional nylon and biodegradable gillnet stored in flow through tanks using untreated unfiltered seawater. Preliminary results have shown no detectable change in breaking strength after a period of 6 months.

Glow in the Dark Netting – snow crab pots

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

April 2017 – Dec 2018

In partnership with 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 April 2018 on the south coast of Newfoundland, Canada. Results forthcoming.

Impact of Green Crab on Lobster Traps

Contact Person: Brett Favaro, Brett.Favaro@mi.mun.ca

Sept 2016 – Dec 2017

The invasion of European green crab in Newfoundland's nearshore waters has raised concern that the invader may impact the ability of fishers to catch lobster – either by the green crabs depleting bait, or by interfering with the ability of lobsters to enter traps. We conducted a field study in which we pre-stocked green crabs, rock crabs (as a procedural control), or no crabs in deployed traps, and compared lobster catch rates as well as data from underwater video and SCUBA to assess how the invader affected trap performance. We found that pre-stocking traps interfered with lobster catchability, but that the impact was not specific to the invasive species.

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

Contact Person : Damien Grelon, Damien.grelon@merinov.ca

Development of a multi-level trawl for the study of bycatch and northern shrimp vertical distribution for the optimization of the shrimp trawl in Quebec's fleet

Contact Person : Marie-Claude Côté-Laurin, marie-claude.cote-laurin@merinov.ca

The main objective of this project is to develop a multi-level trawl in order to collect data on the vertical distribution of northern shrimp and problematic bycatch species in the commercial trawl. The study included three steps: 1) the conception of a multi-level trawl subdivided in three vertical sections; 2) the sea trials (adjustments of the device and sampling methodology); and 3) the realization of a workshop with the industry and experts. The preliminary results showed that the last 4.2m of the shrimp trawl is inefficient in catching shrimp, and that bycatch species, depending on the species, are mostly distributed in the lower and middle sections of the trawl. The project is aiming to better target shrimp by reducing the vertical opening of the trawl and to develop exclusion devices for bycatch.

Development of an efficient and selective trawl for redfish fisheries to mitigate bycatch and improve size selectivity of redfish

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.

Characterization of the bottom contact of the different redfish trawls

Contact Person : Marie-Claude Côté-Laurin, marie-claude.cote-laurin@merinov.ca

This project will document with different technologies and direct or indirect indicators the degree, frequency and duration of bottom contact of the three types of trawls that might be authorized in the redfish fishery (bottom, semi-pelagic, pelagic trawls). The information gathered is aimed to help fishers 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 fishers 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. Trials at-sea and follow-ups with underwater cameras are scheduled for summer of 2018.

Smart gear: Turbot gillnet innovation

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

This two-year project aims to reduce bycatch 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 of working stations like pot hauler and supporting rack onboard lobster boats in Quebec LFA:

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 analysed 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 fishers 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

Multispecies Surveys – Monitoring gear survey bottom contact:

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

Determining on-bottom fishing time or tow duration is critical for estimating bottom trawl swept-area for survey indices which are used in stock assessment. We recently conducted trials of a SCANMAR hydroacoustic bottom contact sensor attached directly to the centre of the footgear of the Campelen 1800 shrimp trawl during the Northwest Atlantic Fisheries Centre (NAFC) 2016 fall surveys aboard the research vessel CCGS Teleost. The primary focus was to verify the extent of bottom contacted as confirmed by a clearance value of zero (clearance data comes from the SCANMAR trawl sounder which has been used to monitor bottom contact of the survey trawl). Our preliminary observations have shown a reasonable agreement between clearance data and bottom contact angle data. The attachment of a bottom contact sensor should deliver more practical information on tow duration and contact, particularly for deep water tows (up to 1500 m), when often there is a failure of recording bottom clearance data from the trawl sounder.

University of Prince Edward Island

Contact Person: Pedro Quijón, pquijon@upei.ca

Catching invasive European green crab with fykenets

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 fykenet. Bycatch counts were 4.4 times lower in the experimental net. See recent manuscript in Fish Res. for more information.

12.4 Denmark

Seal-safe fishery

Contact: Lotte Kindt-Larsen, lol@aqua.dtu.dk, Thomas Noack, thno@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 fishers. 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 harbour porpoise (*Phocoena phocoena*) or different seabirds, 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

The new European Common Fisheries Policy (CFP) has introduced a phased introduction of an obligation to land all catches taken from regulated stocks. However, article

15 paragraph 4b of the CFP regulation (EU) No 1380/2013, allows for the possibility of returning at sea species for which 'scientific evidence demonstrates high survival rates'. Such exemptions aim at reducing the risk under the European landing obligation of bringing onshore individuals that may otherwise survive the capture-and-discard process. Flatfish have been identified as potential candidates for such exemptions. The overall aim of the COPE-project is to create a catalogue of survival rates of the flatfish species subject to the landing obligation for Danish waters, based on information provided by the scientific literature on 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 and gear modifications. In addition, the data gathered within these experiments is used to investigate if vitality can 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 fishers). Based on the estimated survival rates, the Scheveningen group suggests exemptions from the EU landing obligation for the Danish seiner fishery and the winter season of the trawl fishery for the fleet using ≥120 mm for the North Sea/Skagerrak cod stock.

Lost fishing gears

Contact person: Rikke P. Frandsen, rif@aqua.dtu.dk

Dec 2017 - ongoing

National and international awareness of the fate of lost fishing gears is increasing and DTU Aqua is participating in different projects on the issue. There is very little information on the amount and fate of lost fishing gears in Danish waters. Potential hot spots of lost gillnets have been identified by overlaying geographical information on the distribution of stone reefs and wrecks, the routes of cargo vessels and ferries, and finally the fishing effort of active and passive gears. This summer we will test if a sidescan sonar can be used to locate lost gillnets in an area with a high level of interaction between gillnets and trawls.

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

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

2016 - ongoing

The project aims to establish a platform comprised of stakeholders (fishers, netmakers, producer organizations, managers and scientists) with the intention to promote the development of ideas and solutions originating in the industry. Furthermore, the project aims to facilitate and fast track the testing of new designs proposed by stakeholders and their implementation in legislation.

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 realized, 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.

To date, there are 11 selectivity trials being carried out in the project; 3 in the *Nephrops* directed fisheries, 4 in the Baltic cod fishery, and 2 in the North Sea beam trawl fishery for brown shrimp, and 2 in the Skagerrak trawl fishery for *Pandalus*. 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

The response of fish 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

2016 - ongoing

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, and so the responses of one roundfish, cod (*Gadus morhua*), and one flatfish, plaice (*Pleuronectes platessa*), to different light sources are investigated in the laboratory. At sea, points of continuous, green LED-light has been use to investigate the phototactic responses of fish, while a newly developed luminous net, VISIONET, has been used with an aim to take advantage of the optomotor response of fish inside the gear. Also, based on the fish responses obtained in the laboratory, additional light stimuli and light designs will be tested.

Smartfish 2020

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

2018 - ongoing

In the EU funded SMARTFISH2020 project we are leading 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"

The main aim of the first work package is to develop a real-time video monitoring (RTM) system to observe what is entering a trawl during the entire fishing process and an autonomous system to document e.g. *Nephrops* availability in the pre-catch phase in order to make informed decisions which can increase catch rates, avoid unwanted species and sizes, continuously monitor trawl geometry, reduce fuel costs/CO2 emissions, and reduce benthic impacts from trawling. This will be achieved through a two part process:

vi) Developing a cost efficient cable-based RTM system based on state-of–the-art HD video cameras and LED light technology.

vii) Using and further developing new underwater camera technology which enables detailed size and species analysis of the catch and improved image quality in turbid water.

The work is a collaboration between MARPORT, SINTEF Digital, Marine Scotland and DTU Aqua.

The aim of the second work package is 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 will develop LED technology to optimize the catching performance of trawl fishing gears and a catch control system to control the start of the capture process and to maximize the quality and economic value of the catch.

Identifying simple and cost-effective gear solutions which can lead to an effective implementation of the new EU common Fisheries Policy (CFP)

Contact: Valentina Melli (vmel@aqua.dtu.dk)

2015 - ongoing

The *Nephrops* (*Nephrops norvegicus*) directed mixed trawl fishery in the Northeast Atlantic has globally one of the highest bycatch rates and is affected by the landing obligation introduced by the new EU Common Fisheries Policy. More than ever, it is now in fishermen's interest to improve gears selectivity in terms of both size and species composition. Many bycatch reduction devices (BRD) have already been tested for this fishery but the majority of them are not flexible enough to match the highly variable fishing process and fishermen's individual catch goals. Thus, with this project, we are developing and testing a set of BRDs that can be applied either singularly or combined to the gear to modify the selectivity on a haul-by-haul level. The project involves two different groups of BRDs, both aiming at stimulating fish behaviour. The first group consists of anterior modifications designed to prevent fish entrance in the net by creating a counter-herding stimulus (FLEXSELECT project). The second group involves the application of additional stimuli (e.g. LED lights, moving floats etc.) inside the gear to improve species segregation in a horizontally divided trawl codend (VISION project).

Reducing bycatch using modifications to sweeps and lines anterior to the trawl mouth - collaboration between DTU Aqua and Australia (NSW DPI's Fisheries Conservation Technology Unit and IC Independent Consulting)

Contact: Valentina Melli (vmel@aqua.dtu.dk), Steven J. Kennelly (steve.kennelly@icic.net.au), Matt Broadhurst (matt.broadhurst@dpi.nsw.gov.au)

Jan-May 2018

Following the FTFB meeting in New Zealand (2017), a collaboration was established between DTU's fishing gear technology group and NSW DPI's Fisheries Conservation Technology Unit (FCTU) via a shared piece of research done in an Australian fishery. Two experiments were conducted to develop novel anterior modifications to the anterior part of the trawl to reduce the bycatch of unwanted finfish in the Clarence River prawn-trawl fishery. We combined the extensive knowledge regarding bycatch reduction devices in this fishery, and in particular the previously developed Simple Anterior Fish Excluder (SAFE), with the recent results from DTU's FLEXSELECT project. This collaboration set the basis for establishing a link and exchange of ideas between the Australian and the Danish teams.

Gear technical contributions to an Ecosystem Approach in the Danish set-nets fisheries

Contact: Esther Savina, PhD student, esav@aqua.dtu.dk

Although the fleet has reduced since the mid-1990s, Danish gill- and trammelnets are still of importance and are likely to gain increasing interest as environmentally friendly practices. However, such a development may only happen if the ecosystem approach is guaranteed. There is limited knowledge about ecosystem impacts, such as for example physical damage to habitats or discards, and their minimization may require development of alternative practices. With regard to the upcoming challenges of an Ecosystem Approach to Fisheries, the project aims at (1) studying the sweeping behaviour of nets and their effect on the seabed; (2) quantifying invertebrates and fish discards and understanding how the capture process can influence discard behaviour; (3) developing technical innovation that could improve catch quality and therefore maximize the production. Trials are conducted on gill- and trammelnets within the Danish coastal waters. This is a PhD run as part of the Skånfisk project financed by the Ministry of Food, Agriculture and Fisheries of Denmark.

Industry-led gear selectivity improvements, its strengths and weaknesses in the new Common Fisheries Policy (CFP)

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

2015 - ongoing

With the goal of increasing fishers' 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 fishers 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.

12.5 France

IFREMER

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

Summary

The fishing technology activities carried out in France in 2017 are distributed in five main topics :

- Improvement of trawl selectivity, through the study of ecomorphological and functional traits (FUSION-PRONOSTIC) and through selectivity experimentations on commercial vessels in the Celtic Sea, Western Channel, Bay of

Biscay and Eastern Channel (respectively CELSELEC - REJEMCELEC - REDRESSE - SMAC).

- Discards survival (ENSURE);
- Alternative fishing gears: design of fish pots (BAITFISH project) based on the behaviour and ecology of the target fish species
- Evaluation of trawling impact on benthic communities (TETRIS).
- Estimation of the abundance of Nephrops norvegicus in the Bay of Biscay (FU23-24) by counting their burrows using a submarine video camera (LANGOLF-TV).

Projects

FUSION – PRONOSTIC project to determine the selective properties of a T90 cylinder based on ecomorphology and functional traits

Contact persons: Maud Mouchet, maud.mouchet@mnhn.fr , National Museum of Natural History. Sonia Méhault, sonia.mehault@ifremer.fr, Dorothée Kopp dorothee.kopp@ifremer.fr, Fabien Morandeau , Ifremer Fishing gear technology and biology laboratory – Lorient

January 2017 –December 2021

The efficiency of a given selective device is usually estimated by comparing the biomass and length spectrum of caught individuals in a test and control gear, while the morpho-anatomical and functional parameters of species are rarely accounted for. Using an innovative technical device to reduce catches of undersized individuals in a multispecific bottom trawl fishery in the Bay of Biscay, we measured a set of ecomorphological and functional traits on both captured and escaped individuals of 18 species. We identified ecomorphological and functional features related to body size, visual ability and locomotion, and how they differed between the two fractions. As expected, escapees were smaller on average but also tended to be more streamlined, with a relatively bigger eye and fin characteristics involved in manoeuvrability and propulsion.

CELSELEC: Improvement of selectivity in the Celtic Sea

Contact persons: Marion Fiche, marion.fiche@pecheursdebretagne.eu, Producers organization “Les Pêcheurs de Bretagne”, Pascal Larnaud, pascal.larnaud@ifremer.fr, Marianne Robert, Fabien Morandeau, Julien Simon, Jean-Philippe Vacherot, Ifremer Fishing gear technology and biology laboratory – Lorient.

January 2014 – March 2017

http://archimer.ifremer.fr/doc/00403/51488/

In the context of the new European Common Fisheries Policy and in particular the Landing Obligation, trials were carried out between 2014 and 2016 on French bottom trawlers operating in the Celtic Sea and Western Channel, to decrease their discards.

After a state-of-the-art and various workshops organized in partnership between fishers, equipment manufacturers and scientists, 3 basic devices were selected for the trials, depending on the fisheries:

- 100 mm square mesh cylinder - SMC - (in addition to the mandatory 100mm and 120 mm square mesh panels - SMP) with or without scaring floats;
- Extension + codend in meshes turned by 90° ("T90") 100 mm mesh size;
- Monkfish / Skates / Megrim grid (semi-elliptic).

Preliminary experiments were carried out in flume tank and at sea and 38 sea cruises were then realized during three years, with observers on board.

The use of the T90 meshing in the extension and codend offers an answer to the problem of choke species for fishing fleets operating on the West of the Celtic sea, by reducing appreciably the catches of boarfish, mackerel and horse mackerel, which can represent important volumes in occasional and unpredictable catches (75-85 % reduction of the discards in weight). The interest of this device was also demonstrated in reducing the catches of young *Gadidea*, mainly haddock and whiting. Commercial losses for these species can happen in some cases, but without effect on the very positive perception by the skippers of the use of this type of trawl. The implementation of this technique is simple and the global reduction of the volume of catches allows on one hand to limit the sorting work on board and on the other hand to improve the quality of the valuable part. It is important to note that the results were homogeneous in the various situations of use (boat, fishing zone, season …). The recognized efficiency of trawls equipped with an extension in 100mm T90 meshes led to an extension of their use for the fleet operating in Celtic Sea.

The results obtained for the 100mm square mesh cylinder were less clear, even if the escape of the small individuals of *Gadidea* seemed improved. The adjustment of the positioning of the device remains difficult to define and follow-up studies should be led to optimize the technical configurations. In the same way, the interest of the use of a scaring device remains to demonstrate.

For the last prototype of flexible monkfish grid tested (version 4 in the report), a global decrease of 20 % of the weight of discards was observed, without decrease of the landings. We noticed in particular a decrease of the discards of flatfish (megrims, scaldfish) but also of gurnards, dragonets and small dogfish. Concerning anglerfish, escapes were noticed for the small sizes (between 10 and 20cm), but did not led to significant differences in the discards weight.

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

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January 2016 – June 2018

The REJEMCELEC project has been going on for two years and will end in 2018. It was set in a complementary way to the CELSELEC project in the Celtic Sea. The main goal was 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 discards of small haddock, hake and boarfish.

The leader of the project is the producers organization "COBRENORD" (Northern Brittany) in partnership with OPN (producers organization of Normandy). Other partners of the project are IFREMER and the equipment manufacturer Naberan. The funding partners are the association « France Filière Pêche » and the Brittany and Normandy Region Councils.

Five selective devices were tested to minimize undesired catches of four different métiers.

Large square mesh panel (90 mm gauge) on the « baitings » (last tapered section)

Single bottom trawlers of 20-24 meters length using a four faces trawl with 80 mm mesh size codend in the Western Channel.

The selective gear captured more haddock than the standard trawl, which is hard to explain at this stage. The square mesh in the extension piece was efficient to select whiting above the targeted size (32 cm), even if the 90 mm might be slightly too large. However, the high vertical opening at this level of the four faces trawl limited fish attempts to escape, resulting in no clear difference in catches between the two gears. However, fast swimming pelagic fish such as sardine show a significant escapement through the large square mesh panel.

Square mesh panel (80 mm gauge) on the « baitings » (last tapered section)

Single bottom trawlers of 20-24 meters length using a two faces trawl with 80 mm mesh size codend in the Western Channel.

This device is adapted for the fleets targeting whiting and not having haddock an cod bycatch issues, which is the case for vessels operating in the Eastern Channel and the East part of the Western channel. The 80 mm square mesh was chosen to fit to the commercial sizes of whiting targeted by this fleet. The results evidenced a significant decrease in small whiting catches below 30 cm. Large escapement of small sizes of mackerel and horse mackerel were also observed. A commercial loss was detected on the third commercial size category of mackerel (20-30cm) but it could probably be supported by the vessels.

Square mesh panel (80 mm gauge) on the « baitings » + extension and 4 faces codend

Single bottom trawlers of 20-24 meters length using a four faces trawl with 100 mm mesh size codend in the Western Channel.

This device enabled to decrease small haddock catches below 34 cm and whiting below 32 cm, as well as mackerel and horse mackerel bycatch. Nevertheless, commercial losses were observed on whiting between 33 and 36 cm and red mullet. The following case study attempted to improve this selective device for the same métier.

T90 panel (80 mm gauge) on the «baitings» + extension and 2 faces codend

Single bottom trawlers of 20-24 meters length using a four faces trawl with 80 mm mesh size codend in the Western Channel.

Despite a difference observed between the seasons of tests (autumn and winter) and between the trawls used, the T90 in 80 mm seems to be the optimum mesh size in order to target whiting above the fourth commercial size category (27-32cm). The selection size is around 33-35 cm according the statistics and measures made on meshed whiting into the device. In addition, the selective device let undersized haddocks and small sizes of mackerel and horse mackerel escape. Finally, the good vertical opening of the T90 upper panel allowed squids to go straight to the codend so no loss was observed for this species neither for red mullet.

Large T90 panel (100 mm gauge) on the extension as an alternative to the mandatory 120mm square mesh panel

Single bottom trawlers of 20-24 meters length using a four faces trawl with 100 mm mesh size codend in the Celtic Sea.

The main objective of this case study was to find a more appropriate device than the 120 mm SMP to reduce haddock discards and keep the commercial catches (especially hake and big haddock). On the basis of previous trials, it was decided to use a 100 mm T90 mesh to fit the target fish sizes and increase the selective area (x 4) - Figure 12.5.1. The results were positive: the T90 panel allowed small hakes and haddocks to escape while keeping the commercial sizes - Figure 12.5.2. Moreover, the T90 let escape boarfish but not in a massive way compared to the 120 mm SMP, which is already selective.

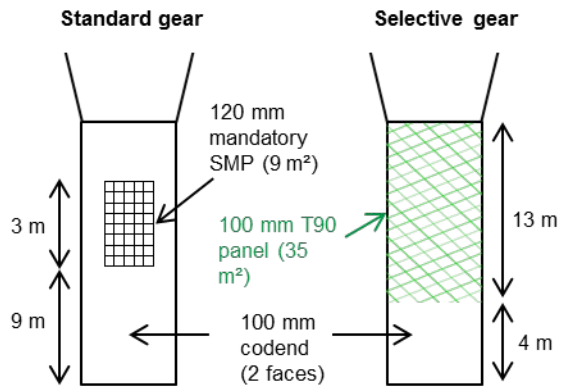
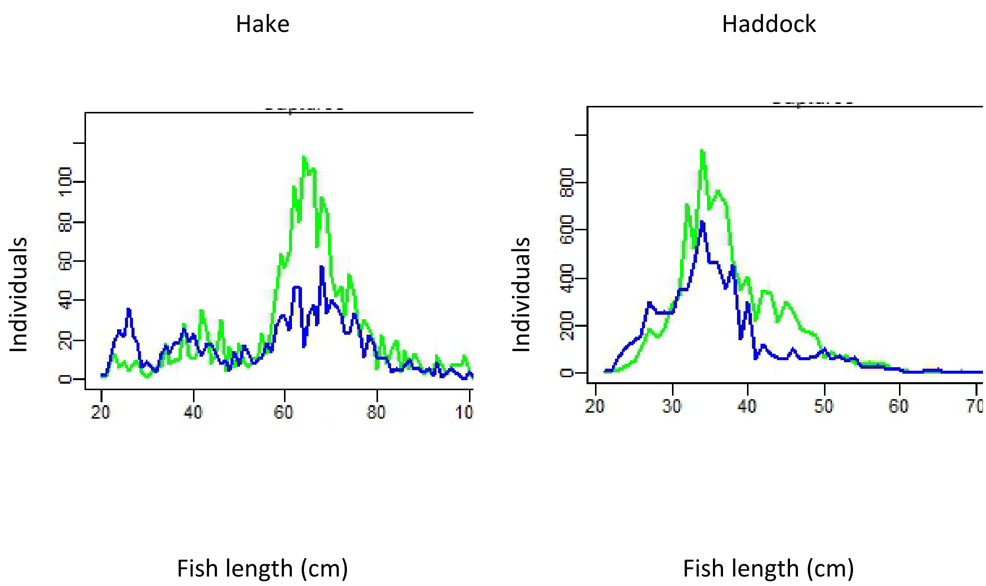


Figure 202.5.1: position of the large T90 100mm panel in the extension.



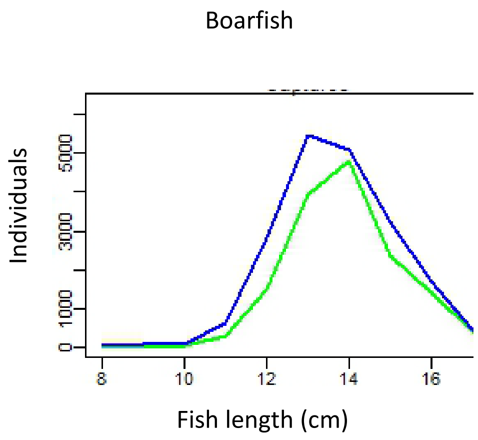


Figure 121.5.2: Large T90 panel (100 mm gauge) on the extension as an alternative to the mandatory 120mm square mesh panel - Size distributions of catches from the tested gear (green) and the standard gear (blue) in alternate trawling protocol.

These studies aim to provide a "tool box" for skippers. This idea is justified by the fact that all the selectivity experiments showed that the escapement of the same selective device can be highly variable across fleets, gears, seasons, etc. So there is not a "one fits all" solution and the fisher might have a choice between several selective devices in order to choose the one that best fits to his activity.

REDRESSE: Discards reduction in the trawl fisheries of the Bay of Biscay

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January 2014 – March 2018

The leader of this project is the AGLIA (Association du Grand Littoral Atlantique). Other partners are IFREMER, CNPMEM (French National Fishermen Committee) and the South Western Waters RAC (Regional Advisory Council). The financial partners are « France Filière Pêche » association and the 4 Regions Councils of the Atlantic french coast, Brittany, Pays de la Loire, Poitou-Charentes and Aquitaine.

The landing obligation implemented under the Common Fisheries Policy promoted the development of fishing gear selective devices. The REDRESSE project conducted in the Bay of Biscay was the opportunity for trawl fleets targeting cephalopods, Nephrops and demersal fish to continue to test various selective configurations to reduce their discards levels. The sea trials were carried out onboard commercial fishing vessels and the experimental tows were sampled by an observer. Most of the selective devices were tested under the twin trawl method, with the gear to be tested on one side and the standard commercial gear on the other. Other devices were tested with the parallel or alternate haul method. The data obtained were used to describe the catch species composition as well as their length profiles. Discards and escapement rates of both discarded and commercial fractions were also calculated. Comparison of discards and commercial catch rates showed the pros and cons of each device tested. The results per species and configuration will allow the fishers to make these devices their own according to the specificities and species composition of their fisheries.

SMAC Sole of the Eastern Channel: improvement of the knowledge for a better management of the stock

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December 2015 – December 2019

Ifremer leads this project which aims at improving our understanding the dynamic of the Eastern English Channe Sole stock. Other partners are Agrocampus Ouest, and the UMR Borea, the three Producers Organizations working in this area: the FROM North, the CME and the OPN; and finally two regional fishers Committees from Normandy and “Les Hauts de France”.The funding partners are “France Filière Pêche”, the Fisheries and Aquaculture French Authority, the regional councils of Les Hauts de France and Normandy, as well as by the three participating research institutes.

One of the work package focuses on analysing the fishing practices and compare the selectivity of soles trammelnets, which are of different design between Normandy and the “Hauts de France”. The first ones have a meshing of 100mm and the second 90mm, but their materials and their height are also different. An experimental net with a new rigging was also tested.

ENSURE: Evaluation of discards survival

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

June 2014 –December 2017

This project is carried out by IFREMER. The other partners are the three “Normandie”, “Hauts de France” and “Pays de la Loire” Fishermen Committees. The project is funded by the association France Filière Pêche and by the Fisheries and Aquaculture French Authority.

The landing obligation introduced in the last European Common Fisheries Policy requires all catches of species under quota to be landed. However, an exemption could be granted for species which “scientific evidence demonstrates high survival rates”. To determine fish survival rate, captivity observations are often used for small sized fish (e.g. plaice and sole) or *Nephrops*. However, for large species such as skates and rays, these methods are more difficult to employ because fish storage limited capacity in tanks. Thus, little information is available on skate survival after release despite an identified high survival potential. In this project, we proposed to use acoustic telemetry to study discarded skates survival in the French Bay of Biscay. Skates were captured from a commercial fishing boat using an otter trawl. Each specimen was examined for vitality state in order to identify whether individuals in excellent or good vitality state have better chance to survive. One hundred and fifty skates were tagged with miniature acoustic transmitter attached to the back of the fish in May 2017. Survival was assessed with 15 acoustic receivers deployed in a semi-enclosed bay and a mobile reception antenna deployed from a boat every month to cover the whole bay. This experiment aimed to confirm the high survival potential of skates not only to grant an exemption to the landing obligation but also to gauge the efficacy of prohibited status of some species whose survival would be valuable for stock replenishment.

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 2022

The goal of the BAITFISH project is to develop fish pots, that will be optimum in targeting commercial fish species, will have low impacts on ecosystem functioning and that will be used by fishers on a regular basis. For that purpose, an ecological approach will be used first to describe fish species ecological characteristics. Then this knowledge will serve to design pots and use them under optimal fishing conditions. Once operational, the gears will be transferred to fishers for testing and their potential impacts will be assessed.

TETRIS: Evaluation of trawling impact on benthic communities

Contact person : Dorothée Kopp, dorothee.kopp@ifremer.fr, Ifremer Fishing gear technology and biology laboratory – Lorient

January 2017 – December 2022

Based on towed underwater videos, diversity patterns and their main environmental and anthropogenic drivers were assessed in the "Grande Vasière" (northeast Bay of Biscay), one of the main French fishing grounds. The density of bentho-demersal megafauna were recorded along 152 transects in this area in 2014. The largest number of taxa and densities were observed on the external margin of the Grande Vasière, in deep areas with low fishing intensity. The highest levels of taxa evenness were located on the central and coastal parts that are shallower and exposed to medium to high trawling intensity. Multivariate analysis identified four different communities driven by fishing intensity, depth, sediment type and bottom current speed. We distinguished three communities in the centre of the Grande Vasière located in medium to highly trawled soft sediments and characterized by hydrozoans, crustaceans and fish. A fourth community was identified on the external margin, in deeper grounds, undergoing lower trawling intensity than the other communities and dominated by sessile filter-feeders. The fragile taxa observed in this study were rarely (if ever) observed by previous studies using scientific trawl sampling. Underwater video thus allowed collecting unprecedented data by direct visualization of the seabed and the observation of fragile taxa that cannot be effectively sampled by traditional scientific sampling methods used in previous studies.

LANGOLF-TV

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

Since 2014

The annual survey (since 2014) 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 RV Gwen-Drez until 2013.

This fourteen days survey has been carried out since 2014 aboard a ship of the Irish P&O (RV Celtic Voyager or RV Prince Madog in 2015).

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" (239 stations in 2018 - Figure 12.5.3). 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.

These videos, saved on DVDs (the use of a high-definition camera is planned for next year) are analysed 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 mission.

The results of this survey are used, after processing, in the Bay of Biscay Nephrops stock assessment carried out at the ICES Working Group WGNEPS.

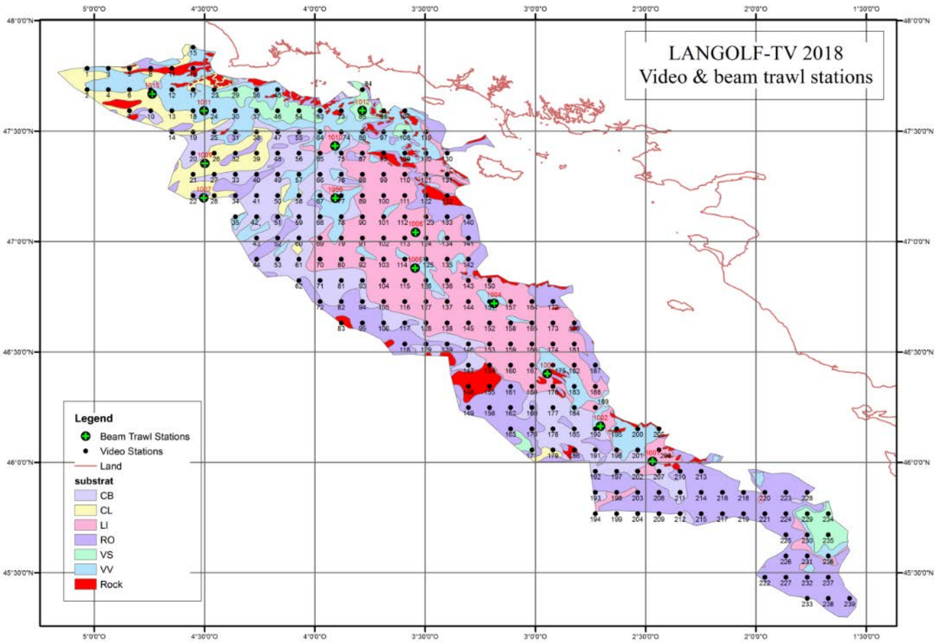

Figure 12.5.22: Video and beam trawl stations – Langolf-TV 2018.

12.6 Germany

Thuenen Institute of Baltic Sea Fisheries

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

Summary

In Germany, research related to fishing gear was conducted by the Thuenen Institute of Baltic Sea Fisheries. The focus of the research in 2017 and beginning of 2017 was

- understanding and improving of trawl selectivity, incl.
  - o codend size selection in Celtic Sea trawl fishery
  - o grid systems in North Sea brown shrimp fishery
  - o pulse characteristics in North Sea brown shrimp pulse-fishery
  - o evaluation of (industry propsosed) new legal codend in the Baltic Sea
  - o technical-extrinsic and fish-intrinsic factors influencing selectivity in trawls
- reduction of unwanted bycatches of marine mammals and birds in gillnets, incl.
  - o modification of gillnets
  - o improvement and test of alternative fishing gears

Projects

Investigating codend size selection in the Celtic Sea trawl fishery targeting megrim, monkfish and hake.

Contact person: Juan Santos, juan.santos@thuenen.de

03/2016 –06/2017 (two cruises)

The sustainability of several European bottom-trawl fisheries is challenged under the obligation to land all catches of listed species. This is also the case in the Spanish fishery targeting Megrim (*Lepidorhombus spp.*), Monkfish (*Lophius spp.*) and Hake (*Meluccius merluccius*) in the Grand Sole Bank (ICES Divisions VIIg,j,h). Data obtained at sea by onboard-observers indicate a remarkable problem of selectivity, due to, among other reasons, the lack of efforts to optimize the fishing techniques applied. Technical regulations force the use of codends with minimum mesh size (MMS, stretched mesh) of 80 mm in all cases, increasing to MMS of 100 mm when expected catches of hake exceeds 20%. Fishers are forced to use the later codend in areas with juvenile hake, regardless catch percentages. While it is expected that the 100 mm MMS codend increase the escape possibilities of undersized hake, the industry has repeatedly claimed this codend (T0-mesh configuration) to produce considerable losses of commercial sizes of the targeted megrim (>25 cm total length). A collaborative project between Cooperativa de Armadores de Vigo (ARVI-Spain), Instituto Espanol de Oceanografía (IEO-Spain) and Thünen Institute (Germany), investigated the selectivity properties of the mandatory codends, and proposed ways of improving codend selectivity in the targeted fishery. Experimental sea trials were conducted onboard the 64,50m, 2900kW German RV/ Walter Herwig III in the Grand Sole bank in June 2017 (a test cruise was conducted in March 2016). The selectivity properties of four different codends - included the mandatory codends (80 mm and 100 mm MMS), and two alternative codends were successfully quantified using codend cover methodology. The alternative codends used the same netting as the mandatory ones, but in T90 configuration. The results obtained, supported the historical claims of the fishers, as the T0-100 mm MMS legal codend significantly reduced the catchability of targeted sizes of megrim compared to the legal T0-80 mm MMS codend. On the other hand, significantly larger amounts of undersized hake were caught by the T0-80 mm MMS codend. Our results indicate that using a T90 codend with a MMS of 80 mm could significantly improve the selectivity of the fishery. For this codend, the catch efficiency on the targeted megrim was similar to the catch efficiency observed for the legal 80 mm, while providing similar escape possibilities for undersized hake as the T0-100 mm codend. Catches obtained during the sea trials were used to successfully collect FISHSELECT data for megrim, hake, boarfish (*Capros aper*) and catshark (*Scyliorhinus canicula*).

Innovative grid designs for brown shrimp size selection

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09/2017 (one cruise, SO739)

The brown shrimp (*Crangon crangon*) fishery is socio-economically one of the most important fisheries in the North Sea. It supports an international fleet of about ~ 500 vessels, employing more than 1000 fishers, and producing yearly revenues up to ~100 million €. In recent years the producer organizations of brown shrimp have initiated a certification process of the fishery by the Marine Stewardship Council (MSC). One of the key criteria for successful certification is an established management system, which should lead to the application of technical measures to improve the exploitation patterns of brown shrimp. Under this context, researchers pointed the need of conduct investigations on codend selectivity in the fishery. This need was mainly addressed within the German project Crannet, launched in 2013 to investigate the size selectivity of a large number of codend designs, varying in mesh configuration and mesh size. Size selection curves obtained during the experimental trials were subsequently applied to simulation tools based on brown shrimp population dynamics, developed to identify codend designs to better contribute in the economic and ecological sustainability of the fishery. Although the project delivered clear recommendations, it was identified that applying sharper size selection curves than those provided by the tested codends might greatly benefit in the sustainability of the fishery. As grids might have a sharper selectivity, a joint German/Dutch cruise on FRV "Solea" was conducted to test several innovative grid systems proposed by Dutch fishers (09/2017, Cruise SO739). This study focused on ways to achieve steeper size selection curves for brown shrimp. The grid systems tested were designed and constructed by the Dutch Industry (Visserijbedrijf Van Eekelen). One of the innovative devices is an adaptation of the grid system tested during SO725 for Nephrops fishery (figure 12.6.1 above). The second design consists of four smaller grids that cover half of the tunnel and are installed after each other all with an individual escape opening (figure 12.6.1 below). The codend designs were fitted to a pulse net and several modifications were tested. Preliminary results show that the first design showed the greatest potential to sort out small and marketable shrimp. Both, the industry and the researchers see potential in the development of grids to be used on a commercial scale.

Results pending, since the length measurement of shrimp is time consuming and still in progress. Preliminary results are expected in summer 2018.

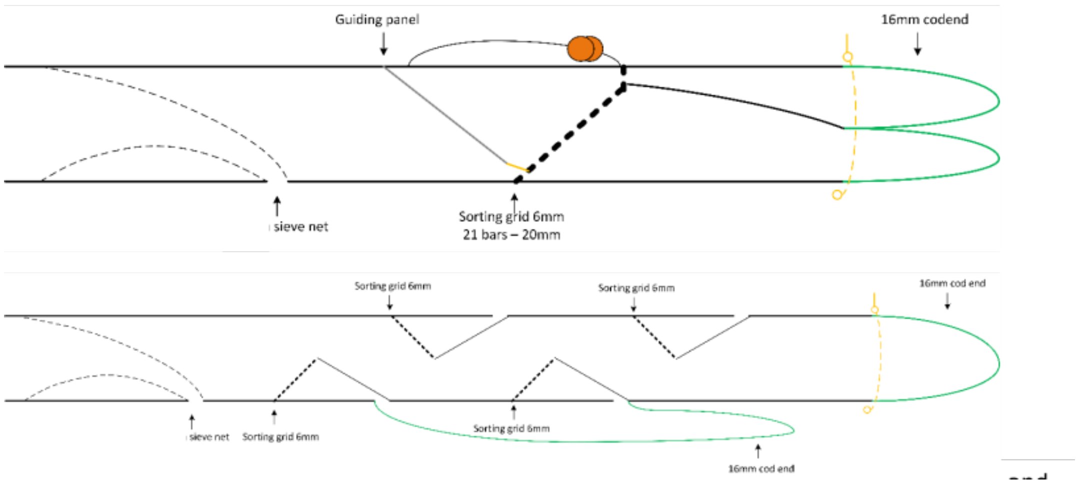

Fig 12.6.1: Side view of the both grid systems tested.

Optimizing pulse characteristics for brown shrimp pulse trawl fishery (part II – field tests)

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

2017 (two cruises)

In 2016, we have conducted with Belgium (Bart Verschueren) and French (Julien Simon) colleagues an experiment to re-evaluate the performance of main pulse-parameters on the startle-reaction of brown shrimp (*Crangon crangon*). Based on the finding of these experiments, the pulses could be shortened and number of pulses could be potentially reduced. For further information on these experiments, please refer to the National report 2017.

To evaluate these findings in the field, two cruises were conducted onboard FRV "Solea" in 2017 (03/2017 and 09/2017). Participants from Germany, Belgium and the Netherlands participated in the cruise. We have used the newly developed pulse-trawl system from LFish (Belgium), which allowed the easy adaptation of specific pulse parameters (such as voltage and pulse duration).

The results from these cruises are pending, since the length measurement of shrimp is time consuming and still in progress. Preliminary results are expected in summer 2018.

The selectivity properties of the new legal codend in the Baltic Sea

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11/2017 (one cruise, SO741)

In the Baltic Sea, the volume of bycatch of small cod (*Gadus morhua*) below Minimum Conservation Reference Size (MCRS=35 cm) is still unacceptable for the industry, considering the obligation of landing all cod catches and counting them against quotas. For a better use of the available quota, the industry searched for technical solutions which should lead to reduced catchability of small cod. The solution proposed was a redesign of the T90 codend, implemented in the Baltic since 2010 (UE 686/2010). In particular, the proposal includes a reduction of the minimum mesh size from 120 mm to 115 mm, an increment in codend circumference from 50 meshes to 80 meshes, and an enlargement of the minimum length of the codend from ~6 meters to 9 meters. Two different sea trials conducted on commercial vessels and based on catch comparisons between the legal T90 codend (referred as T90-2010) and the industry proposed codend (T90-2018) were carried out in 2016. During the commercial sea trials, the T90-2018 codend caught significant less small cod (≤34 cm) relative to the T90-2010, while the catches of sized individuals between 38 cm and 52 cm were significantly higher. The Scientific, Technical and Economic Committee for Fisheries of the European Commission received and assessed the Industry proposal in July 2017 (STECF-17-08). Considering the aim of the industry, the STECF concluded the modified codend to provide positive benefits in terms of reducing unwanted catches of cod below MCRS. However, the STECF also recommended "further experimentation" and in particular advised "selectivity experiments to determine the absolute selectivity of the modified codend compared to the standard gear". Following the recommendations from the STECF, we used FRV "Solea" (cruise SO741) to quantify the selectivity properties of the T90-2018 using the cover codend method (Wileman 1996). For comparison, the selectivity properties of the T90-2010 and the previous T90-2005 were also quantified during the same cruise and in the same experimental conditions. The tested codends were constructed by local netmaker and following the preferences of fishers (see Table 12.6.1 for technical details, it was impossible to get the original codend from industry trials). Average size selection curves were successfully estimated for the proposed codend (8 hauls), the T90-2010 codend (10 hauls) and the T90-2005 (8 hauls). The results conflict with the catch comparison experiments in commercial vessels. The L50 estimated for the T90-2018 was the lowest of the three codends tested, while the Selection Range was similar to the T90-2010 codend (Figure 12.6.2). A small simulation was conducted to assess the expected bycatch of small cod expected from each of the codends. This was done by applying the size selection curves estimated on a simulated cod population, based on observed lengths structure from Baltic Sea Subdivision 24, 4th quarter of 2016 (from the Baltic International Trawl Survey). The results of the simulation also conflict with the industry tests, being the largest bycatch ratio estimated for the T90-2018 (Figure 12.6.2). The T90-2018 codend was implemented in the Baltic Sea in January 2018 (EU 2018/47) without having understood the conflicts between the results obtained in the catch comparison and the cover codend experiments.

Table 12.6.1: comparison of design characteristic of tested codends.

Codend	SMO (mm)	Mesh orientation (°)	Twine thickness (mm)	Material	number of twines	meshes circ. (n)	Meshes long. (n)	Longitude (m)
T90-2018	115.4	90	4	PE	2	80	85	~9
T90-2010	127,3	90	4	PE	2	50	77	~9
T90-2005	115,4	90	4	PE	2	50	84	~9

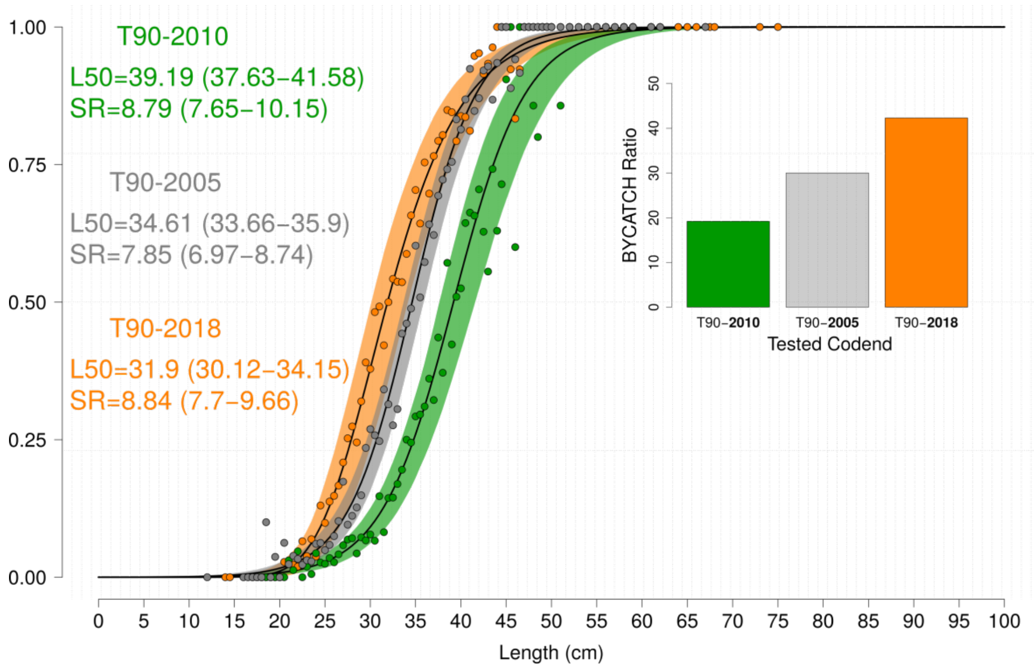

Figure 12.6.2: Selectivity curves and bycatch ratios of tested codends (95% confidence inter-val in brackets).

Investigating technical-extrinsic and fish-intrinsic factors influencing Baltic cod selectivity in trawl gears

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01/2018 (one cruise, SO744)

Research topic a) extrinsic factors: Trawl selectivity studies usually focus on quantifying species selection and size selection within-species for a given gear design. For the later objective, researchers are especially interested on quantifying the selectivity of trawl codends, because this is the part of the gear where catch accumulates and therefore where most of the size selection occurs. It is common knowledge that changes in the codend design can influence size selection significantly. In addition to the wide range of constructive details to control size selection, codend selectivity can be strongly influenced by non-controlled variables even between successive hauls within the same fishing trip (Fryer, 1991). Two examples of technical-extrinsic factors influencing selectivity are catch volume and state of the sea (O'Neill et al., 2003; Herrmann, 2005; O'Neill and Kynoch, 1996). Based on previous experiences, there are indications that the by-catch of flatfish can influence the size selection of cod. Therefore, special attention has been paid on investigating the composition of catches in cod selectivity. Therefore, we used FRV "Solea" (cruise SO744; 01/2018) to further investigate technical-extrinsic factors influencing between haul variation. A T90 codend with 105 mm nominal mesh size and 50 meshes in circumference was used as test. Additionally, FLEX (FLatfish Excluder, see national report 2017) was mounted ahead of the codend. Experimental hauls were conducted using cover codend method (Wileman 1996) enabling the collection of samples from the catch and the fraction of fish who escaped through the codend meshes at haul level. Since FLEX setting (open/closed) can be switched even between successive hauls, this device was used to control flatfish catches at haul level. A Latin-square experimental design considering different hauls durations and FLEX setting was applied, in order to avoid potential collinearity between total catch volume and flatfish catch volume.

Research topic b) intrinsic factors: Based on the huge effort invested in the development and implementation of new codend designs in the Baltic Sea, and the limited success achieved in terms of stock recovery, it must be questioned whether the selectivity induced so far in the fishery has been correctly described and quantified from a biological point of view. As the term "size selection" implies, the size of the fish is globally used as proxy to determine the fate of a fish once it enters in the trawl codend. Tschernij and Suuronen (2002) and Özbilging (2006) investigated if fish individual traits different from body length can influence their ability to escape through the meshes. In particular, these studies investigated the seasonal variation of codend selectivity for cod in the Baltic Sea and haddock in the North Sea, respectively. Both studies found that the selectivity of cod vary inter-seasonally, likely due to differences in the physiological condition of the fish, related to its the biological cycle. Motivated by the mentioned studies, the research cruise SO744 was also used to investigate the influence of individual fish traits on codend selectivity. Two linked sampling protocols were conducted to address this topic. The first protocol was carried out in the web lab to measure individual traits such as sex, maximum girth, gutted weight, liver weight (…) from cod sampled in the codend and cover, separately. The second protocol was conducted in parallel, whereas only live fish collected from the codend and the cover were used. In addition to the individual traits mentioned above, heart and white muscle samples were collected to quantify the activity of enzymes involved in the mitochondrial respiration chain, citrate synthase and lactate dehydrogenase which are respectively indicators of aerobic and anaerobic capacities and can be interpreted as proxies of swim performance in fish. Based on findings from experimental studies and the general fishing mechanism of trawls, it can be expected that traits related to energy metabolism and swim performance are linked to vulnerability to capture in fish (Killen et al. 2015). Similarly, differences in performance traits might influence the ability of an individual to escape from the codend of a trawl. Studies investigating the link between physiological phenotype and ability to escape fishing gear are however lacking (Hollins et al. 2018), which we try to address by the analysis of the data collected in the second protocol. Enzymatic analysis of collected tissues will be conducted at the Institute of Biodiversity, Animal Health, and Comparative Medicine of the University of Glasgow by the Killen-lab.

Catch data and enzyme analysis ongoing. Preliminary results expected during autumn 2018.

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

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01/2018-12/2020

To protect the bottom side of beam trawls (targeting sole or brown shrimp), it is often provided 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 bottom trawling are the so-called „dolly ropes". These are Polyethylene ropes (PE ropes), which are cut to size by the fishers 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 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-projects mainly focused on alternative materials, the new project DRopS aim 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 will focus on the shrimp fishery in the North Sea.

During the project, four different approaches will be evaluated

- Change of gear design, incl.
  - Cutting of the gear: The cutting of the beam trawlnet may provide opportunities to further lift the codend from 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.
  - Achieving a constant cylindrical shape of the codend through ring reinforcements (strengthening ropes) and thus preventing increased diameters at the end of the codend: The end of codends in T0 mesh orientation typically balloon with increasing catch size. This change in circumference could be limited by strengthening ropes.
  - Testing of hydrostatic and hydrodynamic floating devices, such as kites.
  - 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.
- 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:

- Benthos Release Panel (BRP)
- Changes of the groundrope

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

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01/2017 – 12/2019

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

Fishing with gillnets is 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 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 harbour porpoise in the Western Baltic. While gillnet fishing is a highly size selective fishing method, unwanted bycatch includes higher trophic species like harbour 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 fishers 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 fishers. The project comprises the following: 1) estimating fishing effort of the local gillnet fisheries and identifying behavior patterns of different fishers groups. 2) development of gillnet modifications to minimize bycatch of marine mammals and seabirds 3) development of alternative fishing gears 4) analyse motives of fishers 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. In a large field experiment, the efficacy of equipping a gillnet with these acrylic spheres on deterring porpoises from the nets will be tested in summer 2018. Porpoise behavior around modified and standard gillnets will be monitored through acoustic as well as visual observation tools.

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

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

This work package deal with different topics:

- 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 it will be attempted to identify the different influences of entrance parameter on entry- and exit rates into and out of a cod pot with exchangeable entrances ("experimental pot") in a net pen with individually marked cod and flatfish. The fish will be observed will be observed using video camera (daylight and IR sensible for night-time observation) 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). In the next phase, the best performing entrances (ratio no. exits/ no. entries) will then again pitted against a variation of this design. In the last phase entrances with the best parameter combinations will be pitted against variations of this design.
  This will allow controlling for environmental variables (e.g. temperature or cod presence/absence) and to test for individual differences in entry- and exit behavior and link it to fish characteristics (length, age, fitness). The expected outcome is the identification of the influence of cod pot entrance parameters on the entry- and exit rates and thus the catchability of cod pots. The aim is to identify a description of an optimal cod pot entrance for the (German) Baltic sea cod pot fishery. A subsequent study will be undertaken in the field in an actual pot fishery to compare this optimal entrance to (a) common pot entrance(s). The experiments started in May 2018.
- Optimal bait identification for cod potting: 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 potting 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 potting 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 re-

source-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. In a follow-up study, we will want to field test the best performing baits in the field using long-term baited remote underwater infrared video systems (IR-BRUVs).

- Ponton trap trial in Germany: A ponton trap will be tested by a fisher in the Greifswald bay (Southern Baltic Sea). Expected outcome is a catchability description for different target species and a suitability evaluation of this gear for the German SSF. In a later stage this shall be compared to catch results from ponton traps in other areas (DK, SE).

12.7 Iceland

Marine and Freshwater Research Institute (MFRI)

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Summary

Projects have been carried out largely as outlined in 2017 and new projects, such as the gear innovation for lumpfish (C. lumpus) fisheries, fishscanning and quantitative assessments of fishing gear as source of marine litter, have been initiated.

In spring 2017 a new member has permanently joined the gear-team. Georg Haney will work in projects concerning gear innovation as well as assisting in existing projects and survey trawl monitoring.

Projects

Selectivity in four panel T90 codends

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

2014 – 20?

In 2017 the selectivity of a four-panel codend with 110mm T90 meshes was tested compared with a 135 mm regular codend. The target species was redfish (Sebastes norvegicus) and trials were carried out during tows on a commercial vessel. A fine meshed It was shown that the T90 codend has a higher L50 and significantly narrower selection range. One issue with the T90 in redfish fisheries is the higher amount of stickers in the codend. While the length distribution of those individuals mirrors the improved selection range it is an issue that needs to be addressed.

Further, the gear group of the MFRI will assist their colleagues in Canada in the large redfish project currently underway there.

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 fishers 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. Based on observer data the fisheries lost its MSC certification for the year 2018. The need to address the bycatch problem was apparent before but now also can have serios economic implications for the future of the fisheries. The MFRI has decided to launch a pilot project to analyse the possibility for alternative harvesting methods. They must eliminate the bycatch of seabirds and marine mammals as well as be feasible for the fleet of small vessels currently engaged in the

lumpfish fisheries. The project is currently in its inception and awaiting the decision on seed funding. The project will be executed in close consultation with fishers and any interested party.

Fishscanning

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2018 – 2021

This is a development work starting at the end of this year 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 fishers 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.

Information obtained from the planned sensor array will also add intelligence to pelagic and bottom surveys by allowing to pinpoint where fish are collected into the sample trawl.

OptiGear

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2017 – 2019

OptiGear aims to develop and implement a software to collect and analyse 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 analysing 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.

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 seabed. Over the last year it has been tested on various target species and has shown promising reactions for shrimp and haddock. So far this gives a glimpse into to the possibilities of this innovative technology and further funding applications are pending to continue sea trials and modify the prototype.

Fishing gear as contributor to the problem of marine plastics

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2018 – 2019

While the issue of marco and micro plastic has finally made it into the public debate, at least in the countries of the North Atlantic, the knowledge gap and lack of data still hampers adequate scientific solutions.

Part of a broader engagement by the MFRI in the issue of marine waste, a new way to register and classify fishing gear found during research tours will be implemented. This will be used to build a database that together with geographical location will over time give a better picture of the scale and distribution of lost and discarded gear in Icelandic waters. The main contributing tours are the spring and fall groundfish surveys with over 1000 stations combined.

12.8 Ireland

Bord Iascaigh Mhara (BIM), Ireland’s seafood development agency

Contact person: ronan.cosgrove@bim.ie

Summary

Ireland continued to carry out studies related to the avoidance of unwanted catches in 2017. With a value of €63 million in 2016, Nephrops norvegicus is currently the most commercially important fisheries species landed by Irish vessels. However, unwanted catches of small and/or quota limited whitefish such as cod, whiting, haddock, as well as small Nephrops need to be reduced in order to prevent ‘choking’ under the landing obligation and to optimize quota use.

In 2017 a number of gear trials were carried out in Nephrops and whitefish fisheries with an additional Nephrops survival exeperiment carried out in support of an application for exemption to the landing obligation on the grounds of high survivability.

Projects

A general catch comparison method for multi-gear trials: application to a quad-rig trawling fishery for Nephrops

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

January 2017

https://tinyurl.com/ycooxq6r

BIM completed a study which provides a new statistical methodology for comparing catches from more than two gears such as in quad-rig trawling which is the main gear type used in the Irish Nephrops fishery. The study was published in the ICES Journal of Marine Science in January. Factors which affect gear trial outcomes such as catch weight, net position, day/night hauls can now be included catch comparison analyses.

Raising the fishing line to reduce cod catches in demersal trawls targeting fish species

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

March 2017

https://tinyurl.com/raisedfl

This study aimed to raise a demersal trawl's fishing line up to 1 m above the groundgear to allow cod escape while maintaining whiting and haddock catches. The twin-trawl catch comparison trial took place in the Celtic Sea. Cod catches were reduced by 39% by weight, while whiting and haddock catches increased by 87 and 37% by weight respectively, in the raised fishing line compared with a standard fishing line. This led to an increase in total catch value of 14% offsetting the loss in catches of commercial species such as flatfish and monkfish in the raised fishing line. Catches of skates and rays were also reduced by 80% by weight in the raised fishing line. Under a fully implemented landing obligation scenario, the raised fishing line postponed choking on cod from 8 to over 11 hauls but had little effect on haddock.

Assessment of an inclined panel and flotation devices in the SELTRA

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

April 2017

https://tinyurl.com/y6uqqrjh

The first part of this trial focused on whiting catches < minimum conservation reference size (MCRS) of 27 cm that represent a major potential choke issue in the Irish Sea (ICES VIIa). Previous trials showed that the SELTRA achieved a 53% reduction in < MCRS whiting compared with a standard trawl in this fishery but did not reduce catches of very small whiting < 20 cm. In this trial an inclined separating or guiding panel was fitted to the SELTRA and reduced catches of < MCRS whiting and *Nephrops* by 33 and 12% respectively, but was ineffective for very small whiting < 20 cm. Additional work using a camera was undertaken to assess three different float configurations on the SELTRA's 300 mm square mesh panel. The video footage was of major benefit in determining optimal float configuration on the SELTRA which remains an important gear measure in addressing challenges posed by the landing obligation.

Nephrops survivability in the Irish demersal trawl fishery

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

July 2017

https://tinyurl.com/y9umf9nb

The aim of this study was to assess Nephrops survivability using a SELTRA in the Irish demersal trawl fishery for Nephrops to support an application for a high survivability exemption for Nephrops under the landing obligation in ICES area VII. The trial was conducted during summer when air and water temperatures were exceptionally high which provided a worst case survival estimate. A 64% survival rate was obtained for Nephrops caught in a trawl with a SELTRA selectivity device.

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

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

November 2017

https://tinyurl.com/y72hrq7d

In this study we aimed to assess the practicalities and feasibility of deploying Dyneema sweeps and polypropylene scaring ropes ahead of quad-rigged trawls to counteract the herding effect and reduce whiting catches. The trial took place in the western Irish Sea Nephrops fishery. Neither Dyneema sweeps nor fish scaring ropes directly reduced whiting catches. The Dyneema sweeps caught substantially more Nephrops than a standard trawl rig and, consequently, may have potential to postpone choking on whiting in the Nephrops fishery.

12.9 The Netherlands

Wageningen Marine Research

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

Summary

Since last meeting, a gear technology a project has started comparing catch composition of conventional and pulse brown shrimp trawls on commercial vessels. Parallel with this project, trials to mitigate catches of undersized brown shrimp with sorting grids were performed on a research vessel. Several industry gear trials aiming to reduce unwanted undersized bycatch in the commercial sole pulse trawl fishery were done on commercial vessels, including an 80 and 90mm codend selectivity experiment. To facilitate and encourage selective gear development underwater video recordings of fish behavior were made in a sole pulse trawl. This information and other impact assessments of pulse fisheries are assembled in the 'pulse impact assessment' project. Innovative sampling and monitoring systems as 'Discard valves', application of broadband echosounder, remote electronic monitoring are further developed within Wageningen Marine Research

Projects

FLATFISH IN THE PICTURE

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

August 2015 – April 2018

https://www.wur.nl/en/project/Flatfish-in-the-picture-1.htm

FLATFISH IN THE PICTURE creates underwater video recordings of fish behavior in electrified (pulse) beam trawls. The recordings will help fishers to effectively develop selective solutions for the 80mm electrified (pulse) beam trawl fishery targeting Dover sole. However, gear innovation has not been sufficient yet for this fishery to meet the current EU landing obligation. For this fishery bycatches of undersized fish are problematic with a full implementation of the landing obligation, therefore several projects were executed to develop more selective trawls. However, none of the trawl designs are used commercially as minor discard reductions were accompanied by unacceptable losses of commercial catches. With limited knowledge of fish behavior in this fishery, development of selective devices is frequently based on trial and error without understanding the mechanism behind these devices. This underwater video recordings are available online and provide fishers and scientists with fundamental knowledge of fish behavior in electrified trawls. A method was developed to collect underwater recordings of flatfish behavior in commercial pulse trawls. With knowledge of fish behavior, targeted development of species-specific selective devices can enhance and provide scientists and fishers with information to reduce unwanted bycatch in the sole pulse trawl fishery.

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, Remote Electronic Monitoring (REM) also has the ability to improve data collection for gear technology trials. In particular, species with a lesser abundance in the catch or specific fisheries would benefit from a system like REM, 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 initiates the development of automated monitoring for different rays species in the Dutch North Sea fisheries. The first project phase will start in the second half of 2018.

DISCARD SURVIVAL FLATFISH AND RAYS

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August 2016 – December 2018

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 codend (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.

Within all species, discards survival probabilities varied among sea trips. Discards survival probability estimates and their 95% confidence intervals based on all sea trips combined were 14% (11-18%) for plaice, 19% (13-28%) for sole, 30% (20-43%) for turbot, 13% (7-23%) for brill and 53% (40-65%) for thornback ray. For spotted ray discards survival probabilities of 21% and 67% were observed during two sea trips. The proportion of fish in the best condition is small and their high survival probability has little effect on the survival probability of the entire population in the catches. Measures that aim to increase discards survival should focus on improving the condition of discarded fish.

BROWN SHRIMP PULSE

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January 2018 – December 2019

In this project the differences in selectivity of pulse and conventional gears in the Dutch shrimp fishery is investigated. Furthermore the project will contribute to further development and innovation of current shrimp pulse gears. The outcome of this project supports evaluation of sustainable management of shrimp fisheries in general and in marine conservation areas, e.g. Natura2000, in particular.

The project will run from 2018 – 2019. In the first year, 2018 a baseline study will be conducted on board of the 5 pulse trawls which are active in the Netherlands. The general question is whether or not shrimp fishing using pulse trawl result in higher amounts of undesired bycatches of undersized shrimp, fish and benthos as compared to the traditional shrimp beam trawl fisheries, and if these possible differences are affected by time and location of the fisheries. Data on catches of shrimp landings and bycatch will be collected through year-round data recording; the five puls trawlers as well as five conventional vessels record information on their catches and landings per haul. Comparative studies on board of the pulse trawls; 3 weeks per quarter the pulse trawls fish with pulse on one side and conventional on the other. Detailed data on catch composition is collected through self sampling and with observers. In 2019 the aim is to further optimize the selectivity and the performance of the pulse fishing gear for shrimp. Therefore, a meeting will be organized with pulse fishers in which an inventory of possible innovations will be presented by the consortium and discussed by all participants. Afterwards, if a derogation on the technical limitations can be obtained, a limited number of ideas will be tested by the fishers.

SEPCRAN

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June 2017 – April 2018

SEPCRAN is developing selective devices for brown shrimp fisheries. Improvement of the exploitation patterns of the largely unrestricted brown shrimp (*Crangon crangon*) fisheries have not sufficiently been addressed because the lack of management incentives. Most effort so far has been focused on the reduction of fish bycatch. The Marine Stewardship Council (MSC) certification process is the main driver behind new studies into improved exploitation profiles. This is as an addition to the work done on codend selectivity in the CRANNET project because using larger mesh sizes is seen as undesirable by fishers and to explore if a steeper selection curve could be attained.

This study focused on ways to achieve steeper size selection curves for brown shrimp. In September 2017 two selective designs made by the Dutch Industry (Visserijbedrijf

Van Eekelen) were tested onboard of the German RV Solea. One of the innovative devices is an adaptation of the grid system tested in the Dutch Nephrops fishery (Figure 12.9.1). The second design (Figure 12.9.1) consists of four smaller grids that cover half of the tunnel and are installed after each other, all with an individual escape opening. The codend designs were fitted to a pulse net and several modifications were tested. Preliminary results show that the first design showed the greatest potential to sort out small and marketable shrimp. Both the industry and the researchers see potential in the development of grids to the extend where it could be used on a commercial scale.

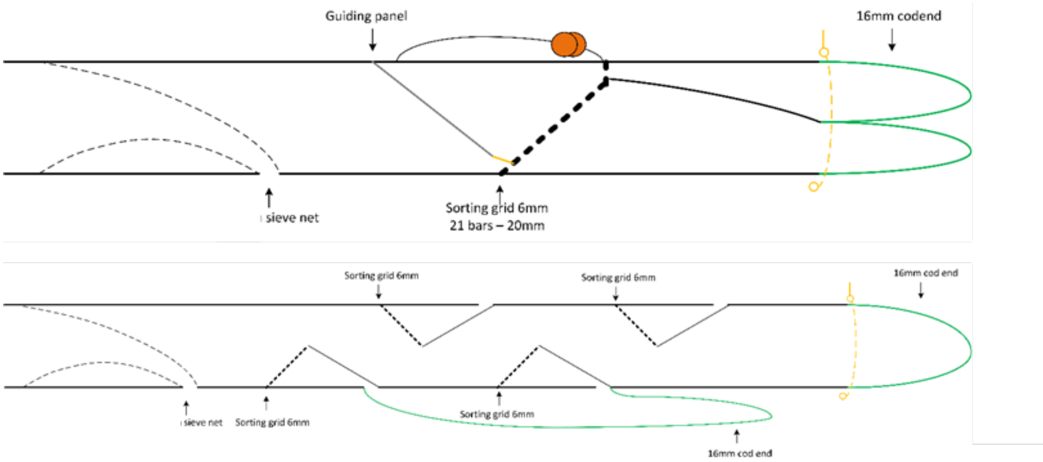

Figure 12.9.1 The single grid design after the design tested for the Nephrops fishery (above) and the design with four smaller grids (below).

ECOSYSTEM ACOUSTICS

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January 2018 – December 2018

Monitoring of the pelagic ecosystem is a key component of the statutory survey programs in the EU to deliver annual data underpinning policy drivers such as MSFD, CFP and DCF. The project aims to further develop acoustic ecosystem monitoring techniques (acoustic optical). Therefore, it will keep the methods at the most current state and explore alternative ways to apply new and upcoming techniques.

With the shift in survey focus towards an ecosystem approach, data collected on acoustic surveys needs to be supplemented with standard and complementary sensors to improve monitoring and classification of (many more) species. There are higher demands on the interpretation of acoustic data and low cost optical systems as proposed here could be used to give valuable additional information about when, where, and how much is sampled by the trawl when verifying (ground trothing) acoustic observations.

The acoustic optical net camera sampling system, that was started off previously, will be further developed (Figure 12.9.2). This will be used during pelagic ecosystem surveys for improved ecosystem characterization. Additionally trails with the net camera system SIMRAD FX80 on RV "Tridens" are planned.

Multi Beam fisheries EchoSounders (MBES) can provide detailed acoustic images of the water column across a large swathe. This provide fish school shapes in 3D and have potential to improve fish species identification but also provide information on fish behavior. Using the ME70 from RV "Tridens", processing are being developed (Figure 12.9.3).

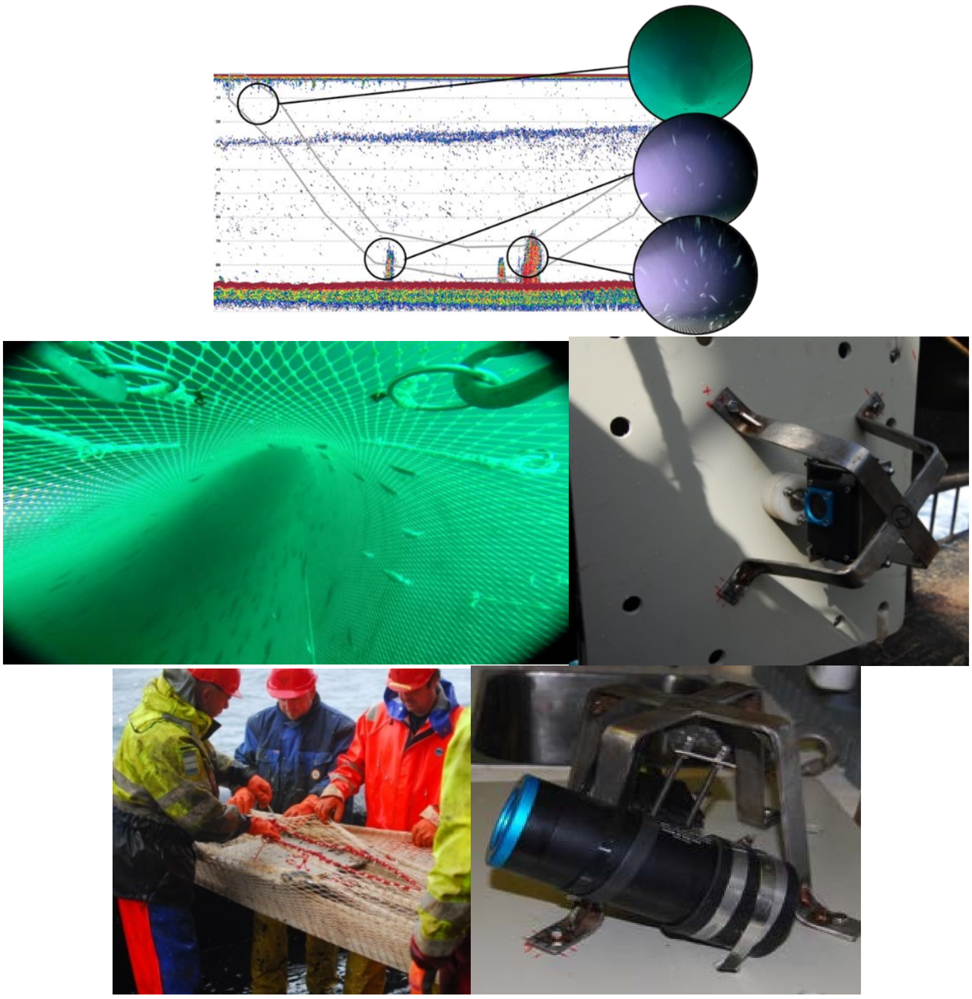


Figure 12.9.2. Impressions of the GoPro net camera system and camera snapshots associated with acoustic records.

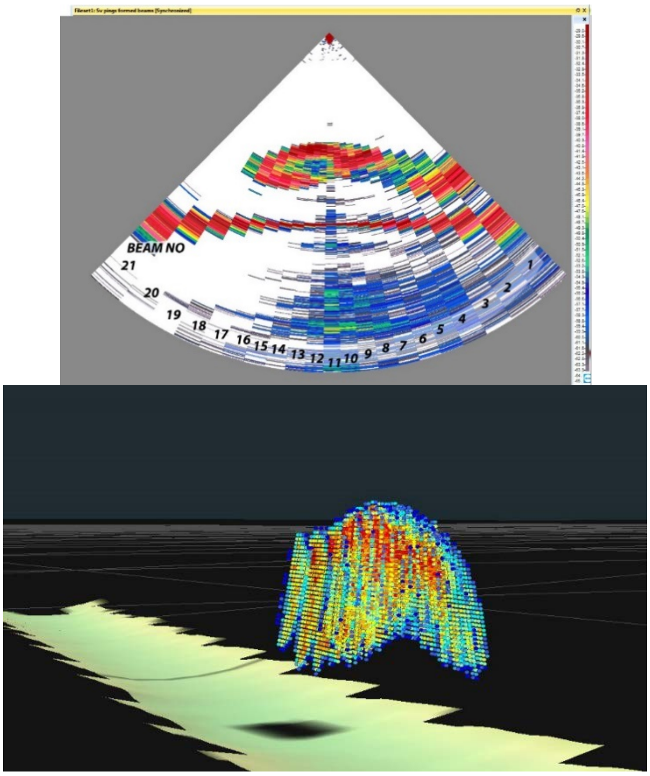


Figure 12.9.3. Impressions of the GoPro net camera system and camera snapshots associated with acoustic records.

REAL-TIME FISH CLASSIFICATION FROM ACOUSTIC BROADBAND ECHOSOUNDER

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

January 2016 – December 2019

Newest generation echosounders utilize broadband technology that can transmit a continuous frequency band in one ping. These have considerable advantages over narrowband systems, such as increased image resolution, leading to better detection of fish targets, and high frequency spectrum resolution, giving improved identification potential of the returned signal.

Through data collected by 3 fishing vessels in the North Sea, this project aims to develop a software to identify Herring, Horse mackerel and Mackerel in real time (Figure 12.9.4). Length estimation methods are also developed within this project. Machine learning methods are used as classification methods. The training of the algorithm is based on data collected by industry vessels since 2014. The resulting software will help fishers to improve selectivity in fishing activities.

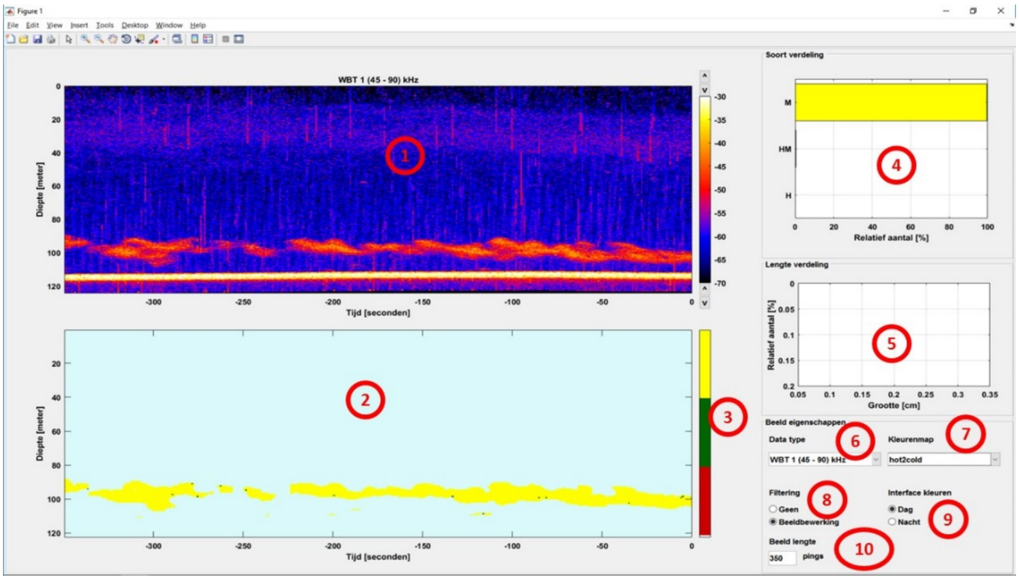


Figure 12.9.4. Screenshot of the software being developed. (1) Echogram display; (2) Fish school detection and classification display with one colour per species (see colour bar (3)); (4) species composition in displayed echogram in % for each of the species (M: Mackerel, HM: Horse Mackerel, H: Herring, 100 % Mackerel here); (5) length distribution estimate (not implemented yet); (6): drop down menu with data type selection, as displayed in echogram; (7): echogram colour map; (8):echogram filtering; (9): day/night mode (i.e. interface background colour); (10): number of pings displayed in echogram.

KB Towards a better understanding of Fishers' Behaviour

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

January 2016 – December 2018

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.

Fisheries behaviour research in fisheries science is predominantly done by natural scientists and economists. Mostly by assessing available catch and effort data and by modelling. Fisheries behaviour currently is thus approached by inferring human behaviour from statistics. From recent projects (CCTV, displacement, landing obligation) we have learned that our current research approaches can be strengthened by making use of social science methods (interviewing, focused group discussions). This 'add-on' approach can however be taken a step further by fully integrating the methods and by building a new theoretical framework of understanding fisheries behaviour. Our literature search revealed an article written by Boonstra and Hentati-Sundberg (2016) Classifying fishers' behaviour. An invitation to fishing styles, that we found a useful approach. We have decided to reproduce the method in the Dutch context. Also we have co-organized a session at the ICES ASC 2018 (session R - Towards a better understanding of human behaviour for improved fisheries science and management), to further discuss the topic. In addition we are studying possibilities to understand fishers' behaviour in waste management at sea and in harbours from a behavioural economics perspective, in order to see where opportunities lie for improved results.

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.

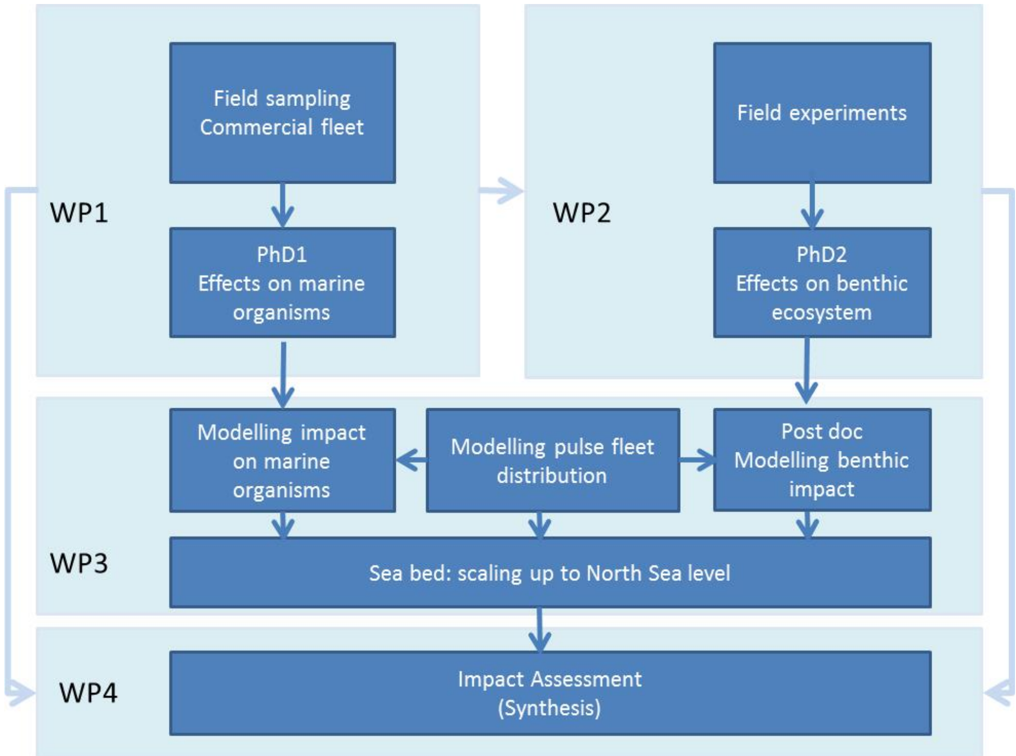
The research project comprises of four interrelated work packages using a variety of complementary approaches, that will ultimately to an integration in a 5th work package (Figure 12.9.5).

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 seabed 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 synthesized 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 organized in a flexible manner to investigate the effects of pulse trawling on the marine ecosystem. The project comprise of four work packages (figure 12.9.5) 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).



Figur 12.9.5. Relationship and flow of information between the work packages.

TRAWL INNOVATION IN DEMERSAL FISHERIES 2

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

January 2016 – December 2018

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 will be tested in the following fisheries: sole pulse trawl, plaice twin-rig, 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 many cases followed up by a detailed catch comparison with Wageningen Marine Research or ILVO scientists onboard.

In the flyshoot fishery two sea trials with escape panels, lights and camera's were done. In the sole pulse fishery trials with an electic bethos release panel were performed in 2017. For the second half of 2018 trials focusing on herding brushes ahead of the electrical stimulation and sole separation panels are planned to achieve preferred species separation. Double codends will be used to asses separated catch fractions. The Nephrops fishery is focusing on enhancing SepNep gear performance with trials on a commercial vessel and additional trials with floating sweeps and modified grids to reduce unwanted fish bycatch in conventional nephrops trawls.

AUTOMATIC DISCARD MEASURING VALVES

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

January 2018 – December 2018

This follow up project aims to develop a portable sea state compensated automatic discard weighing valve system that can be used to measure more accurate discard amounts on board of commercial vessels. It solves the problem of negative discard estimates when total catches are underestimated by observers. The development of such a system will follow a design process based on existing examples and practical expertise. The deliverables would result in a more efficient discard monitoring. Final results are expercted by December 2018 and will be disseminated in the scientific community and in the fishing industry.

BEST PRACTICES II – WP4 codend selectivity

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

January 2017 – December 2018

BEST PRACTICES II – WP4 asseses the selectivity of 80 and 90mm codends for sole (*Solea Solea*) and plaice (*Pleuronectus plattessa*) in North Sea pulse trawl fisheries. Two trails were performed in June and august 2017 on a commercial pulse trawler, with 80mm codends on starboard trawl and 90mm on portised. The selectivity was assessed using 40mm covered codends. During the trials 48 haul were sampled and all sole and undersized plaice were collected and weighed. For 26 sampled hauls sole and undersized plaice were length measured. Final results are expected in the last quarter of 2018.

12.10 Norway

Institute of Marine Research

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Projects

DEEP VISION

Contact person: Shale Rosen, shaler@hi.no

https://www.deepvision.no/deep-vision/deep-vision

The Institute of Marine Research and Scantrol Deep Vision AS continue to develop the Deep Vision camera system for identifying and measuring fish inside a fishing trawl. This work is supported by the CRISP Center for Research Innovation (http://crisp.imr.no/). Work in 2017-2018 has focused on improving the hardware design and analysis software (including automation of image analysis). Support for Deep Vision images has been added to the LSSS software package used for analysis of multifrequency acoustic data, making Deep Vision data a useful tool for interpretation of acoustic data (Figure 12.10.1).

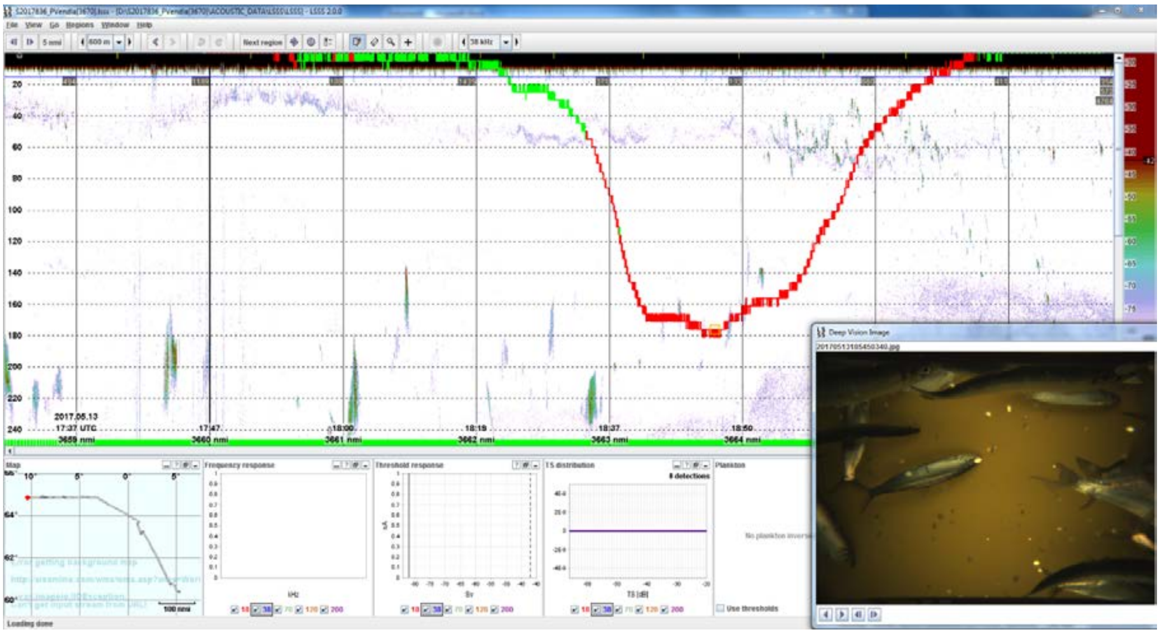

Figure 12.10.1. Ecogram with trawl path (green and red line) and Deep Vision image of Atlan-tic herring (Clupea harengus). Image was taken at position along trawl path indicated by the small yellow box.

CATCH REGULATION IN TRAWLS

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As part of the CRISP Center for Research Innovation (http://crisp.imr.no/), the Institute of Marine Research has worked for several years on a dynamic catch control system to limit catches in the whitefish demersal trawl fishery. Previous experiments have shown that the system does not work well in conjunction with selection grids which are mandatory in Norwegian waters. Experiments carried out in 2017 compared selectivity and performance of the dynamic catch control system in a twin-trawl with one codend using a standard Flexi-grid size selection device with 130 mm two-panel codend and the other using a 152 mm four-panel codend with lastridge ropes 30% shorter than the stretched length of the codend netting. The four-panel codend with short lastridge ropes was more size selective (caught significantly less undersized fish) than the Flexi-grid codend. Results from this experiment suggest that the 152 mm codend with shortened lastridge ropes can better incorporate the dynamic catch control system while also delivering better size selectivity than the Flexi-grid system currently used.

TRAWL MODIFICATION FOR IMPROVING SIZE SELECTION IN THE SHRIMP FISHERIES

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The trials using shrimp trawls with reduced belly lengths that started in 2016 were continued in 2017. The project is run in collaboration with fishers and fishing gear manufacturers. A trawl with a 37.5 m long belly was fished along with an otherwise identical standard commercial trawl with a 60-m long belly in a twin-rig setup. The shorter trawl was considerably more size selective, with retention inversely related to shrimp size. Above 18.5 mm carapax length, the trawls fished equally, while half of 15.7 mm carapax length shrimp were retained. Minimum legal size is 15 mm carapax length. Modifying trawl length is a simple design adjustment to reduce catches of small shrimp and can be an alternative or supplement to size sorting grids for shrimp.

SHORTENING LASTRIDGE ROPES IMPROVES CODEND SELECTION OF SHRIMP AND JUVENILE FISH IN THE NORTHERN SHRIMP FISHERY

Contact person: Ólafur Arnar Ingólfsson, olafuri@hi.no, Terje Jørgensen, terjej@hi.no

Bycatch of juvenile cod (Gadus morhua), haddock (Melanogrammus aeglefinus), redfish (Sebastes sp.) and Greenland halibut (Reinhardtius hippoglossoides) is a major concern in the northern shrimp fishery in north Norway and the Barents Sea. Maximum allowed bycatch rates per 10 kg shrimp are 8, 30, 3, and 3 specimens, respectively. The juvenile fish are not excluded by the mandatory use of the Normøre grid and regular 35 mm diamond mesh codends allows for only minor selection of fish juveniles. Selectivity experiments, applying the twin trawl method in 2017 showed considerably improved selection of shrimp and fish using codends with shortened laststidge ropes.

USE OF LIGHT TO IMPROVE SIZE SELECTION OF SHRIMP

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The use of artificial light to improve size selection of shrimp in the belly region of a short-bellied trawl was tested during a comparative fishing experiment in November 2017. The results showed significantly sharper selection curves when light was used.

CATCH CONTROL IN PURSE-SEINE FISHERIES

Contact person: Maria Tenningen, maria.tenningen@hi.no

March 2017 – March 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 (project leader), 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, (further) development of acoustic and optic catch identification technologies and indicators of catch condition. The project is expected to provide the fleet with better control of the gear and the catch and thereby improve profitability and ensure responsible purse-seine fisheries.

REDSLIP: REDUCING SLIPPING MORTALITY IN PURSE-SEINES BY UNDERSTANDING INTERACTIONS AND BEHAVIOUR

Contact person: Mike Breen, michael.breen@hi.no

Feb 2015 – Feb 2018

https://www.forskningsradet.no/prosjektbanken/#/project/NFR/243885/Sprak=en

The main object of this National Research Council funded project was to reduce slipping mortality by improving our understanding of how the purse-seine performs and how the fish behave in, and interact with, the net during the capture process. Evidence from this project, collected in controlled experiments and observations in commercial fisheries, supports the principle that releasing, or "slipping", unwanted catches from the purse-seine can be a responsible catch control practice; if done before the captive fish become too crowded and in a way that maintains their ordered behaviour. That is, mackerel tolerated moderate crowding densities (~88 kg m-3) and relatively low oxygen concentrations (~40% saturation) without significant mortality. Furthermore, such conditions were generally not observed until late in the haul-back phase, particularly in slipped catches. However, it was concluded that the current method of using predetermined fixed limits based on purse-seine length for regulating slipping is not an optimal method; because the variability of seine dimensions and catch sizes, as well as the complex net geometry, make it difficult to predict the volume of free space available to the catch, and hence the potential crowding density. Alternatively, observed changes in behaviour at sublethal (e.g. increased activity and disrupted schooling function) and potentially lethal crowding densities (e.g. disordered breakdown of schooling structure) could be used as potential indicators of the welfare status of the catch.

GEAR AND CATCH MONITORING SYSTEMS IN PURSE-SEINE

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http://crisp.imr.no/en/projects/crisp/

In 2017, this work package focused on three topics: 1) further testing of the "In-seine" sonar technology (SIMRAD SN90) for catch control; 2) monitoring purse-seine geometry and performance using sonar and transponder technology; and 3) monitoring the welfare status of purse-seine catches. Kongsberg Maritime, SIMRAD, installed a SN90 multibeam sonar in the scientific keel of FV "Eros". Having the transducer located in the scientific keel, about 8 m below the surface, significantly reduced air-bubble interference and facilitated continuous monitoring of the school and the net during most of the capture process. The SN90 sonar can now be calibrated and once the calibration equations are finalized, the biomass of the monitored schools will be computed. In collaboration Project RedSlip and Project "Catch control in Purse-seines", work continued on the development of a prototype probe for monitoring fish behaviour and environmental conditions in purse-seine catches. The current prototype contains a 360o camera, as well as instrumentation for measuring oxygen, temperature and depth. In 2018, development will continue to include a stereo-camera system for improved description of behaviour and estimation of fish size; as well as instrumentation for describing the orientation of the probe.

SELECTIVE FLATFISH SEINE

Contact person: Olafur Ingolfsson, olafuri@hi.no

The aim of this project is to develop a species selective Danish seine to target flatfish, mainly plaice (Pleuronectes platessa), and to avoid catching cod. A low headline height demersal seine (low-rise seine) with 0.6 m vertical opening was designed and tested on fishing grounds in Northern Norway. The low-rise seine was compared with a conventional seine with a vertical opening of ~3.5 m, and fished both during day and night. The low-rise seine caught no less plaice than the conventional seine during daytime fishing, but had reduced catching efficiency at night. Cod and haddock catches were reduced by 94 and 98%, respectively. As a management tool, the low-rise seine therefore allows for targeting flatfish, while avoiding gadoid catches, yet loss of plaice during night-time fishing may be expected.

USING ARTIFICIAL LIGHT IN FISH POTS

Contact person: Odd-Børre Humborstad, odd-boerre.humborstad@hi.no, Svein Løkkeborg, sveinl@hi.no, Anne Christine Utne Palm, annecu@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. Underwater camera observations have shown that krill are attracted by light and that cod feed on krill. In 2016, we performed controlled laboratory studies to unveil the effect of wavelength composition, light intensity and flickering frequency on krill and cod's attraction and repulsion response to a light stimulus. We found green light (530 nm) to be the most attractive individual wavelength, while broadband white (425 - 750 nm) light was an equally attractive light source. These light stimuli appeared to be slightly repulsive for cod. A fishing trial was carried out in 2017 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 and high), while green was only tested at low intensity. High intensity white light gave the best result with catches up to 200 kg of cod in one pot. Artificial light has also been tested to increase catch rates of cod pots in four periods and areas in commercial coastal fisheries. No significant effect of artificial light was demonstrated. However, a tendency towards larger fish and greater occurrence of light attracted prey (krill) in the stomachs of cod were observed. Catch rates were negatively affected by increasing water current, and video observations revealed that the pots did not perform well at high current speeds. A prerequisite for lights to have a positive effect on catch rates is that light attracted prey aggregate in the light beam. Currently, the effects of intensity and wavelength on krill attraction are being investigated in a more comprehensive field study using light traps. The most promising wavelengths from our laboratory study (green, blue and white) were compared with red light at three different light intensities (each intensity differing by an order of magnitude). CPUE of krill in light traps demonstrated that wavelength is important as red light caught no krill, whereas similar catches were obtained for white, blue and green light, i.e. light within the wavelength sensitivity range of krill. Catches increased with increasing light intensity.

USING ARTIFICIAL LIGHT IN SNOW CRAB (Chionoecetes opilio) POTS

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Recent studies in Canada have shown that adding a low-powered light emitting diode (LED) light inside baited pots significantly improved catches of snow crab. In June 2017, we compared the catch rates of baited and illuminated pots in the Barents Sea fishery. Pots with purple and white LED lights and squid bait were compared with pots baited with squid only. The catch rates were very low and were affected by depth, soak time and fishing location. Although the pots equipped with purple and white LED lights produced a higher mean CPUE than traditionally baited pots, the increases were marginal and only significant for the purple light. Mean CPUE were 1.95, 2.22, and 2.1 for control pots, pots with purple light and white light, respectively. The results also indicated that CPUE increased for both illuminated pots and control pots with increasing soak time.

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.

The Arctic University of Norway UIT, Faculty of Biosciences, Fisheries and Economics – Norwegian College of Fishery Science

Contact person: Roger B. Larsen, roger.larsen@uit.no

SUMMARY

During 2017, we participated in several projects on bottom trawling and new types of gillnets for the Northeast Atlantic cod fisheries led by the SINTEF Ocean and IMR (CRISP). These projects will be reported by SINTEF Ocean and IMR. Several studies on the national project by UIT, IMR, SINTEF Ocean and Møreforskning on "Optimizing the shrimp trawl fishery 2016-2019" are under execution.

Projects

EFFECT ON SELECTIVITY DURING SHRIMP TRAWLING BY CHANGING GRID LENGTH, GRID ANGLE AND BY ADDING A SECOND GRID

Contact person: Roger B. Larsen, roger.larsen@uit.no

The Nordmöre grid is regarded as an efficient bycatch reducing device during shrimp trawling, but still in some areas bycatch remains a problem that seriously impacts commercial trawl activities. Previous studies have reported that a reduced operating angle can lead to a lower grid passage probability for bycatch fish species and shrimp. In our study we tested and compared the performance of two versions of the Nordmöre grid in the Deepwater Shrimp (Pandalus borealis) fishery of the Barents Sea. The test setup comprised a standard version of the Nordmöre grid with an operating angle of ca. 45° and a 40% longer version of the grid with an operating angle of ca. 30°. Both Nordmöre grids were with 19 mm bar spacing. Using the longer grid, the grid passage probability for the bycatch of juvenile cod, haddock, American plaice and redfish increased significantly for certain size ranges of fish. The longer grid also resulted in a significant increase in grid passage probability for large shrimp. Our results demonstrate that a longer Nordmöre grid more than compensates for the reduced operational angle. During the second part of the study we inserted a second grid with 9 mm bar spacing 2 m behind the standard Nordmöre grid (at operating angle of 45o). Obtained results demonstrated that the additional grid improved the release of the smallest Deepwater shrimps significantly with an estimated 45% of these sizes of shrimp being released.

HOW ARTIFICIAL LIGHTS AFFECT BYCATCHES OF FISH AND THE DEEPWATER SHRIMP DURING TRAWLING IN THE BARENTS SEA

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The Nordmöre grid, as used in Norway with 19 mm bar spacing, will reduce a large proportion of the bycatch of fish species. The bycatch is therefore small-sized fish species and juveniles that are able to pass through the grid and enter the codend, along with the targeted Deepwater shrimp (Pandalus borealis). The bycatch of fish not only leads to additional sorting work onboard, but it clearly has negative impact on the ecosystem due to increased fish mortality. A minor proportion of small fish and juveniles will escape through the outlet above the grid, without making contact with the grid itself. We investigated if introduction of Led lamps could promote this behavior could potentially reduce bycatch in shrimp trawl fisheries. We conducted experimental fishing trials over two periods to assess the size selective properties of the 19 mm bar spaced Nordmöre grid with and without LED lamps. In the first study we placed 5 green LED lamps around the escape outlet. Adding green LED-lamps small haddock were significantly discouraged from seeking the escape outlet. For the other bycatch species, results indicated a similar trend but they were not as clear and were not statistically significant. In the second study we attached 4 green LED lamps in the lower part of the Nordmöre grid. Adding LED lamps, we found for the four bycatch species investigated that 50-99 % of small fish passed through the Nordmöre grid. The addition of green LEDs to the Nordmöre grid did not significantly affect the escape probability and the size selectivity of any of the investigated species. In both studies very few shrimps were found to escape through the escape outlet independent of the presence of the green LED lamps mounted on the grid.

THE EFFECTS OF COMBINING A STANDARD NORDMÖRE GRID WITH A SIEVE PANEL IN AN ATTEMPT TO REDUCE BYCATCHES OF FISH DIRUING SHRIMP TRAWLING

Contact person: Roger B. Larsen, roger.larsen@uit.no. MSc Thesis by Nadine Jacques.

The Nordmöre grid and the sieve net are two of the main devices to reduce bycatch of fish species in trawl fisheries targeting shrimp species. However, even with such devices mounted some small sized fish enter the codend of the trawl together with the targeted shrimp. Therefore, bycatch reduction remains to be a problem in some shrimp fisheries. One such fishery is the Northeast Arctic deep-water shrimp (Pandalus borealis) fishery where it is mandatory to use a Nordmöre grid. In this fishery we investigated and compared the bycatch reduction efficiencies and patterns for several fish species between the standard Nordmöre grid and an experimental sieve net. We also explored the effect of combining these devices. The bycatch reduction patterns differed significantly between the two devices and a more efficient reduction could be obtained by combining them. However, while the loss of commercial sized shrimp was only between 0 and 2% for the Nordmöre grid, it was between 37 and 66% for the tested sieve net making this completely unacceptable for commercial fishing. Therefore, before a sieve net can be an option for the fishery investigated other sieve net designs with significantly lower loss in shrimp catches need to be identified.

QUANTIFYING BELL-SHAPED SIZE SELECTIVITY IN SHRIMP TRAWL FISHERIES: EFFECT OF CODEND DESIGN

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Often trawlers targeting shrimp use a Nordmöre sorting grid ahead of a small-mesh codend. The purpose is to avoid bycatch while shrimps are efficiently caught. However, small fish can pass through the grid to enter the codend and risking being retained. This makes the size selection processes in a trawl fishery targeting shrimps complex, and the size dependent curve often adopt a bell-shaped signature. In this study we quantified the bell-shaped size selection pattern for the standard Nordmøre grid used together with each of three different codend designs. 1) the baseline with a 35 mm diamond mesh codend, 2) a 35 mm square mesh codend and 3) a "hour-glass" section comprising two 9 mm grids inserted between the Nordmöre grid and the 35 mm diamond mesh codend. Results were obtained for Deepwater shrimp (Pandalus borealis) and four bycatch species based on fishing trials in the Northeast Barents Sea. The size selectivity for the bycatch species showed the characteristic bell-shaped size selection pattern expected with low retention probability of very small fish and bigger fish, while certain sizes of juveniles had high retention probability. Our results identified which size ranges of the different bycatch species that for the different codends would result in high risk of capture and thereby provided guidance on which size ranges that should be avoid to fish on with the different codends.

ASSESSING POSSIBLE SELECTION IN THE CODEND DURING BUFFER TOWING OF COD (Gadus morhua)

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Due to the high abundancies and densites of cod (Gadus morhua) in the Barents Sea, a new practice has appeard among trawlers, termed buffer towing. The rationale for this practice is to avoid any stop in the onboard factory by deploying the trawl directly after taking a catch onboard. In many cases the approximate amount of catch is caught before the catch from the previous haul is processed, resulting in buffer towing. During buffer towing, the trawl is lifted from the seabed so the catching process stops. The trawl with the catch is then towed midwater at low speed until the production capacity in the factory onboard is restored. However, enforcing management authorites claim that catches that have been buffer towed contain conspisousley fewer undersized fish, as well as fish floating behind vessels that buffer tow. Cod that escape from the codend when it is shallower than the initial fishing depth are exposed to an increased likelihood of mortality due to barotrauma-related injuries, increased disease susceptibility, and predation. Therefore, this study investigated and quantified the fish escape rate and size selectivity during buffer towing. A new method was applied that allows using the same trawl configuration as applied during commercial fishing and avoid potential bias in the assessment of buffer towing size selection. Our results demonstrated a significant size selection for cod during buffer towing where cod measuring up to at least 43 cm in length escaped. In particular, at least 60% of the cod measuring 20 cm that were retained at depth escaped during buffer towing. For cod measuring 30 cm and 40 cm, at least 53% and 45% escaped during buffer towing, respectively. A scientific paper was published.

ASSESSING THE IMPACT OF BUFFER TOWING ON THE QUALITY OF THE CATCH

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Buffer towing (also called for "short wiring") is a method often applied during conditions with high densities of fish, as currently encountered in Barents Sea. However, this practice has caused some concern, both from the fishing industry, due to indication of reduced catch quality, indicated by increased frequency of gear marks and dead fish, poorer exsanguination, ecchymosis, skin abrasion, fillet gaping, and fillet redness. The aim of this study was to document the effects of buffer towing on fish quality. The quality was assessed using two different indices, one for whole cod and one for cod fillets. The results proved that buffer towing has a negative impact on fish quality. Specifically, cod subjected to buffer towing, in contrast to direct haul-back, had an increased relative probability of 371% for poor exsanguination and an increased relative probability of 209% for fillet redness. Furthermore, combining scores of the different quality categories within the indices (e.g. gear marks, ecchymosis, poor exsanguination, and skin abrasion) proved a significant reduction the quality of cod subjected to buffer towing.

IMPROVING CATCH QUALITY WITH A DUAL SEQUENTIAL CODEND

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Trawl-caught fish are frequently associated with deteriorated catch quality. In 2017 a new dual sequential codend concept was tested onboard a commerical trawler in the Barents Seam 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 any form for catch damage was five times higher when using the dual sequential codend. Furthermore, cod caught in the sequential codend had significantly reduced probability of incurring specific catch damage, such as gear marks, poor exsanguination, ecchymosis, and skin abrasions.

SINTEF Ocean

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Projects

RELATIVE FISHING EFFICIENCY OF BIODEGRADABLE PBSAT GILLNETS ON SPAWNING COD FISHERY.

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Gillnets made of a new biodegradable resin (Polybutylene succinate co-adipate-co-terephthalate PBSAT was tested under commercial fishing condition to compare their fishing performance. The relative catch efficiency, catch rate and effect of use and wear (aging) was studied for biodegradable PBSAT gillnets and conventional polyamide 6 (nylon) gillnets, covering the entire winter fishing season for cod in northern Norway. The results generally showed better catch rates for the nylon gillnets for most sizes of cod, except for sizes between 80 and 90 cm. Aging had a larger negative effect on the catch efficiency of biodegradable gillnets than that of nylon gillnets. The reduction of catch efficiency observed in the PBSAT gillnets, especially for big fish, might be explained by the loss of tensile strength and elongation caused by use and wear of the material. Tensile strength measurements of the biodegradable PBSAT gillnets samples taken before and after the fishing trials showed in average a 9% loss of tensile strength and 13% loss of elongation.

CATCH COMPARISSON OF FISHING EFFICIENCY OF BIODEGRADABLE PBSAT GILLNETS AND NYLON GILLNETS ON SAITHE AND COD FISHERY.

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Fishing trials were carried out to compare the relative fishing efficiency of gillnets made of a new biodegradable resin (polybutylene succinate co-adipate-co-terephthalate (PBSAT) with conventional (nylon) nets. The fishing trials covered two consecutive fishing seasons (2016 and 2017) for cod (Gadus morhua) and saithe (Pollachius virens) in northern Norway. Results generally showed better catch rates for the nylon gillnets. The difference in catch efficiency observed between the PBSAT gillnets and the nylon gillnets can be explained by the loss of tensile strength and elongation caused by the use and wear of the gillnets throughout the fishing season. Tensile strength measurements of the nylon and PBSAT gillnets carried out before and after the fishing trials showed that the both types of gillnets had significant reductions in tensile strength and elongation at break, especially in 2017.

EXPERIMENTAL FISHERY AND UTILIZATION OF MESOPELAGIC FISH SPECIES AND KRILL

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Extensive mesopelagic acoustic scattering layers (SLs) were found over the North-East Atlantic NEAFC RA1 Reykjanes Ridge area in 2016 and 2017. 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 analyses 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 analysed for unwanted substances such as dioxins, PCBs, PAH, pesticides, and heavy metals, showing values far lower than limiting values.

SMARTFISH H2020

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Sintef Ocean is coordinating an EU H2020 project SMARTFISH with 18 partners in total. SMARTFISH will run for four years starting 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, analysing and improving processes for all facets of the fishing sector, from extraction, to assessment, to monitoring and control. The SMARTFISH systems will:

- assist fishers 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.

SNOW CRAB FISHERY AND SIZE SELECTION

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Snow crab pots are known to be selective fishing gears. Results from a research cruise in the Barents Sea in April and March 2018 show that there is a positive correlation between soaking time and the size selection of smallest crabs. For 5 to 6 days soaking time, 10-15% of the crabs never try to get out of the pots and consequently they are sorted out onboard, with uncertain mortality on crabs thrown back into the sea. For 14 days soaking time, the size distribution of snow crabs is different; here 100% of the crabs are in contact with the meshes of the pots. The study concludes that optimal selection requires a soaking time of minimum nine days.

EFFECT OF BAIT TYPE AND BAIT SIZE ON CATCH EFFICIENCY IN THE EUROPEAN HAKE MERLUCCIUS MERLUCCIUS LONGLINE FISHERY

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We investigated the effect of bait type and bait size on the catch efficiency of a demersal longline fishery targeting European Hake Merluccius merluccius in the North Sea. Automation of the labor-intensive processes onboard fishing vessels requires finding alternatives to the traditional bait used in the fishery (i.e. whole European Pilchard Sardina pilchardus). Of the six alternative baits investigated, four resulted in significant reductions in catch efficiency ranging from 32% to 90%. Only chopped Atlantic Herring Clupea harengus was a reasonable alternative bait, with an estimated non-significant loss of only 2.12% in European Hake catch efficiency. Our results demonstrated that choice of bait type and size can affect the catch efficiency of different sizes of European Hake. Thus, the choice of bait may also affect the size distribution of the catch. The latter highlights the importance of considering fish size when inferring the effect of bait choice on the catch efficiency of longline fisheries.

ETHICAL CAPTURE AND KILLING METHODS IN TRAWL FISHERIES

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Limited focus has been placed on fish welfare and other ethical aspects of catching and killing processes for wild fish. Recent studies reveal that teleost fish have a capacity for mental awareness, and there is a growing concern for the welfare of fish. For farmed fish, welfare requirements are included in laws and regulations, but for wild fish, the industry and government, probably for practical and economic reasons, has not prioritized animal welfare. Wild fish is included in the Norwegian Animal Welfare Act, and in 2014, the Norwegian Council for Animal Ethics gave the following advices for commercial fisheries; a) Strive to shorten the harvesting time, particularly the time fish are experiencing high levels of stress, fear or pain; b) There must be made more gentle handling and minimal damage in the capture time; c) The fish has to be stunned by electricity or percussion stunning, followed by killing by bleeding; d) Bycatch must as far as possible be reduced, e) Fish that have been in contact with the gears, but that does not get caught or released after capture, should be undamaged and physically able to survive afterwards.

This project seeks to reflect on and integrate ethics in the development of new technologies and methods, with the aim of improving fish welfare in some key phases and processes in trawl fisheries. Trawling is a dominant fishing method in Norway and internationally, and improvements here can have significant overall impact.

Specifically, the project will establish a framework for ethical assessment of new technology, develop and evaluate a new trawl codend for improved fish welfare, and investigate and assess stunning and killing methods.

COMBINATION OF A SORTING GRID AND A SQUARE MESH PANEL TO OPTIMIZE SIZE SELECTION IN THE NORTHEAST ARCTIC COD (GADUS MORHUA) AND REDFISH (SEBASTES SPP.) TRAWL FISHERIES

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Sorting grids and square mesh panels are the two most-applied technical devices to supplement codend size- and species-selection in demersal trawls. In the Barents Sea gadoid fishery, the compulsory size-selectivity system comprises a mesh section with a sorting grid followed by a diamond mesh codend. We tested the size-selective performance of a new sorting section that comprised a sorting grid combined with a square mesh panel as a potential alternative for the grid sections currently in use. The new sorting section was shorter and therefore more manoeuvrable than the existing sorting grid sections. The investigation was carried out on cod and the bycatch species redfish. The grid was found to contribute to the largest proportion of fish release, and the release through the square mesh panel was low. But, the results showed that the grid was successful at guiding fish not escaping through the grid to a second selection process in the panel. However, the square mesh panel did not result on the intended release efficiency except for the smallest sizes of fish, most likely because the guiding angle of the grid and the square meshes in the panel used did not provide a suitable escape path for the desired size range of fish. Therefore, optimizing the mesh size/shape in the panel and/or the guiding angle for the grid potentially could lead to the desired selectivity pattern in the new sorting section.

12.11 Spain

AZTI-TECNALIA

Contact persons: Esteban Puente (epuente@azti.es), Luis Arregi (larregi@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 fleets 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 or ling). During 2017 and 2018 two selectivity cruises were carried out on board a commercial trawler in the ICES division 6. During these cruises the more problematic species behavior with underwater video was assessed and a complete upper panel with square mesh in the extension piece has been tested. The results show promising escaping rates for some choke species in the fishery like saithe or haddock, but some escapement for target species in commercial sizes was observed as well.

SELEM

Contact person: Luis Arregi, larregi@azti.es

Jan 2017 – Dec 2018

SELEM 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 (Figure 12.11.1) had been tested to improve the contact probability with a SMP onboard the RV Emma Bardan, with a total of 32 valid hauls for selectivity experiments (8 hauls for each one of the tested configurations). In June 2018 a new cruise will be carried out to continue improving fish guiding devices, new lights, as well as a new configuratios of the SMP will be tested.

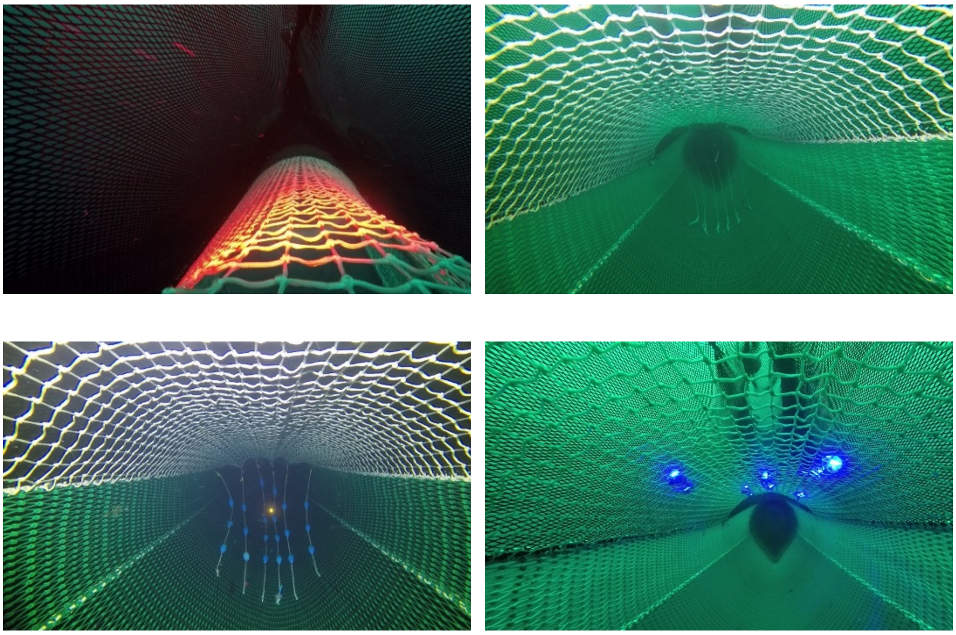


Figure 12.11.1. Four different configurations tested in the selective device during the cruise. SMP -control-(Top left.), SMP+Guiding ropes (top right.), SMP+Guiding ropes with Floats (Low left) and SMP+Blue Led lights (Low right).

MENDES

Contact person: Esteban PuenteJan 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 will be performed according to the observer's database to detect principal problematic species. Workshop with skippers to review and select the more suitable selective devices for each fishery/species would be held. Sea trials in all fisheries (commercial vessels) will be carried out to test the selective devices and analyse the socio-economic impact of the implementation of such technical measures-

SUPERV

Contact person: Iñigo Onandia, ionandia@azti.es

Mar 2016 – Dec 2018

SUPERV is 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 presents 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 (Figure 12.11.2) 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 are being developed.

Figure 12.11.2: Captive anchovies (*Eugralis 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). As of January 1, 2019, the Landing Obligation (LO) will apply to all fleets that fish for TAC species. Small-scale segment can then be significantly affected in certain fisheries, particularly in gillnets, when there are significant catches of mackerel and horse mackerel during some periods of the year. In this sense, the Technology Committee between AZTI and small-scale fishers in its meeting of March 6, 2017 agreed that it is necessary to take the initiative to investigate technical alternatives with which 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 have entered into application of the LO previously (purse-seine and trawl).

SIBALO

Contact person: Xabier Aboitiz, xaboitizi@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 will be a significant increase in the workload of the crew as well as several problems for storing the former discards and will include new limitations in the vessels and fishing trips. Physical condition of the crew will be monitored and measured with a motion suit and analysed the increment in the workload vs current situation. Managing the discard at harbours (infrastructure and labor needed) and finding destination for the discarded fish will be another scope of the project.

12.12 Sweden

SLU Aqua

Contact person: Hans Christer Nilsson, hans.nilsson@slu.se

Summary

Between 2014 and 2017 the Swedish government has set aside special funding for collaborative research on selective fishing gears. The main background was the need for a larger toolbox of documented and workable gears for the industry to choose from 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 2017, 34 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 project is reported in Table 12.12.1 active fishery and Table 12.12.2 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

Table 12.12.1 Active gear

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 12.12.2 Passive gear

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 12.12.2 Passive gear

12.13 United Kingdom

Cefas

Contact person: Thomas Catchpole, thomas.catchpole@cefas.co.uk

Summary

Work continues developing and testing modified fishing gear designs that will assist in the implementation of the EU Landing Obligation. The latest trials have focused on improving codend selectivity in the Celtic Sea mixed demersal otter trawl fishery, and in the North Sea Nephrops trawl fishery. Other trials have been conducted to reduce unwanted ray catches in an inshore trammelnet fishery and some initial trials using lights to modify fish behavior during the trawl capture process.

Projects

Fisheries Science Partnership Programme

Contact person: Thomas Catchpole, thomas.catchpole@cefas.co.uk

Ongoing

https://www.gov.uk/government/organisations/centre-for-environment-fisheries-and-aquaculture-science/about/research#fisheries-science-partnership-fsp

The Fisheries Science Partnership (FSP) is a Defra (UK Government Ministry) funded collaborative research programme of scientific research between the UK fishing industry and scientists. Since it was established in 2003 the programme has undertaken around 100 projects, covering annual time-series surveys of stocks subject to traditional assessments and *ad hoc* projects on, e.g. gear selectivity, discard survival, tagging and migration, and fishery development. A full description of the aims and all completed reports of the FSP programme can be found on the Cefas website (www.cefas.defra.gov.uk). Charter of suitable fishing vessels for projects approved by Defra and its

FSP steering committee. It is arranged through an open tendering procedure, with scientific and operational work plans developed in line with the agreed and commissioned project between Cefas and the selected vessel. In the last year, studies included trials to test codend different configurations in the Celtic Sea mixed demersal otter trawl fishery, and in the North Sea Nephrops trawl fishery.

ASSIST

Contact person: Thomas Catchpole, thomas.catchpole@cefas.co.uk

2013-2019

http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18902

The ASSIST project (Applied Science to Support the Industry in delivering an end to discards) is six-year Defra-funded programme, which started in 2013 to assist English fishers in making the transition to the discard ban, and to support and advise DEFRA in the adoption of the reformed CFP. The ASSIST project uses a collaborative approach, working with Defra, fishers and other stakeholders to facilitate the CFP implementation, by helping the fishing industry prepare for changes to policy. In the last year, trials have been conducted to reduce unwanted ray catches in an inshore trammelnet fishery and some initial trials have completed using lights to modify fish behavior during the trawl capture process.

12.14 United States of America

Massachusetts Division of Marine Fisheries - Conservation Engineering Program

Contact person: Mike Pol, (mike.pol@state.ma.us)

Summary

Our research this year focused on maintaining or increasing access to healthy stocks of fish and shellfish in a multispecies fishery where many stocks are in poor condition. Improved access was sought through introduction of new gear types, modification of existing gears, and increasing temporal access.

Projects

Off Bottom Trawl (OBT)

Contact person: David Chosid, david.chosid@state.ma.us

Jan 2017 – Dec 2018

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 trawlnets (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 fishers 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. Tuning trials were held in summer 2017 to familiarize the captain and crew with the gear and to adjust rigging. Multiple sensors and cameras were used. Testing of designs on commercial vessels is planned for summer 2018.

ExpandedWhiting: Revision of Existing Whiting Special Access Areas

Contact person: David Chosid, david.chosid@state.ma.us

Mar 2016 – Jan 2018

Special access areas face obsolescence due to temporal and spatial changes in distributions and abundances of fish populations in response to climate change and other factors. A two-week experimental fishery was held in July 2016 and 2017 to collect catch and bycatch data from commercial vessels using the mandatory raised footrope trawl to investigate possible alteration of timing of whiting (*Merluccius bilinearis*) small mesh (64-76 mm) areas. The two week fishery was held prior to the opening of the standard fishery. Catch rates of target species were similar between years and within years between the experimental and standard fisheries. Groundfish discard ratios by tow exceeded the management threshold of 0.05 in both years, and in both the experimental and standard fisheries. The primary contributor to discards was haddock (*Melanogrammus aeglefinus*), a species at 706% of its biomass condition. A vessel effect was observed, despite all vessels using the same trawl design.

TickleDredge: Bycatch Reduction in the Sea Scallop Fishery

Contact person: Mike Pol, mike.pol@state.ma.us

Dec 2015 – Dec 2017

In collaboration with Provincetown Center for Coastal Studies (O. Nichols), we tested a simple modification to the New Bedford-style scallop (*Plactopecten magellanicus*) dredge to reduce flatfish bycatch by suspending drop chains from the bail. The intent was to physically contact flatfish and skates that are on the bottom, causing them to swim away from the approaching cutting bar and preventing capture in the dredge. A finalized design was developed in March 2017 using video; it maximizes coverage of the dredge path and practicality of attachment (Figure 12.14.1). Comparisons of 104 paired tows revealed slight increases in catch of scallops as well as some flatfish and non-target species with the TickleDredge modification, but no significant differences in catch between modified and standard dredges were observed. Also, no changes in shell heights of scallops or lengths of flatfish were observed due to the dredge modification. Overall rates of bycatch were low.

Figure 12.123.1: Still images from GoPro camera attached to dredge frame. Tickler chains making bottom contact during comparison tows.

NOAA Fisheries, Northeast Fisheries Science Center (NEFSC), Conservation Engineering Group, Woods Hole, Massachusetts

Contact person: Henry Milliken, henry.milliken@noaa.gov

Summary

In 2017, the NEFSC conducted three gear-related projects investigating methods to reduce sea turtle bycatch in fishing gear.

Projects

Comparative study of the ability of a large 12” (30.5 cm) mesh low profile gillnet to reduce sea turtle bycatch

Contact person: Henry Milliken, henry.milliken@noaa.gov, Eric Matzen

http://www.nefsc.noaa.gov/read/protspp/PR_gear_research/.

We compared two different tie-down configurations: standard (12 meshes with 48 in (1.2 m) tie-downs) and low profile (eight meshes with 24 in (0.6 m) tie-downs) using the same experimental protocol. Previously this configuration proved successful at reducing the bycatch of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) with little effect on the targeted catch of monkfish (*Lophius americanus*) and winter skate (*Leucoraja ocellata*). Sixty paired sets (120 hauls) were completed in waters off Cape Hatteras, NC, an area chosen because of the high densities of sea turtles in winter months. Results are being analysed but there was no significant difference in the capture of loggerhead sea turtles between treatments. Fourteen loggerheads were captured in the control nets and eight were captured in the experimental nets (P= 0.125). It is interesting to note that during the first seven trips of the study, ten loggerhead turtles were captured in the control nets while none were captured in the experimental nets. During the final five trips of the study, eight loggerheads were captured in the experimental nets and four were captured in the control nets. We are looking at environmental changes that may have caused these results.

Test of a cable-sorting grid to reduce turtle bycatch in the summer flounder fishery

Contact person: Henry Milliken, henry.milliken@noaa.gov

Eric Matzen

http://www.nefsc.noaa.gov/read/protspp/PR_gear_research/.

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. As such, additional bycatch reduction devices (e.g. topless trawls, cable grids) have been investigated. In 2016 the NEFSC was funded to run a comparative study of a NETIII (a type of cable grid)-equipped trawl to that of a standard flatfish trawl in the summer flounder trawl fishery. The study documented operational issues and compared the catch data aboard two commercial fishing vessels. Aboard the FV Darana R, significant reductions (29-45%) in summer flounder catch were observed during leg 1 and 2 of the project. Aboard the FV Jersey Cape, a modified configuration was used and no significant reduction in summer flounder catch was observed. In total, four configurations were tested throughout the study in an attempt to improve target catch efficiency. From an operational and safety standpoint, the NETIII system was a substantial improvement from previous research using rigid grid TEDs. Because these studies proved to be a proof of concept for this gear, in 2017 we did a full study of the NETIII system in the most successful configuration form 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%. These results suggest that this TED 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

http://www.nefsc.noaa.gov/read/protspp/PR_gear_research/.

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 2017. The vessel was able to complete 38-paired tows in six days. Results from this work, using a twin trawl configuration, showed that the cable equipped net caught similar quantities of longfin squid compared to an identical net without the cable TED attached. A modification was made to the floatation used to address an increase in benthic species encountered. The change reduced the catch of benthic species.

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

Projects

Reducing flounder bycatch in haddock trawls: Testing a modified European grid system in the Georges Bank trawl fishery

Contact person: Pingguo He, phe@umassd.edu

http://www.smast.umassd.edu/fish/

Recent regulatory restrictions on the Northeast groundfish fishery made it impossible to fully utilize allocations of the robust haddock stock. Yellowtail flounder (*Limanda ferruginea*) and windowpane flounder (*Scophthalmus aquosus*) are two of the most severe quota-limiting "choke" species on Georges Bank that impact the successful harvesting of haddock. We tested a German-style flatfish-excluding grid system to reduce the catch of yellowtail and windowpane flounder while retaining the catch of legal size haddock. The results indicate that the grid with 70 mm spacing reduced total flounder catch by 51.3%, while there were no differences in the catch of Atlantic cod. Haddock was reduced by almost 40% by weight, but the reduction was mainly for small fish. Behavioral observation of fish during fishing indicates that differential spacing with smaller spacing in the top part and larger spacing in the bottom part may result in greater release of flounders and better retention of haddock.

Testing a modified Sort-X grid system to reduce the catch of juvenile haddock and cod in the Georges Bank haddock fishery.

Contact person: Pingguo He, phe@umassd.edu

http://www.smast.umassd.edu/fish/

This project was in collaboration with Massachusetts Division of Marine Fisheries to test a modified Sort-X grid to reduce undersized haddock to help the long-term sustainability of the haddock fishery. Recent research trips revealed that a large portion of haddock brought to the deck of the vessel was below the minimum landing size when the 165 mm legal size codend was used. Many fish escaped while the codend was on the surface due to slacks and swells. These surface escapees are likely to suffer greater mortality than those that escaped while the net is still on the seabed. The reduction in juvenile haddock will also reduce wastes of resource, and unaccounted fishing mortality, leading to healthier stocks and robust fisheries resources. Two sets of Sort-X grid system have been fabricated with 40 and 55 mm spacing. Sea trials were conducted in spring of 2017. Results indicate a significant reduction in juvenile haddock (< 40 cm) in both 40 mm and 55 mm grid systems. Additionally, the data indicates that the grids were more effective as bycatch levels increased. During tows with high levels of skate bycatch, the catch rate of juvenile haddock was reduced by 43.5% compared to the control codend.

Swimming speed and reaction capability of yellowtail and windowpane flounder at different temperatures

Contact person: Pingguo He, phe@umassd.edu

http://www.smast.umassd.edu/fish/

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 time and reaction time of flounders will be measured at different temperatures to predict their swimming speed during different seasons.

Behavior of river herring and its predator as observed by acoustic camera

Contact person: Pingguo He, phe@umassd.edu

http://www.smast.umassd.edu/fish/

This project uses SoundMetrics Adaptive Resolution Imaging Soanr (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 will also attempt to count the number of fish passing through sections of the river, which will be compared with count data from other means.

University of Rhode Island Fisheries Center, Kingston, Rhode Island, Department of Fisheries, Animal and Veterinary Sciences

Contact person: Dr. Kathleen Castro, kcastro@uri.edu

Laura Skrobe, Barbara Somers, and Mitch Hatzipetro

Projects

The flatfish deflector bar: Excluding flatfish from scallop dredges in the northeast

Contact person: Dr. Kathleen Castro, kcastro@uri.edu

Industry Collaborators: Eastern New England Scallop Association,

Michael Marchetti (President)

This is a collaborative research project with industry and scientists to design and test an effective bycatch reduction device to reduce the catch of flatfish in the sea scallop dredge without impacting the catch of scallops. The gear modification is the inclusion of a Flatfish Deflector Bar (FDB) ahead of the sea scallop dredge. The objective of this research is to test FDB in the field on Limited Access General Category (LAGC) sea scallop dredge vessels and determine if the FDB reduces the catch of flounders (and other bycatch species) in the catches while maintaining the catch of sea scallops. Two pilot days and 2 additional days for underwater video collection were conducted in fall 2017. Comparative fishing trials on board three LAGC vessels are currently being conducted. Vessels are using their standard scallop dredge and then attaching the FDB to the dredge in an alternating fashion. Dredge sizes range from 8 ft to 10.5 ft in width and the FDB is half the length of the dredge. Analyses will be conducted to compare the catch weight of flatfish and scallops between hauls when the FDB is used and not used. Mean length and length–frequency distributions will be compared for flatfish as well.

Anderson Cabot Center for Ocean Life – New England Aquarium (ACCOL/NEAq), Boston, Massachusetts

Contact person: Tim Werner, twerner@neaq.org

Projects

Development and Evaluation of Reduced Breaking Strength Rope to Reduce Large Whale Entanglement Severity

Entanglement in non-mobile fishing gear has been identified as one of the leading causes of mortality for North Atlantic right whales (*Eubalaena glacialis*). Past studies suggest that broad adoption of ropes with breaking strengths of 1700lbf or less could significantly reduce life-threatening entanglement events. A collaborative project between fishers, engineers and rope manufacturers has developed and is field testing buoy rope with reduced breaking strengths. Participating fishers include eight commercial fishers throughout Massachusetts and New Hampshire waters in the lobster, whelk and black sea bass pot/trap fisheries. We anticipate this cooperative research will provide guidance for determining under what fishing conditions this gear modification is feasible. This research is funded by a grant from the Massachusetts Office of Energy and Environmental Affairs to ACCOL/NEAq, the Massachusetts Lobstermen's

Association and the South Shore Lobstermen's Association, and private grants to the ACCOL/NEAq.

Field Testing an Electric Decoy for Reducing Elasmobranch Bycatch in Longline Fisheries

The goal of this research is to evaluate the potential of a battery-powered bait decoy to reduce the bycatch of elasmobranchs in a pelagic and a coastal bottom longline fishery. Our work includes: (i) refining the design of a prototype device for durability and feasibility in oceanic fishing conditions; (ii) testing the efficiency of the electronic decoy in fisheries independent longline experiments; and (iii) deploying the device on commercial pelagic longline vessels 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 Florida consisting of 56 experimental longline sets. We are planning to conduct additional field trials in commercial fishing conditions during summer 2018. This work is funded through the NMFS Saltonstall-Kennedy competitive research program.

Ropeless Fishing: Testing an Innovative Prototype for Preventing Whale Entanglement

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 fish. Current testing consists of deploying units off the dock and research vessels, and later in 2018 to assess the performance of this system under actual fishing conditions by collaborating with the commercial lobster fishing industry in Massachusetts. Current work is funded under the Marine Mammal Commission and private grants to the ACCOL/NEAq.

Pacific States Marine Fisheries Commission (PSMFC)

Contact person: Mark J.M. Lomeli, mlomeli@psmfc.org

http://www.psmfc.org/bycatch/

Summary

In 2017, the Pacific States Marine Fisheries Commission and project collaborators conducted studies using artificial illumination to reduce bycatch in two US West Coast trawl fisheries; the Pacific hake (*Merluccius productus*) midwater trawl fishery and the ocean shrimp (*Pandalus jordani*) otter trawl fishery. In general, findings among our studies were similar in that the presence of artificial illumination appears to enhance fish' optomotor response and their ability to perceive escape areas in and around the trawl gear that they would not be able to perceive as well under dark conditions. In 2018, we have two studies occurring. The first study will evaluate the efficacy of elevated trawl sweeps in the West Coast Limited Entry groundfish bottom trawl fishery, while the second study seeks to measuring the overall effectiveness of LED lights to reduce fish bycatch in the ocean shrimp trawl fishery.

Projects

Effects on the bycatch of eulachon and juvenile groundfish by altering the level of artificial illumination along an ocean shrimp trawl fishing line

Contact person: Mark J.M. Lomeli, mlomeli@psmfc.org

Mark J.M. Lomeli (PSMFC), Scott D. Groth (Oregon Department of Fish and Wildlife [ODFW]), Matthew T.O. Blume (ODFW), Bent Herrmann (SINTEF), W. Waldo Wakefield (NMFS Northwest Fisheries Science Center [NWFSC]), and ocean shrimp fishers

July – September 2017

This study examined how catches of eulachon (*Thaleichthys pacificus*), juvenile groundfish, and ocean shrimp could be affected by altering the level of artificial illumination along an ocean shrimp trawl fishing line. In the ocean shrimp trawl fishery, catches of eulachon are of special concern as their southern distinct population segment (DPS) is listed as "threatened" under the US Endangered Species Act (ESA). Using a double-rigged ocean shrimp trawl vessel, with one trawl serving as the treatment and the other as the control, we compared the catch efficiencies for eulachon, juvenile groundfish, and ocean shrimp between alternating treatment trawls configured with 5-, 10-, and 20-LED lights along the trawl fishing line and the control trawl (unilluminated). The addition of artificial illumination along the trawl fishing line significantly affected the average catch efficiency for eulachon, juvenile rockfish (*Sebastes* spp.) and flatfish. All three LED configurations tested caught significantly fewer eulachon, juvenile rockfish and flatfish than the control trawl, without impacting ocean shrimp catches. For Pacific hake, the 10-LED configured trawl caught significantly more fish than that control trawl. For the 5-LED configuration, mean Pacific hake catches did not differ from the control trawl whereas results for the 20-LED configuration were inconclusive due to large uncertainties in the estimated effect. Aside from Pacific hake, the three LED configurations tested generally performed equally at reducing fish bycatch while not affecting ocean shrimp catches. As the southern DPS of eulachon faces many uncertainties in their ESA recovery, our study contributes new data on how artificial illumination along an ocean shrimp trawl fishing line can affect eulachon catches (and other fish) and contribute to their conservation. Funding for this study was provided by NOAA NMFS Saltonstall-Kennedy Competitive Research Program.

Influencing the behavior and escapement of Chinook salmon out of a midwater trawl using artificial illumination

Contact person: Mark J.M. Lomeli, mlomeli@psmfc.org

Mark J.M. Lomeli (PSMFC), W. Waldo Wakefield (NMFS NWFSC), and Pacific hake fishers

September 2015 – November 2017

http://www.psmfc.org/bycatch/documents/Lomeli_and_Wakefield_2016.pdf

https://www.youtube.com/watch?v=_Fn_C1wnAys&feature=youtu.be

The Pacific hake midwater trawl fishery is the largest groundfish fishery off the US west coast by volume. While catches comprise mainly Pacific hake, bycatch of Chinook salmon (*Oncorhynchus tshawytscha*) can be an issue affecting the fishery as ESA-listed Chinook salmon represent a portion of the total Chinook salmon bycatch. We conducted two separate experiments evaluating the influence of artificial illumination on Chinook salmon behavior and escapement out a bycatch reduction device (BRD) in a Pacific hake midwater trawl. In experiment-1, we tested if Chinook salmon could be attracted towards and out of specific escape windows of a BRD (equipped with multiple escape windows) using artificial illumination. In experiment-2, we compared Chinook salmon escapement rates out of the BRD between tows conducted with- and without-artificial illumination on the BRD to determine if illumination can enhance their escapement overall. In experiment-1, we found the proportion of Chinook salmon to exit out an illuminated escape window was significantly greater than the proportion of Chinook salmon to exit out a non-illuminated escape window. In experiment-2, our results showed the proportion of Chinook salmon to exit the BRD when artificial illumination was present was significantly greater than the proportion of Chinook salmon to exit the BRD when artificial illumination was absent. Findings from this study demonstrate that artificial illumination can influence where Chinook salmon exit out the BRD we tested, but also that illumination can be used to enhance their escapement overall. As conservation of ESA-listed Chinook salmon is a management priority, our research contributes new information on how artificial illumination can minimize adverse interactions between Pacific hake trawls and Chinook salmon. Funding for this study was provided by NOAA NMFS Bycatch Reduction Engineering Program.

Minimizing seafloor and benthic macroinvertebrate impacts: An evaluation of elevated sweeps on a west coast groundfish bottom trawl

Contact person: Mark J.M. Lomeli, mlomeli@psmfc.org

Mark J.M. Lomeli (PSMFC), W. Waldo Wakefield (NMFS NWFSC), and groundfish fishers

April – September 2018

This upcoming study will evaluate the efficacy of elevated trawl sweeps (groundcables) in the US West Coast groundfish bottom trawl fishery. Specifically, this research will 1) compare the catch efficiencies between two alternative elevated sweep designs (designed to reduce seafloor contact and interactions with macroinvertebrates) and the conventional continuous bottom-tending sweep used in the fishery, and 2) estimate the degree that the alternative sweep designs reduce seafloor contact. The alternative sweeps are 110 m in length and consist of 1.5 cm steel cable covered with polyethylene fiber. To raise sections of the sweeps off the seafloor, 15 cm diameter rubber discs (alternative design-1) and 20 cm diameter discs (alternative design-2) will be placed at 9 m intervals along their length. In concept, these alternative sweep configurations would elevate over 95% of the sweeps off bottom. The conventional sweep consists of 1.5 cm cable covered with continuous 7.5 cm rubber disks over its length of 110 m. Dual-frequency IDentification SONar (DIDSON) and a video camera system will be mounted on a sled and towed in a transect over the trawl's path to observe how the sweeps interact with the seafloor. Results from this work are anticipated to identify an alternative sweep configuration that can maintain fish catches while reducing seafloor contact and trawl-induced disturbances (e.g. injury and unobserved mortality) to bottom dwelling organisms and the physical habitat. Funding for this study is being provided by NOAA NMFS Bycatch Reduction Engineering Program.

Measuring the overall effectiveness of LEDs to reduce eulachon and darkblotched rockfish bycatch in the ocean shrimp trawl 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 (NMFS NWFSC), and ocean shrimp fishers

June – September 2018

This upcoming research will measure the overall efficacy of LED lights to reduce bycatch of eulachon, darkblotched rockfish (*S. crameri*), and other groundfish in the ocean shrimp trawl fishery. Specifically, this work will determine the degree to which eulachon, darkblotched rockfish, and other groundfish avoid trawl entrainment in response to LEDs. Catch rates and efficiencies will be compared between two shrimp trawls fished simultaneously. One trawl will incorporate 5 LED lights along the central portion of the trawl fishing line (treatment), whereas the other will serve as the control (no LEDs). Results from this research will show the degree to which eulachon and groundfish avoid trawl entrainment in response to LEDs and provide valuable data for fishers and fisheries management. Funding for this study is being provided by NOAA NMFS Bycatch Reduction Engineering Program.

Cornell University and Alaska Pacific University

Contact person: T. Scott Smeltz, ts428@cornell.edu

Suresh Sethi (Cornell University), Bradley Harris (Alaska Pacific University)

Projects

A seascape scale fishing impacts model to assess trade-offs between spatial closures and gear modifications

Spatial closures and technological solutions such as gear modifications that lift gear components off the seafloor are two potential strategies fisheries managers may employ to reduce habitat impacts from fishing. Evaluation of the efficacy of any such policy requires a quantitative framework that can incorporate fleet dynamics, gear specifications, and habitat characteristics at seascape scales and produce outputs that are readily integrated into existing management workflows. To meet these needs, we developed a 'Fishing Effects' model that incorporates spatially and temporally explicit impact and recovery dynamics in a discrete-time framework to produce a time-series of cumulative habitat disturbance across spatial regions of interest to fisheries managers. We implemented the Fishing Effects model in the North Pacific, producing monthly estimates of habitat disturbance on 5 km grid cells over a spatial domain encompassing 1.2 million km^2. Domain-wide, we estimated that less 2% of the North Pacific shelf is currently disturbed from fishing impacts, and that implementation of gear modifications in flatfish trawls beginning in 2011 have led to an estimated 28% reduction in habitat disturbance. As a tool to evaluate management policies, we used the Fishing Effects model framework to assess the trade-offs managers need navigate when evaluating the potential efficacy of spatial closures and gear modifications. We simulated fishing effort by modelling fleet dynamics using an ideal free distribution and considered a range of fishing intensity, habitat recovery, local abundance, local depletion dynamics, closure sizes, and gear modifications scenarios. We found that the efficacy of a spatial closure is determined primarily by the balance between reductions in catch efficiency and dispersion/aggregation of effort after implementation of a closure. Comparing closures to gear modifications, we found that reducing habitat disturbance from spatial closures tends to be most effective when fishing intensity is high, whereas gear modifications tend to be more effective where fishing intensity is low.

12.15 Italy

National Research Council (CNR)

Institute of Marine Sciences (ISMAR) – Fishing Technology Unit, Ancona – Italy

Project Life+ EFFICIENTSHIP

(Emilio Notti, Fabrizio Moro, Jacopo Pulcinella, Sara Bonanomi, Alessandro Colombelli, Antonello Sala)

The EfficientShip project (LIFE13 ENV/FR/000851) will demonstrate the efficiency of an innovative ORC technology for reducing the GHG emissions of thermal engines. The project challenges are:

To adapt an innovative heat recovery technology (ORC) to mobile thermal engines, allowing the reduction of between 5 to 10% of the GHG emissions.

To raise awareness of the European fishing sector on the importance of the reduction of the vessels GHG emissions in a context of global warming and to offer them some simulation on the adaptation of the EfficientShip innovation on their vessels.

Implementation of the ORC system

A bottom otter trawler operating in Adriatic Sea was involved in the project since September 2017.

The ORC (Organic Rankine Cycle) belongs to the WHRSs (wasted heat recovery systems), and aims at reducing the fuel consumption of the fishing boat. The production of electric energy of the ORC system is supposed to lower the energy normally requested to the genset of the boat, thus reducing its fuel consumption.

The exhaust gases coming from the main propulsion engine pass through a boiler, which provide for the evaporation and overheating of a working fluid. The fluid increases hentalpy (i.e. increases pressure and temperature) passing through the boiler and then it is delivered to a high-speed turbine, that is coupled with a electric generator.

Expanding in the turbine, the working fluid reduces pressure and temperature. Part of the residual heat of the working fluid is adopted in the regenerator, to prepare another portion of working fluid to be evaporated.

At the end of the cycle, the working fluid must be condensed and transformed in a liquid, to be pumped for a new cycle. In Figure 1 the architecture of the ORC system.

In order to evaluate the impact of the ORC in the energy profile of the boat, preliminary investigation on the energy demand of number of users has been conducted for the determination of the electric power demand.

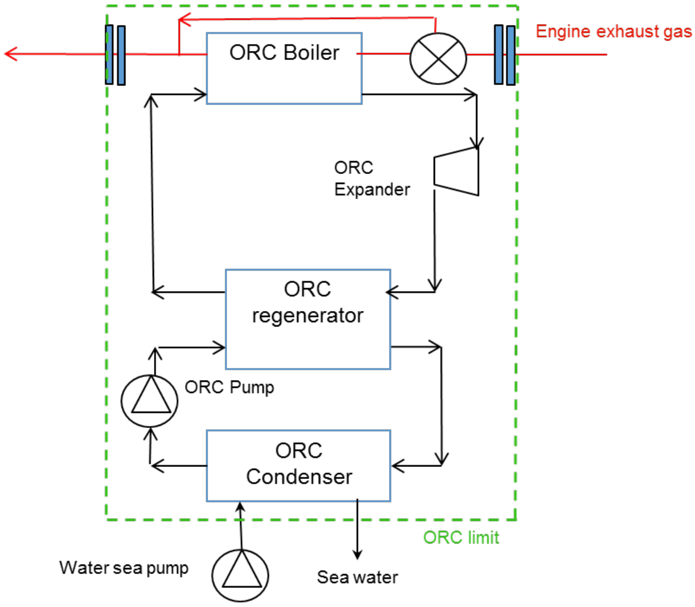


Figure 242.15.1. ORC system architecture.

Energy profile of electric devices onboard

In Figure 12.15.3 it is report the trend of the overall electric power demand of the boat during normal fishing activity (black dots), the portion of the electric power demand covered by the genset (blue dots) and the portion covered by the ORC system (green).

During a first set of trials, the ORC system produced 5 to 6 kW (mean values). When the ORC system is running, the fuel consumption of the genset decreases of 2 l/h, passing from 14 to 12 l/h (mean values).

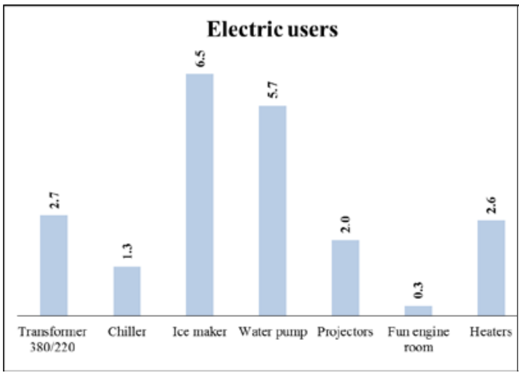


Figure 126.15.2. Power demand of electric users.

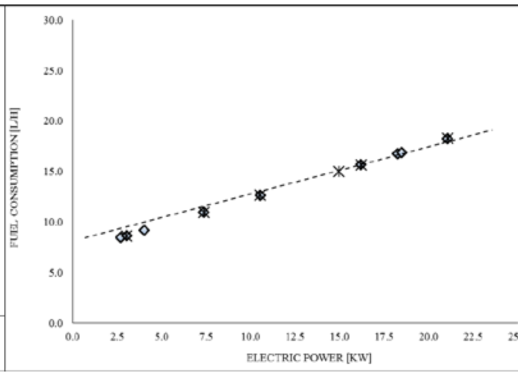


Figure 127.15.28. Electric power against fuel consumption of the genset.

Table 129.15.4. Electric users and class of utilization

Device	Description	Usage	kW	l/h
Idle	engine running in standby		-	5.4
Transformer 380/220	Transformer from 380 to 220 Volt for electric users	Continuous	2.7	3.1
Chiller	Chilling system for refrigerated room, for storing fresh fish during activity	Continuous	1.3	0.7
Ice maker	System that produces ice necessary for well maintaing the fish	Continuous (different intensity for hot and cold seasons)	6.5	3.5
Water pump	high flow sea water pump adopted between trawling phases, to clean the main deck and the fish caught	alternate	5.7	3.0
Projectors	High power lights on the stern of the boat to illuminate the rear part of the deck during night	alternate	2.0	1.1
Fun engine room	injecting fun from outside to the main engine, for a better operating of the main engine turboharger	Continuous	0.3	0.1
Heaters	electric devices for heat production of rooms onboard, during cold seasons	only in cold seasons	2.6	1.4
Total (max)			**21.1**	**18.3**

Impact of the ORC system on fuel consumption

During fishing activity of the boat, especially during trawling and during cruising, the quantity and temperature of exhaust gases are at the maximum values, and large part of the heat contained by the exhaust can be recovered.

An optimization of the ORC system electronic control system is ongoing as the system is supposed to produce up to 7-8 kW, thus reducing fuel consumption of up to 4 l/h, which represents 25% of the fuel consumption of the genset and up to 6% of the overall fuel consumption (main engine + genset).

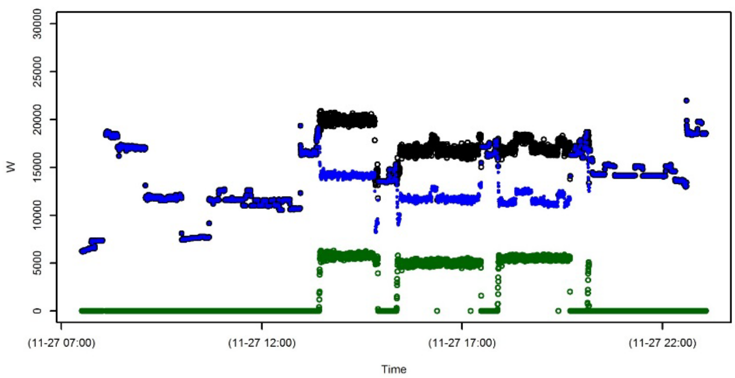


Figure 130.15.31. Daily trend of the electric power demand (black), portion of the electric power from the genset (blue), portion of the electrico power from the ORC system (green). Values are repoted in Watt.

More info at: www.efficientship.eu

12.16 Japan

Nagasaki University

Contact person: Yoshiki Matsushita, yoshiki@nagasaki-u.ac.jp

Summary

Currently, Nagasaki University, Fishing technology Laboratory of Nagasaki University is conducting research on Fish Aggregating Devices (FADs) and Fish attraction lighting systems to enhance efficiencies of small-scale fisheries such as squid jigging and set-net fishing.

Projects

MEXT/JSPS Grant-in-Aid for Scientific Research

Contact person: Yoshiki Matsushita

Apr 2016 – Mar 2019

Impact of fish attraction using light on feeding habit of swordtip squid *Uroteuthis edulis* has been studied. Juveniles of commercial fish such as tuna species are identified as squid bait in addition to forage fish under artificial lighting condition. Also the hypothesis that cannibalism increases under lighting condition has been tested.

Development of underwater fish attraction lighting system for the midwater set-net

Contact person: Yoshiki Matsushita

Aug 2017 – Mar 2020

Underwater fish attraction lighting system that consists of an underwater LED light, a water-proof container, a timer and batteries has been tested in the midwater set-net fishing ground in Aomori, northern Japan to increase fish catch. Last year, initial operations suggested potential increase of mackerel species when light was used.

National Fisheries University

Contact person: Yoritake Kajikawa, kajikawa@fish-u.ac.jp

Summary

Fishing gear laboratory of National Fisheries University is developing LED fishing light for squid jigging of small-scale fishery and Bycatch Reduction Device (BRD) for offshore trawl fishery.

Projects

Development of LED fishing light for squid jigging of small-scale fishery

Contact person: Yoritake Kajikawa

April 2016 – Mar 2019

Squid jigging of Small-scale fishery, fuel consumption by fishing light during operation is higher than fuel consumption during cruising. Fuel cost accounts for more than half of expenses for this fishery. We designed trial LED fishing light, based on the measurement data of the existing fishing light (Halogen). Trial LED fishing light consisted of 6 blue LED panels. Total electrical power consumption was 1/5 of the existing fishing light. From the results of fishing experiments, the catch amount of fishing boat using trial LED fishing light was almost same catch amount of fishing boats using the existing fishing lights.

Development of Bycatch Reduction Device for offshore trawl fishery

Contact person: Yoritake Kajikawa

April 2017 – Mar 2020

In this study, Bycatch Reduction Device has been developed to avoid bycatch of juvenile fish for the offshore trawl fishery in Yamaguchi, western Japan. Fishing experiment of this BRD will be conducted in this year.

13 Other Business

13.1 The 2019 Annual Meeting date and Venue

The Food and Agriculture Organization of the United Nations (FAO) proposes to hold the 2019 annual meeting of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) between 8 and 12 April 2019 in Shanghai, China. The meeting will be organized by FAO in collaboration with Shanghai Ocean University. This proposal was endorsed by WGFTFB members attending the working group meeting in Hirtshals, Denmark on 8 June 2018.

ICES and FAO have had a fruitful working relationship on fishing technology and related fields for many years. ICES WGFTFB was given a global mandate in 2002 when FAO accepted the invitation of ICES to form a joint Working Group with the new name 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 and operational issues into stock assessment surveys and fishery management advice including the impact of fishing on the environment, such as bycatch, unaccounted fishing mortality, habitat impacts, energy use, and greenhouse gas emission. The expanded mandate also fosters global collaboration and information exchange among experts in the field.

FAO has significantly contributed to and benefited from the body of knowledge developed under the Working Group. Such exchanges have provided a stimulus among WGFTFB members to further strengthen the relationship and take advantage of synergies resulting from the global nature of WGFTFB. Consequently, in the 2011 FAO-ICES exchange of letters, FAO agreed to co-chair the WGFTFB and host the annual meeting of WGFTFB every third year in a location chosen by FAO, beginning in 2013. So far, FAO has held the 2013 WGFTFB meeting in Bangkok (Thailand) and the 2016 meeting in Merida (Mexico).

Based on this background, FAO assumes responsibility for the 2019 WGFTFB meeting. FAO proposes to hold the meeting between 8 and 12 April 2019 at Shanghai Ocean University in Shanghai, China, with which FAO has started paperwork for the meeting.

The meeting structure will include a three-day symposium (8 – 10 April), and a two-day regular WGFTFB meeting (11 - 12 April). The three-day symposium provisionally titled “Responsible Fishing Technology for Healthy Ecosystems and Clean Environment” is intended to advance our knowledge of the subject matter and to draw upon the unique regional expertise in the Asia-Pacific region. The symposium represents an opportunity for the Working Group to meet its goals of providing a forum for global synthesis of scientific knowledge of fishing technology, fish behaviour, and their application in conservation and sustainable utilization of world’s marine resources. Symposium sessions will be led by a team of conveners from both within and outside ICES countries, and FAO representatives.

The over-arching goals of the symposium are: (i) provide a forum for global synthesis of the scientific knowledge of fishing technology and its effective use; (ii) evaluate the role and potential for capture technologies and practices to reduce fishing impacts on the environment and energy use; (iii) review and discuss advances in technology and analytical methods used to study these effects; and (iv) foster new partnerships among scientists/technologists from developed and developing economies. The symposium sessions may include the following topic areas:

1. Theory and technology for modelling, simulating, and observing fish and fishing gear
2. Light fishing technology – Use of light to increase fishing efficiency and/or to reduce bycatch
3. Fuel use in fisheries and measures to reduce fuel use and greenhouse gas emission
4. Technological advance and best practices in trawl fisheries
5. Technology and practice for managing bycatch and reducing discards
6. Abandoned, lost or otherwise discarded fishing gear (ALDFG): Assessment of quantity and measures to reduce its impact
7. Chinese fisheries: status, challenges, strategies, and opportunities

13.2 Requests from other ICES Working Groups to WGFTFB

Two recommendations (requests for assistance) relevant to WGFTFB were submitted to the ICES SharePoint Recommendations 2017. That was a request from WGBIFS about advice from WGFTFB experts for new survey trawl and another from IBTSWG for a joint workshop for developing a new standard survey trawl. The working groups have been in contact and at the meeting, the current state was presented with a short discussion afterwards. Two other recommendations were given to WGFTFB connected to cooperation's with WGFAST. This will be followed up by the group with joint meetings.

13.2.1 Request from WGBIFS 2017

A request from WGBIFS was addressed to WGFTFB at 2017 as this "Because WGBIFS has not enough competence for proposing particular type of pelagic trawl, like to ask the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) for advice, which type of pelagic trawl, incl. fully rigging, would be the best for BIAS and BASS surveys in the Baltic Sea conditions". A first discussion was held during WGBIFS 2016 (see WGBIFS-report). Prior to the current discussion, there were two meetings between Olavi Kaljuste (chair WGBIFS), Haraldur Arnar Einarsson (chair WGFTFB) and Daniel Stepputtis (Thünen-Institute, Germany) to discuss the basic needs. During the January 2018 meeting (25.01.2018 in Copenhagen), the group agreed to have a wider discussion during the WGBIFS-meeting 2018. That meeting was held with WebEx and the WGBIFS on 27th of March 2018. The WGBIFS gave Haraldur Arnar Einarsson (on WebEx) and Daniel Stepputtis (on WebEx) a brief overview of the status and the main reasons why the group think there is a need for pelagic–net standardization. It has to be said that there is no common agreement in WGBIFS whether or not a new standard gear should be developed, nor a common understanding of the rationale or reasons were presented. One of the presented reasons is that some members of WGBIFS wish to have a comparable catchability for all countries during the acoustic surveys. This comparable catchability includes pelagic (such as herring and sprat), but also cod – which lives pelagic in some areas of the Baltic Sea and hence cannot be caught by bottom trawls. However, the ships in use for pelagic surveys differ in size and engine power. Additionally, environmental factors like depth and oxygen depletion vary significantly between survey areas. Therefore, it can be difficult to develop one standard gear to perform in all situations. In addition to the discussion about basic trawl-design, it was pointed out (Germany, Estonia, Sweden) that a multisampler could help to identify specific echo targets and layers and hence to improve the survey result.

From this meeting discussion, the following needs where identified:

- standardization of technical specification of the gear
  - basic gear
    - two sizes needed (e.g. 30m and 10-15m in the vertical opening) due to different vessel size and fishing areas
    - possibility to fish close to or even at the bottom (especially in shallow western Baltic and slope areas in Baltic basins)
    - standardized trawl doors
  - codends
    - currently two sizes, discussion needed whether it is possible to harmonize
  - multisampler
- re-evaluation of BIAS-manual related to the fishing operation and vertical stratification (e.g. in relation to vertical opening and the use of multisamplers)
- standardization of trawl-geometry monitoring/net monitoring
- standardization of regular documentation of net specifications for each used net

The following next steps were agreed

- Share of Information regarding existing trawls
  - Haraldur Einarsson distribute information about the mackerel trawls
- Search for experts for further discussions (task force)
  - WGBIFS-members should volunteer to be part of a task force
  - WGBIFS-members should find gear experts in their countries
  - Haraldur Einarsson and Daniel Stepputtis will present the topic briefly at WGFTFB (June 2018) to ask gear technologists for their participation.

At the WGFTFB meeting in Hirtshals, Daniel Stepputtis and Haraldur Arnar Einarsson had a brief introduction about the standardization of pelagic fishing gear in the Baltic pelagic survey and explained the WGBIFS request for the WG. Experts were encouraged to come into this work especially from those countries involved in BIAS surveys. The main discussion about two of the requests for assistance regarding survey gears was taken together on the Friday-meeting and is described in chapter 13.2.3.

13.2.2 Request from IBTSWG 2017

The recommendation from the IBTSWG was addressed to WGFTFB 2017 to "Establish a joint workshop (WGFTFB and IBTSWG) for developing a new standard survey trawl and rigging for the NS-IBTS and the NE Atlantic IBTS". It was put on the WGFTFB agenda to have an overview presentation about this from IBTS. Dave Stokes from The Marine Institute Ireland gave presented via Skype to explain the NS-IBTS and the NE Atlantic IBTS survey context and the history behind recommendation at this time.

To facilitate catch comparisons for the expanding IBTS surveys in the North Sea and Baltic a ‘standard’ gear, the Grande Overture Verticale (GOV), was proposed 1978 (Heesen et. al. 1997). While the exact interpretation of the net plans was always a discussion point, the trawl showed limitations as IBTS expanded into the NE Atlantic (IBTS “Western Area”) from the mid-1990’s. To date the GOV has been used in the Western Area by France, Ireland and the UK (including Scotland) only. It has not been deemed appropriate to the areas or target species of Spain, Portugal or UK Northern Ireland (Irish Sea).

With the arrival of new research vessels and start of new time-series in 2003 Ireland and the UK pursued a more robust survey gear. This was a strengthened Baca trawl similar to that used by Spanish surveys at the time and up to the current day. Following initial trials in 2003 a discussion within ICES led to a more formal approach to the GOV trawl issues documented by IBTS for this area. The result was to continue with the GOV for the interim and establish a series of expert Study groups to look at the development of a new survey trawl (ICES, SGSTG 2003, SGSTS 2009). These study groups reported ultimately in 2009 with clear recommendations for demersal survey trawl gear in general and a proposed new "SurveyTrawl" design specifically. Implementation of the SurveyTrawl proved problematic and did not progress however.

A number of factors coincide however to support the recommendations from SGSTG/SGSTS study groups be acted upon at this point.

1. A number of new research vessels are due to arrive in to the fleet in the next few years. This presents the usual opportunities and challenges of reviewing existing time-series and calibration of new vessels along with any forced or planned changes that arise.
2. A number of significant technical issues with the trawl design and operation have been documented by IBTS and touched on during the current presentation. The result being returning everyone to a 'standard' GOV design and operation will likely create as many problems as it solves, if not more.
3. There is currently a lack of IBTS survey coverage in the important transition area between the North Sea and Celtic Sea (ICES Area 7.d – Fig 1). France have suggested they reallocate effort to cover this, but indices they currently contribute for important species such as Celtic Sea cod are already at extremely data poor level. With the current IBTS protocol of ->10 nmi between hauls within a survey the opportunity for Ireland to increase sampling in the Celtic Sea area is very limited. To ensure coverage and maintain data levels into assessments therefore the strongest option would seem to be to improve the efficiency of the current sampling trawl. With mesh size in the mouth and belly of the GOV currently at 200mm for a fisheries recruitment survey there would seem to be ample scope to improve in this as well as the other design areas highlighted during the presentation and by IBTS reports previously.

The road map currently is for the main IBTS participants at least of the earlier study groups at least to meet up for a scoping meeting. This will be hosted by Benoit Vincent, another SGSTS group member, at the IFREMER Lab and flume tank in Lorient. Objectives will be to discuss two designs meeting the original SGSTS recommendations to be evaluated later in the year by Ireland and Scotland. Some initial thoughts on rigging will also be looked at during the Lorient meeting in the flume tank. A more formal proposal for development, sea trials and workshop(s) to include greater participation in final design of the new survey trawl will then be circulated. As well as this input from the assessment groups and other expert groups such as WGISDAA will be required to ensure a coordinated approach to evolving the time-series. This can then be done if and when Institutes and stock assessors are in a position to take up an improved design once available and they feel it would be desirable to do so.

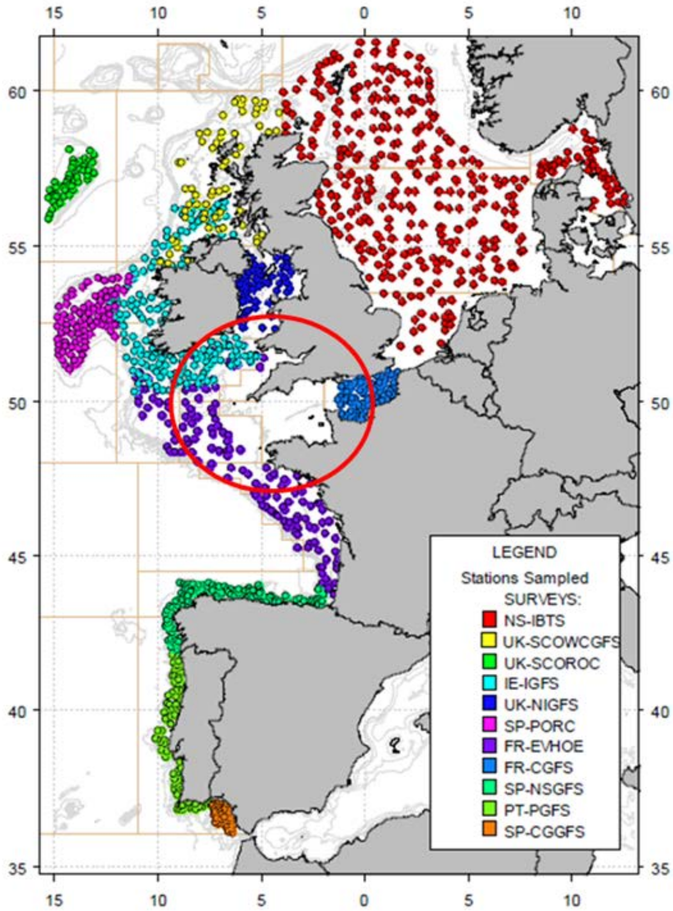


Fig 13.1. Station positions for the IBTS carried out in the Northern Atlantic and North Sea area in summer/autumn 2016. Quarters 3 and 4.

Hessen, H., Dalskov, J., and Cook, R. M. (1997). The International Bottom Trawl Survey in the North Sea, Skagerrak and Kattegat. (No. CM 1997/Y:31) (p. 25). International Council for the Exploration of the Sea (ICES).

ICES. (2003, February 12). Study Group on Survey Trawl Gear for the IBTS Western and Southern Areas (SGSTG).

ICES. (2009). Report of the Study Group on Survey Trawl Standardisation (SGSTS) (ICES Council Meeting documents [ICES Council Meeting Documents. Copenhagen]) (p. [np]).

13.2.3 General about requests for design assistance of new survey trawls

The meeting had a general discussion about those requests for assistance. When there was no strong response to those requests it was pointed out that our members, in general, do not design gear but investigate them for their use and effects. To develop a new survey gear, it would be better to work in collaboration with a net designer. But at the same time, the group understand that experts from FTFB might be needed into such work as well.

It might be a better way to propose to ICES a new Working Group with survey gears as the subject. This Working Group could include expert members from FTFB and relevant experts from others working groups. Among the term of references for such a group could be; making recommendations for standards of survey trawls; helping to write and review manuals of maintenances and use. For interested FTFB members, it would be easier to work and attend a few days meeting in such specific working group instead of having only a few minutes of attention in a big meeting like the WGFTFB meetings. A group like this could have a yet undetermined number of tasks. It is conceivable that the group might be paused or dissolved once it has completed those tasks. It is still too early to outline the details of such a group and the tasks are in a reasonable progress, but this will be further discussed over the coming year to evaluate if a new Working Group will be proposed.

13.3 Manual of methods of measuring the selectivity of towed and static gears

Like in the years before, the group before and during the formal meeting discussed the need to update the ICES Cooperative Research Report, No. 215. 'Manual of methods of measuring the selectivity of towed fishing gears' (1996). The meeting of WGFTFB agreed, that updating this essential manual is of importance. It was pointed out, that gear design has moved on a great deal, as has technology and computing power. The old manual is still used by newcomers to gear technology and students. Especially in countries with a lack of gear technologists the manual is a vital teaching tool. Bringing it up to date is therefore urgent.

The meeting did discuss how this could be achieved. It was also discussed if the manual should be split in two, one manual for towed and the other for static gears. While the catching methods are very different between towed and static gears, some of the statistical analyses are similar and possibly can be cross-referenced between manuals if needed.

Some discussions were about the format of the manual and who should be in charge of publishing. ICES or FAO are obvious candidates as publishers, either as collaboration or separately. However, it is too early for those issues to be decided. It was suggested that the format could include paper but also electronic versions with the possibility of including interactive content.

The Working Group agreed that next year's meeting would be the right time to propose a Topic Group that would deal with the task of a new towed gear selectivity manual. A new Topic Group on passive gear is proposed to start next year. The work of this topic group could then inform a potential new passive gear manual. The Topic Group on a gear selectivity manual would start at WGFTFB meeting in 2020 and run for 3 to 6 years.

13.4 Topic Groups for the 2019 WGFTFB Meeting

New Topic Group: Passive fishing gears (Passive)

A WGFTFB Topic group convened by Peter Ljungberg (Sweden), Isabella Kratzer (Germany) and Lotte Kindt-Larsen (Denmark) will be formed in 2019 on passive gears.

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, seabirds 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 of 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, seabirds 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.

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 will meet for the second year.

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.

The goals of 2019 meeting will be to:

i) welcome new community members;

ii) identify work on using artificial light for bycatch mitigation that was not previously presented at the 2018 meeting and new projects, and discuss ongoing research;

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) continue discussions of common challenges when using light as a selectivity tool;

v) begin to explore the database of combined studies.

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 ongoing 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.

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

The WGFTFB topic group convened by Roger Larsen, Pingguo He and Antonello Sala will continue the work on the knowledge of designs of groundgear and other components that are usually in contact with the seabed during bottom trawling, which was initiated during the 2017 WGFTFB meeting in Nelson, New Zealand and continued in Hirtshals, Denmark 2018.

A final report from the Groundgear topic group will be provided at the ICES-FAO WGFTFB meeting in April 2019. Publication of the report (or part of it) in FAO Fisheries Report or in a peer-reviewed journal is envisaged.

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:

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.

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 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 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.

Factsheets on fishing gear selectivity and catch comparison trials (Facts)

A WGFTFB topic group convened by Barry O'Neill (Denmark) and Jordan Feekings (Denmark) will continue the work Factsheets on fishing gear selectivity and catch comparison trials, which was initiated during the 2018 WGFTFB meeting in Hirtshals, Denmark. The topic group recommends that a comprehensive trial run be held to produce factsheets for the 2019 WGFTFB meeting, shown here in revised ToR.

Revised terms of reference

It is proposed that prior to the 2019 WGFTFB meeting:

1. a template will be circulated with guidelines on content, design, style and format;
2. 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;
3. members will submit their factsheets along with their national reports.

It is proposed that during the 2019 WGFTFB meeting:

4. the topic group meet to review and edit the submitted factsheets;
5. consider and make recommendations on the guidelines, design, style and format of the factsheets;
6. consider and make recommendations on medium to long-term storage of the factsheets.

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.

Annex 1: List of participants

Name	Institute / Organization	Country
Damien Grelon	Merinov	Canada
Gebremeskel Kebede	Memorial University	Canada
George Legge	Memorial University	Canada
Khanh Nguyen	Memorial University	Canada
Marie-Claude Côté-Laurin	Merinov	Canada
Paul Winger	Memorial University	Canada
Thomas St-Cyr Leroux	Merinov	Canada
Cheng Zhou	Ocean University of China	China
Hao Tang	Shanghai Ocean University	China
Liming Song	Shanghai Ocean University	China
Liuxiong Xu	Shanghai Ocean University	China
Jure Brčić	University of Split	Croatia
Luka Mimica	University of Split	Croatia
Barry O'Neill	DTU-Aqua	Denmark
Esther Savina	DTU-Aqua	Denmark
Jordan Feekings	DTU Aqua	Denmark
Junita Karlsen	DTU Aqua	Denmark
Lotte Kindt-Larsen	DTU Aqua	Denmark
Ludvig Krag	DTU Aqua	Denmark
Marco Nalon	DTU Aqua	Denmark
Niels Madsen	Aalborg University	Denmark
Paul Michael Petersen	Technical University of Denmark	Denmark
Rasmus Ern	Aalborg University	Denmark
Rikke Petri Frandsen	DTU-Aqua	Denmark
Thomas Noack	DTU-Aqua	Denmark
Tiago Da Veiga Malta	DTU-Aqua	Denmark
Ulrik Jes Hansen	CATch-Fish	Denmark
Valentina Melli	Technical University of Denmark	Denmark
Petri Suuronen	Natural Resources Institute Finland	Finland
Maud Mouchet	French Museum of Natural History	France
Pascal Larnaud	IFREMER	France
Bernd Mieske	Thünen Institute of Baltic Sea Fisheries	Germany
Daniel Stepputtis	Thuenen Institute of Baltic Sea Fisheries	Germany
Isabella Kratzer	Thuenen Institute for Baltic Sea Fisheries	Germany

Juan Santos	Thuenen Institute of Baltic Sea Fisheries	Germany
Karsten Breddermann	University of Rostock	Germany
Mathias Paschen	University of Rostock	Germany
Stefanie Haase	Institute for Hydrobiology and Fishery Science	Germany
Uwe Lichtenstein	University of Rostock	Germany
Chryssi Mytilineou	HCMR	Greece
Geir Gudmundsson	Optitog ehf.	Iceland
Georg Haney	MFRI	Iceland
Halla Jonsdottir	Optitog ehf.	Iceland
Haraldur Arnar Einarsson	MFRI	Iceland
Torfi Thorhallsson	Optitog ehf.	Iceland
Daragh Browne	Bord Iascaigh Mhara	Ireland
Martin Oliver	Bord Iascaigh Mhara	Ireland
Matthew McHugh	Bord Iascaigh Mhara	Ireland
Mikel Aristegui-Ezquibela	Marine and Freshwater Research Centre, GMIT	Ireland
Ronán Cosgrove	Irish Sea Fisheries Board (BIM)	Ireland
Amit Lerner		Israel
Antonello Sala	Italian National Research Council (CNR)	Italia
Michele Luca Geraci	National Research Council	Italia
Pingguo He	Food and Agriculture Organization (FAO)	Italia
Sergio Vitale	Consiglio Nazionale delle Ricerche	Italia
Yoritake Kajikawa	National Fisheries University	Japan
Chun Woo Lee	Pukyong National University	Korea
Pyungkwan Kim	National Institute of Fisheries Science, Korea	Korea
Subong Park	Pukyong National University	Korea
Bob van Marlen	Free	Netherland
Pieke Molenaar	Wageningen Marine Research	Netherland
Carol Scott	Southern Inshore Fisheries Management Co Ltd	New Zealand
Emma Jones	NIWA	New Zealand
Anne Christine Utne Palm	Institute of marine Research	Norway
Bent Herrmann	Sintef	Norway
Eduardo Grimaldo	SINTEF Ocean	Norway
Jesse Brinkhof	UiT, Arctic University of Norway	Norway
Lasse Rindahl	Mustad Autoline AS	Norway
Leonore Olsen	SINTEF Nord	Norway
Manu Sistiaga	SINTEF Ocean	Norway
Maria Tenningen	Institute of Marine Research	Norway
Melanie Underwood	Institute of Marine Research	Norway
Mike Breen	Institute of Marine Research	Norway
Odd-Børre Humborstad	Institute of Marine Research	Norway
Ólafur Arnar Ingólfsson	Institute of Marine Research	Norway
Roger B Larsen	UIT The Arctic University of Norway	Norway
Svein Løkkeborg	Institute of Marine Research	Norway
Terje Jørgensen	Institute of Marine Research	Norway
Elsa Cuende	Azti Tecnalia	Spain

Iñigo Onandia	Azti Tecnalia	Spain
Erika Andersson	Institute of Marine Research	Sweden
Hans Nilsson	Swedish University of Agricultural Sciences	Sweden
Peter Ljungberg	Institute of Coastal Research, (SLU)	Sweden
Ronald Kröger	Lund University	Sweden
Adnan Tokaç	Ege University	Turkey
Enis Noya Kostak	Ege University Natural Applied Sciences	Turkey
Yunus Emre Fakıoğlu	Mersin University, Fisheries Faculty	Turkey
Barbara Koeck	University of Glasgow	UK
Dan Watson	SafetyNet Technologies	UK
Ron Douglas	City, University of London	UK
Shaun Killen	University of Glasgow	UK
Thomas Catchpole	Cefas	UK
Bradley Harris	Alaska Pacific University	USA
Chris Rillahan	University of Massachusetts	USA
John Wang	NOAA - Pacific Islands Fisheries Science Center	USA
Lauren Fields	National Oceanic and Atmospheric Administration	USA
Mark Lomeli	Pacific States Marine Fisheries Commission	USA
Michael Osmond	WWF	USA
Noëlle Yochum	NOAA Alaska Fisheries Science Center	USA
Suresh Sethi	Cornell University	USA
T. Scott Smeltz	Cornell University	USA

Annex 2: Agenda

Monday 4th June

Fishing-gears and impact

08:30	Registration and house keeping
09:00	WGFTFB Opening
09:20	FAO briefing on relevant activates.
	Pingguo He
09:40	50 years of fishing technology at University Rostock
	Mathias Paschen, Harry Stengel and Bob van Marlen
10:00	Coffee break
10:20	FTFB Business – Standardization of pelagic fishing gear in the IBAS surveys, from WGBIFS
	Daniel Stepputtis and Haraldur Arnar Einarsson
10:40	Global marine mammal bycatch in fisheries through the List of Foreign Fisheries: An analysis of fishing regions and gear types
	Lauren G. Fields, Nina M. Young
11:00	Fish and shout: understanding the acoustic reflectivity of modified gillnets
	Isabella Kratzer, Ingo Schäfer, Daniel Stepputtis, Jérôme Chladek, Lotte Kindt-Larsen, Finn Larsen
11:20	Swedish small-scale coastal seining
	Peter Ljungberg, Sara Königson, Maria Hedgärde, Sven-Gunnar Lunneryd
11:40	Estimating the sediment put into the water column by towed demersal fishing gears
	F G O'Neill and K Summerbell
12:00	Lunch Break
13:30	A seascape scale fishing impacts model to assess trade-offs between spatial closures and gear modifications
	T. Scott Smeltz, Suresh Sethi, Bradley Harris
13:50	Discussion

Selectivity in a broad sense

14:10	Research on trawl selectivity and selective fishing technology in China
	Liuxiong Xu, Jian Zhang and Zhongqiu Wang
14:30	Understanding size selectivity of 3 species in New Zealand inshore trawl fisheries.
	Emma Jones, Jure Brčić, Collin Sutton, Karl Warr, Bent Herrmann

14:50	Modelling gear and fishers size-selection for escapees, discards and landings: a case study in Mediterranean trawl fisheries
	Mytilineou Chryssi, Herrmann Bent, Mantopoulou-Palouka Danai, Sala Antonello and Megalofonou Persefoni
15:10	Coffee break
15:30	Modelling the effects of mesh size on gillnet selectivity in the hake fishery to the South and West of Ireland
	Mikel Aristegui-Ezquibela, Cóilín Minto, Daragh Browne, Ronán Cosgrove, Peter Tyndall, Daniel McDonald
15:50	Changes in operational tactics as a powerful tool to adjust to the landing obligation for bottom-set-nets
	Esther Savina, Ludvig Ahm Krag
16:10	Using ecomorphology and functional traits to understand the efficiency of a selective device in a mutli-species fishery
	Maud Mouchet, Fabien Morandeau, Camille Vogel, Sonia Méhault, Dorothée Kopp
16:30	Shape your fish stock: Using a length- and age-based population model to find the optimal harvest strategy
	Stefanie Haase, Sarah Kraak, Juan Santos, Daniel Stepputtis, Axel Temming
16:50	Discussion
17:10	Flume tank

Tuesday 5th June

	Mean and methods in surviveal, biogradeble and design
08:30	Registration and house keeping
08:40	Effect of codend design on discard survivability
	Thomas Noack, Esther Savina, Junita Karlsen
09:00	Monitoring individual-level behaviour of mackerel (Scomber scombrus) in relation to crowding and oxygen concentrations in commercial purse-seine catches
	Mike Breen, Jostein Saltskår, Neil Anders, Bjørn Totland, Jan Tore Øvredal and Hector Peña
09:20	Assessing physiological stress to understand collateral mortality in the Antarctic krill (Euphausia superba) trawl fishery
	Ludvig Ahm Krag, Bjørn A. Krafft, Bent Herrmann, Peter Vilhelm Skov
09:40	Biodegradable fishing gears in Korea; its challenge and future
	Yongsu Yang, Pyungkwan Kim, Jae-Hyun Bae, Seonghun Kim, Donggil Lee
10:00	Coffee break

10:20	Comparison of fishing efficiency between biodegradable PBSAT gillnets and conventional nylon gillnets in the cod (Gadus morhua) fishery in northern Norway.
	Eduardo Grimaldo, Bent Herrmann, Biao Su, Heidi Moe Føre, Jørgen Vollstad, Leonore Olsen, Roger B. Larsen, Ivan Tatone
10:40	Design and performance of software based trawl fishing simulator
	Subong PARK, Chun Woo LEE* and Jihoon LEE
11:00	Evaluating the drag and lift coefficients of self-spreading helical ropes against conventional PA, and PE ropes at different attack angles and towing speeds
	Gebremeskel Eshetu Kebede, Paul Winger, Harold DeLouche, George Legge, David Kelly, and Haraldur Einarsson
11:20	Flow simulation in a double sorting grid system
	Karsten Breddermann, Mathias Paschen

Spesies and size selectivity in crustasean fishery

11:40	Discussion
12:00	Lunch Break
13:30	FTFB Business - Establish a joint workshop (WGFTFB and IBTSWG) and flume tank experiments for developing an new standard survey trawl and rigging for the NS-IBTS and the NE Atlantic IBTS
	Haraldur Arnar Einarsson
13:50	Understanding and predicting the size selectivity of mantis shrimp (Squilla mantis) in Nephrops creel fishery
	Jure Brčić, Bent Herrmann, Marina Mašanović, Svjetlana Krstulović Šifner, Frane Škeljo
14:10	Rope-panels for species separation in Nephrops trawls
	Juan Santos, Bernd Mieske , Daniel Stepputtis, Bent Herrmann, Stefanie Haase, Pieke Molenaar
14:30	Effect on selectivity during shrimp trawling by changing grid length, grid angle and by adding a second grid.
	Roger B. Larsen, Manu Sistiaga, Bent Herrmann, Jesse Brinkhof,
	Ivan Tatone, Juan Santos
14:50	Use of Swedish designed escape grids to optimize the size selectivity of Pandalus Borealis in the Danish trawl fishery
	Jordan Feekings, Rikke Frandsen, Tiago Veiga-Malta, Daniel Valentinsson
15:10	Coffee break

15:30	Catch and release efficiency for bycatch and target species in shrimp fishery by using a Nordmøre grid or a sieve net
	Bent Herrmann, Roger B. Larsen, Manu Sistiaga, Jesse Brinkhof, Ivan Tatone, Eduardo Grimaldo, Juan Santos
15:50	Reducing trawl length improves size selection in the Northern Shrimp fisheries
	Ólafur Arnar Ingólfsson, Terje Jørgensen
16:10	Discussion
16:30	Introduction to the posters session
16:50	Poster session

Wednesday 6th June

Gear tehcnology for better selectivity

08:30	Registration and house keeping
08:40	Gearing Up
	Tom Catchpole
09:00	Four years of the Swedish secretariat for Selective fishing
	Hans C Nilsson and Daniel Valentinsson
09:20	When is enough, enough? From theory to practice
	Tiago Veiga-Malta, Jordan Feekings, Bent Herrmann, Ludvig A. Krag
09:40	Size selection in Dyneema netting codend compared to traditional codend in Mediterranean bottom trawl fisheries
	Adnan Tokaç, Celalettin Aydın
10:00	Coffee break
10:20	Flatfish behavior in electrified beam trawls
	Pieke Molenaar, Michiel Dammers
10:40	Reducing Flounder Bycatch in the Georges Bank Haddock Fishery: Application of a Modified European Grid System
	Christopher Rillahan and Pingguo He
11:00	Trawl separating flat- and round fish
	Erika Andersson, Johan Lövgren
11:20	Raising the fishing line in demersal whitefish trawls to reduce cod catches
	Matthew McHugh, Daragh Browne, Martin Oliver, Peter Tyndall, Cóilín Minto and Ronán Cosgrove
11:40	A Simple Groundgear Modification to Reduce Bycatch of Elasmobranchs in the Mediterranean Trawl Fishery

	Yunus Emre Fakıoğlu, Hüseyin Özbilgin, Gökhan Gökçe, Ebrucan Kalecik, Oğuzhan Demir, Yeliz Özbilgin, Esin Yalçın, Bent Herrmann
12:00	Lunch Break
13:30	Benefits of an inclined separator panel and two codends with different selectivity measures in the Irish Nephrops mixed fishery
	Ronán Cosgrove, Daragh Browne, Coilin Minto, Peter Tyndall, Martin Oliver, Mike Montgomerie, Matthew McHugh
13:50	Trials of measures to reduce bycatch of whiting in the Irish Sea mixed fishery targeting Nephrops
	Daragh Browne, Ronan Cosgrove, Martin Oliver, Matthew McHugh
14:10	A new flexible grid to improve selectivity in the otter trawl fisheries targeting anglerfish
	Larnaud Pascal, Lamothe Julien, Robert Marianne, Fiche Marion, Simon Julien, Morandeau Fabien, Vacherot Jean-Philippe
14:30	Combination of a sorting grid and a square mesh panel to optimize size selection in the northeast Arctic cod (Gadus morhua) and redfish (Sebastes spp.) trawl fisheries
	Manu Sistiaga, Bent Herrmann, Eduardo Grimaldo, Roger B. Larsen, Leonore Olsen, Jesse Brinkhof, and Ivan Tatone
14:50	Sequential codend improves quality of trawl-caught cod
	Jesse Brinkhof, Stein H. Olsen, Ólafur A. Ingólfsson, Bent Herrmann, Roger B. Larsen
15:10	Discussion
15:30	Break

Trip + Conference dinner

Thursday 7th June

Topic session: Artifical lights with fishng gears

08:30	Registration and house keeping
08:40	Introduction to the Light session and the Topic Group Lights
	Noelle Yochum and Junita Diana Karlsen
09:00	The luminous net VISIONET – a guiding swimway to the exit or a stressor?
	Junita D. Karlsen, Valentina Melli, Ludvig Ahm Krag
09:20	Some recent trials with illuminated grids
	F G O'Neill and K Summerbell
09:40	Catching Northern Prawn without benthic contact
	Einar Hreinsson, Hjalti Karlsson, Geir Gudmundsson, Halla Jonsdottir, Torfi Thorhallsson

10:00	Coffee break
10:20	Trawlight – Using artificial lights to modify fish behaviour in trawls
	Sam Smith, Tom Catchpole
10:40	Location, orientation, and economic performance of low-powered LED lights inside snow crab traps in eastern Canada
	Khanh Q. Nguyena, and Paul D. Winger
11:00	Discussion
11:20	Introduction to the Topic groups
	Facts (F G O'Neill, and Jordan Feekings)
	Contact (Daniel Stepputtis and Bent Herrmann)
	Groundgear (Roger B. Larsen, Pingguo He and Antonello Sala)
12:00	Lunch Break
	ToR: Topic group work
13:30	Topic Group work
15:10	Coffee break
15:30	Topic Group work

Friday 8th June

	ToR: Topic group work
08:30	Registration and house keeping
08:40	Topic Group work
10:00	Coffee break
10:20	Topic Group work
12:00	Lunch Break
13:30	Country report summary
	(Rapporteur)
13:50	Summary Topic Group (Facts)
	F G O'Neill, and Jordan Feekings
14:10	Summary Topic Group (Lights)
	Noelle Yochum and Junita Diana Karlsen
14:30	Summary Topic Group (Contact)
	Daniel Stepputtis and Bent Herrmann
14:50	Summary Topic Group (GroundGear)
	Roger B. Larsen, Pingguo He and Antonello Sala
15:10	FTFB Business
	Haraldur Arnar Einarsson and Pingguo He

Next year Topic Groups

Next year meeting – Symposium ideas - Place and time

Other business

Adjourn

Posters

A study of discard survival in set-net fisheries

Rasmus Ern, Katrine Molbo, Trine H Jensen, Sergey V Kucheryavskiy, Peter R Møller, Iben W Rathje, Niels Madsen

Size selectivity of barrier traps for Gilt-head Sea Bream: A FISHSELECT application

Gökhan Gökçe, Hüseyin Özbilgin, Adnan Tokaç, Hasan Atar, İsmet Saygu, Bent Herrman

Improved catch monitoring in purse-seine fisheries using acoustic methods

Maria Tenningen1*, Héctor Peña1, Gavin Macaulay1

Determining the effect of mesh size on scaling up of model net of tuna purse-seine in physical. **Model testing**

Hao Tang, Liuxiong Xu, Fuxiang Hu, Taisei Kumazawa, Mamoru Hirayama, Cheng Zhou, Xuefang Wang, Wei Liu

Identifying the design alternatives and flow interference of tuna purse-seine by numerical. Modelling approach

Cheng Zhou, Liuxiong Xu

Understanding and predicting size selection of greater forkbeard (Phycis blennoides) for. Bottom trawl codends: a simulation-based approach

Adnan Tokaç, Bent Herrmann, Enis Noyan Kostak

Quantifying bell-shaped size selectivity in shrimp trawl fisheries: effect of codend design

Roger B. Larsen, Bent Herrmann, Manu Sistiaga, Jesse Brinkhof, Ivan Tatone

Experimental fishery and utilization of mesopelagic fish species and krill in the North East. Atlantic – NEAFC RA 1 Reykjanes ridge area.

Eduardo Grimaldo, Leif Grimsmo, Marte Schei, Bendik Toldnes, Merethe Selnes

Behavioural Responses of Krill and Cod to Artificial Light in Laboratory experiments

A.C. Utne-Palm, M. Breen, S. Løkkeborg and O-B. Humborstad

Using artificial lights to illuminate gillnets as a strategy for reducing the bycatch of sea turtles and other marine species

John Wang, J. Barkan, F. Carvalho, S. Fisler, J. Mangel, J. Alfaro-Shigueto, S. Pingo, A. Jimenez, Y. Swimmer, Dwi Ariyoga Gautama, W. Teguh, C. Ngesti Handyani

Shedding light on Swedish shrimp potting

Peter Ljungberg, René Bouwmeester

Effects of population density on catch rates of snow crab traps using artificial light in the Barents Sea

Khanh Q. Nguyena, Odd-Børre Humborstad, Svein Løkkeborg, and Paul D. Winger

LED lights to reduce bycatch in trawls: does phototaxis come into play?

Valentina Melli, Ludvig A. Krag, Bent Herrmann, Junita D. Karlsen

Using Artificial Illumination to Reduce Bycatch in Two US West Coast Trawl Fisheries

Mark J.M. Lomeli, W. Waldo Wakefield, Scott D. Groth, Matthew T.O. Blume, Bent Herrmann

How artificial lights affect bycatches of fish and the Deepwater shrimp during trawling in the Barents Sea

Roger B. Larsen, Bent Herrmann, Manu Sistiaga, Jesse Brinkhof, Ivan Tatone, Lise Langård and Jure Brčić.

Annex 3: Recommendations

There are no recommendations from the group this year.

Annex 4: Multiannual Term of Reference for ICES-FAO WGFTFB

The ICES-FAO **Working Group on Fishing Technology and Fish Behaviour (WGFTFB)**, chaired by Haraldur A. Einarsson*, Iceland, and Pingguo He (FAO), will meet to work on the following Terms of References (ToRs) and produce deliverables as listed in the following table for the years 2017 through 2019. This multiyear ToRs will be updated annually. WGFTFB will report on the activities and findings by 25 June each year to EOSG.

Year	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2017	4-7 April	Nelson, New Zealand	Interim report by 25 June to EOSG	Petri Suuronen outgoing FAO Chair
Year 2018	4-8 June	Hirtshals, Denmark	Interim report by 13 July to EOSG	Pingguo He new FAO chair
Year 2019	8-14 April	Shanghay, China	Interim report by 25 June to EOSG	

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	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.	28,29, 30, 31primarily; others are possible (e.g. 11,12, 27)	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.	29, 30	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).	27, 30, 31	Year 1	JFATB report
D	Help organize an ICES-sponsored international fishing technology and fish behaviour symposium	The last similar symposium was ten years ago (2006).	28, 29, 30, 31	Fall 2020 (outside scope of this Multiannual ToR)	Symposium and special issue in ICES JMS
E	Support survey working group with gear expertise support upon request	EOSG has identified gear expertise gaps in survey working groups.	31	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 40–50 regular members and chair-invited members. Participation is about 70 - 90 in the year when FAO-ICES mini-symposium is held.
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 EOSG, e.g. WGFAST, and the survey groups.
Linkages to other organizations	The WG is jointly sponsored with the FAO.

Annex 5: Factsheets on fishing gear selectivity and catch comparison trials

decreasing codend circumference to reduce whiting discards in a *Nephrops* trawl

AIM

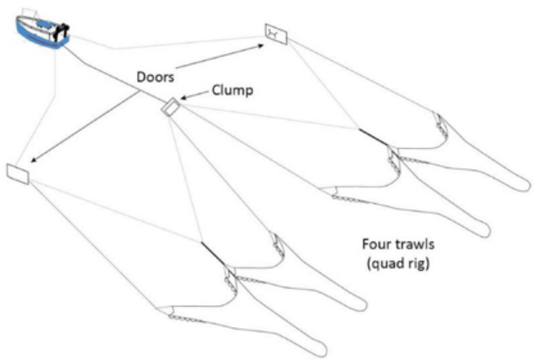
To assess the effect of decreasing codend circumfernce on catches of whiting.

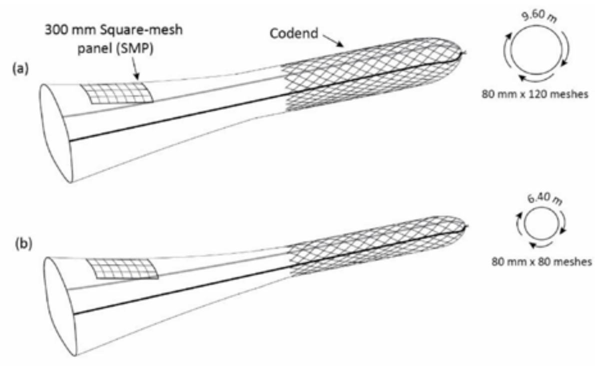
TARGET SPECIES

Nephrops norvegicus

AREA, VESSEL

The 12 haul quad-rig catch comparison trial took place in the Irish Sea (ICES 7a) on board a 23 m, 328 kW trawler during February 2018.





GEAR MODIFICATION

The test codend was constructed from 80mm* mesh with a circumference of 80 meshes round.
The standard codend was constructed from 80mm* mesh with a circumference of 120 meshes round.
A 300 mm square meshed panel was fitted between 9 and 12 m from the codline on both gears.
The fishing circle of the quad-rigged *Nephrops* trawls was 400 X 80mm*.

***nominal mesh size**

RESULTS

Moderate reductions in catches of whiting below MCRS of 27 cm.

Greatest reductions in very small whiting < 20 cm.

Total *Nephrops* catches reduced by 14% (by weight) and 8% (by value).

Species	Standard 80 mm (kg)	Test 80 mm (kg)	Difference (%)
Whiting <27 cm	229	215	-6
Whiting <20 cm	144	122	-15
Nephrops	444	383	-14

FURTHER INFORMATION

http://www.bim.ie/our-publications/fisheries/

BIM Ireland's Seafood Development Agency

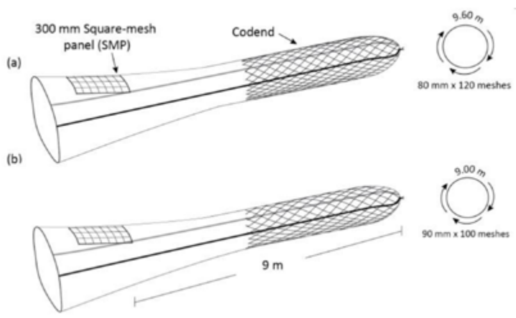
DiscardLess

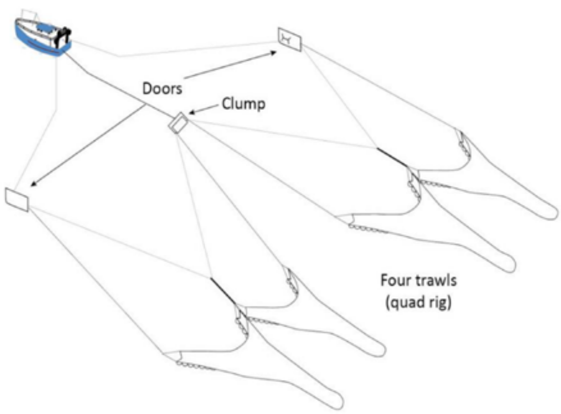
increasing codend mesh size from 80 to 90mm to reduce whiting discards in a *Nephrops* trawl

AIM
To assess the effect of a codend mesh size increase on catches of whiting.

TARGET SPECIES
Nephrops norvegicus

AREA, VESSEL
The 12 haul quad-rig catch comparison trial took place in the Irish Sea (ICES 7a) on board a 23 m, 328 kW trawler during February 2018.





GEAR MODIFICATION
The test codend and extension piece were constructed from 90mm* diamond mesh with 100 meshes in circumference.
The standard codend and extension piece were constructed from 80mm* diamond mesh. with 120 meshes in circumference.
A 300 mm square meshed panel was fitted between 9 and 12 m from the codline on both gears.
The fishing circle of the quad-rigged *Nephrops* trawls was 400 X 80mm*.
***nominal mesh size**

RESULTS
Substantial reductions in catches of whiting below MCRS of 27 cm.

Greatest reductions in very small whiting < 20 cm.

Total *Nephrops* catches reduced by 33 % (by weight) and 23 % (by value).

Species	Standard 80 mm (kg)	90 mm (kg)	Difference (%)
Whiting <27 cm	229	121	-47
Whiting <20 cm	144	57	-60
Nephrops	444	295	-33

FURTHER INFORMATION
http://www.bim.ie/our-publications/fisheries/

BIM Ireland's Seafood Development Agency

DiscardLess

Effect of increasing circumference of T90 codends on Baltic cod selectivity

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

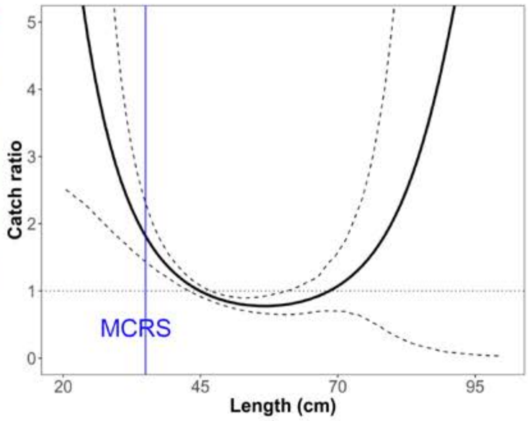
The trial took place in the Baltic Sea (ICES 24 and 25) on board R218 Judith Bechmann (26 m, 485 kW)

GEAR MODIFICATION

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, and in particular it caught significantly more under sized cod less than the minimum conservation reference size (MCRS) of 35 cm.



FURTHER INFORMATION

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DTU

DiscardLess

Effect of codend material type on the selectivity of Baltic cod

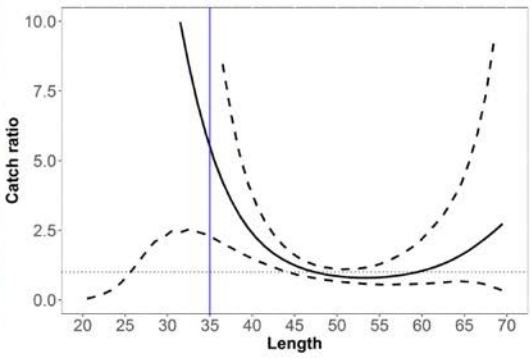
AIM
To observe what effect changing the codend material from polyethylene to polyester has on the selectivity of cod (*Gadus morhua*).

TARGET SPECIES
Cod (*Gadus morhua*)

AREA, VESSEL
The trial took place in the Baltic Sea (ICES 24 and 25) on board R218 Judith Bechmann (26 m, 485 kW)

GEAR MODIFICATION
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. In particular, catches of undersized cod at the minimum conservation reference size of 35 cm were 5 times more likely to be caught in the polyster codend in comparison to the polyethylene one.



FURTHER INFORMATION
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DiscardLess

Effect of codend circumference, mesh size & lastridge ropes

on cod selectivity in the Baltic Sea

AIM

To reduce the capture of small cod and increase the capture of larger cod

TARGET SPECIES

Atlantic cod (*Gadus morhua*)

AREA, VESSEL

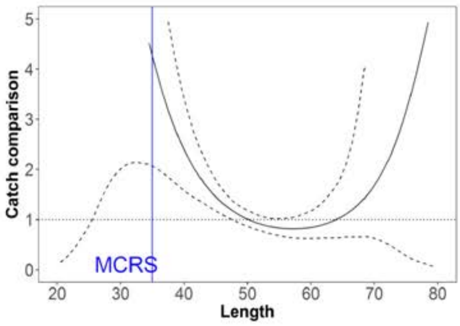
The trial took place in the Baltic Sea (ICES Divisions 27.3.d.24 and 27.3.d.25) on board R218 Judith Bechmann (25.9 m, 485 kW)

GEAR MODIFICATION

A T90 codend with 110 mm mesh size, a circumference of 92 meshes and lastridge ropes was compared with a standard T90 codend with 120 mm mesh size, 50 meshes in circumference and with no lastridge ropes.

RESULTS

The modified codend significantly increased the retention of cod under 47 cm, but also increased the retention of undersized cod (at least 2 times more 30 cm cod). For individuals over 47 cm there is no significant difference in catch rates between the two codends.



Species	Hauls	Number of fish sampled	Mean effect in catch weight
Cod < 35 cm	10	699	+ 413%
Cod ≥ 35 cm	10	9071	+ 45%

FURTHER INFORMATION

Jordan Feekings (jpfe@aqua.dtu.dk)

DTU

DiscardLess

Use of an escape grid to optimise the size selectivity of *Pandalus borealis*

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

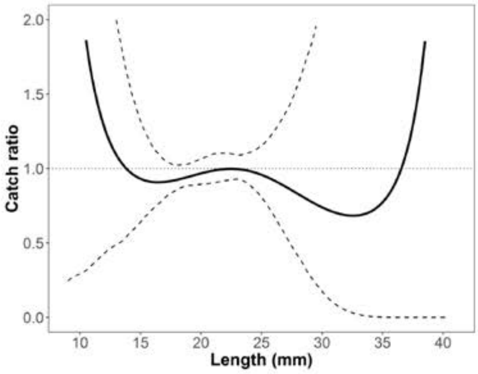
The trial took place in the Skagerrak (ICES IIIa) on board S486 Sajoni (28 m, 746 kW)

GEAR MODIFICATION

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 and there was no significant difference across all length classes. Underwater observations showed there were large issues with clogging of the escape grid.



FURTHER INFORMATION

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DTU

DiscardLess

Size selection of Norway lobster in the Mediterranean commercial creel fishery

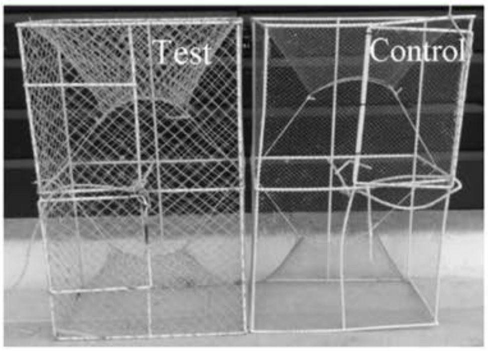
AIM
To estimate size selection of *Nephrops norvegicus* in creel fishery in the Mediterranean Sea

TARGET SPECIES
Norway lobster (*Nephrops norvegicus*)

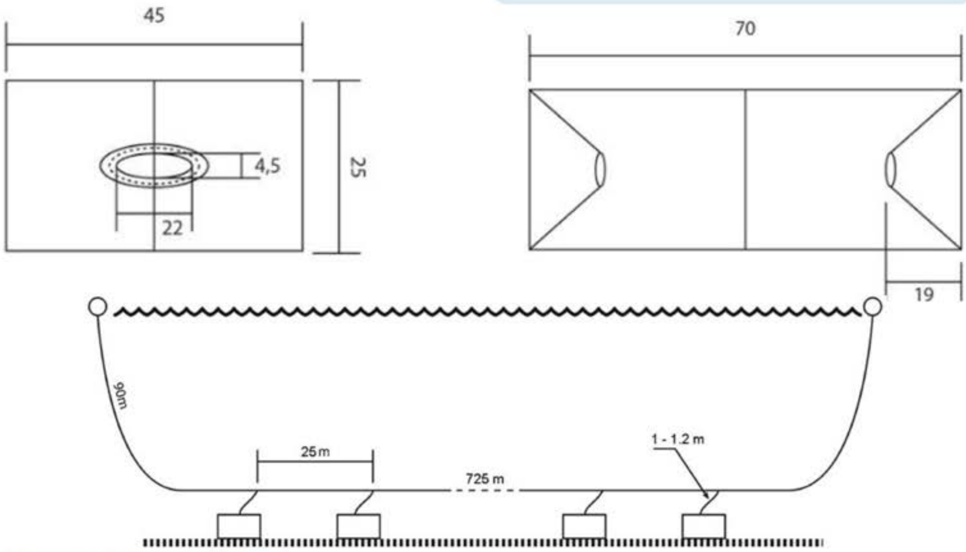
AREA
Adriatic Sea

VESSEL
on board small commercial fishing vessel (LOA 6.90 m, 84 hp)

GEAR SPECIFICATION
Commercial creels made of 41 mm mesh size knotless polyamide netting were compared with standard creels made of 12 mm knotless polyamide netting



RESULTS
- All individuals caught in the test creels were above the minimum conservation reference size (20 mm CL),
- 28.8% to 65.9% increase in selectivity compared to trawls equipped with 40 mm square or 50 mm diamond codends.



FURTHER INFORMATION
Jure Brčić (jure.brcic@unist.hr)
Brčić, J., Herrmann, B., Mašanović, M., Baranović, M., Šifner, S.K., Škeljo, F., 2018. Size selection of Nephrops norvegicus (L.) in commercial creel fishery in the Mediterranean Sea. Fisheries Research 200, 25-32.

DiscardLess

Testing mesh sizes in gillnets to reduce catches of small European hake

AIM

To reduce the capture of small European hake (*Merluccius merluccius*) of less than 60 cm in gillnet fisheries.

TARGET SPECIES

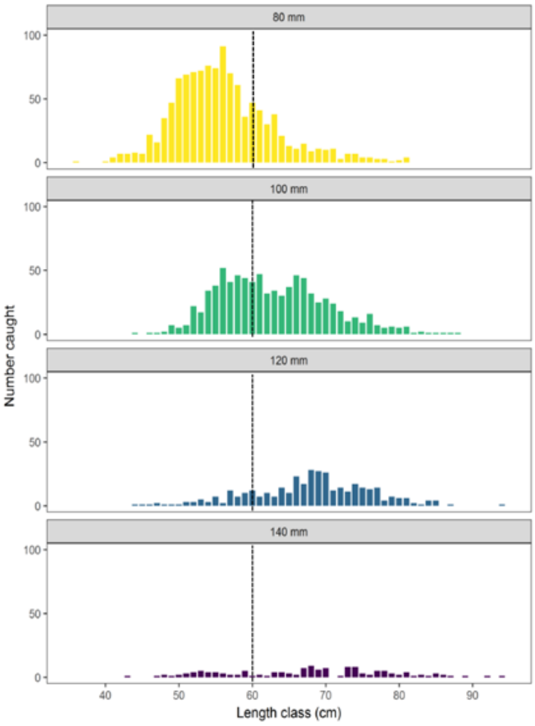
Eurpean hake (*Merluccius merluccius*).

AREA, VESSEL

The trial took place to the South and West of Ireland (ICES VII b, g & j) on board Atlantic Fisher fishing vessel (22 m, 310 kW).

GEAR MODIFICATION

Four mesh sizes were tested: 80, 100, 120, 140 mm.



(%)	100 mm	120 mm	140 mm
small hake	- 62	- 93	- 95
large hake	+ 77	+ 6	- 66

% change in comparison to 80mm mesh size gillnet

RESULTS

In relation to the 80 mm gillnet, the 100 mm caught 62% less of small hake, the 120 mm caught 93% less, and the 140 mm caught 95% less.
Meanwhile, in relation to the 80 mm, the 100 mm caught 77% more of large hake, the 120 mm caught 6% more, and the 140 mm caught 66% less.

BIM Ireland's Seafood Development Agency | GMIT Galway-Mayo Institute of Technology | Marine and Freshwater Research Centre

FURTHER INFORMATION

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DiscardLess

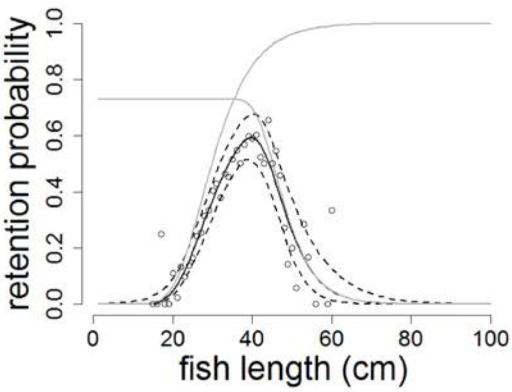
using a sorting grid
to change the size selectivity of *Gadus morhua*

AIM
A sorting grid was used to reduce the capture of small and very large cod (*Gadus morhua*) to improve stock recovery.

TARGET SPECIES
Cod (*Gadus morhua*)

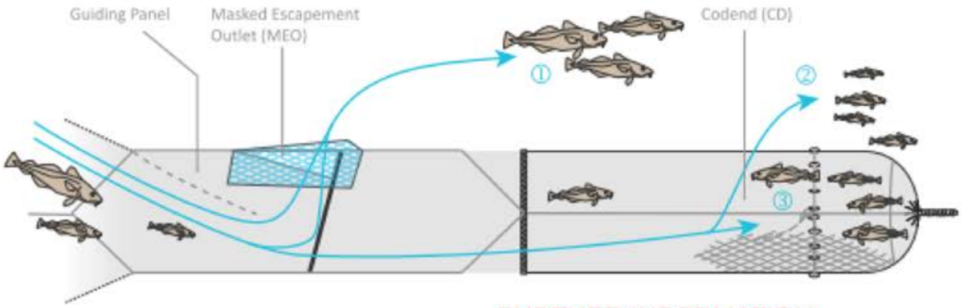
AREA
Western Baltic Sea (SD 24)

VESSEL
FFS Solea (42,4 m, 1780 kW)



GEAR MODIFICATION
The sorting grid (42.5 mm and 50 mm) prevents very large cod passing through to the codend and guides them to an upper escapement outlet which is masked with small-meshed netting.
Medium and small cod pass through the grid and the selection of small cod occurs in the codend (105 mm and 120 mm).

RESULTS
It was possible to reduce the number of small and very large cod in the catch. The specific size distribution of the catch is determined by the grid bar spacing and the codend mesh size. The contact probability should be improved.



FURTHER INFORMATION
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ICES CIEM
Food and Agriculture Organization of the United Nations
THÜNEN

FLEXSELECT: a counter-herding device to reduce bycatch in Norway lobster trawl fisheries

AIM

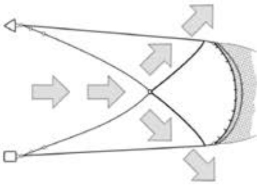
To reduce the bycatch of both roundfish and flatfish in the Norway lobster trawl fishery.

TARGET SPECIES

Norway lobster (*Nephrops norvegicus*)

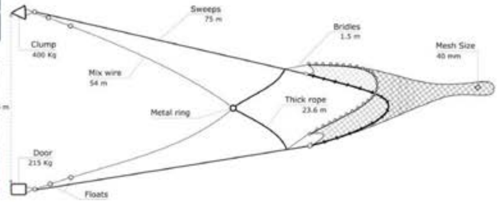
AREA, VESSEL

The trial took place in the Skagerrak (ICES IIIa) on board RV Havfisken (17 m, 373 kW)



GEAR MODIFICATION

The device, tested in a twin trawl rig against a control gear, consisted of four lines (mix wires and thick ropes) connected to a central metal ring, located approximately 20m ahead of the trawl mouth.



Species	N valid hauls	N individuals measured	Mean effect
Nephrops	4	5850	+ 7 %
Cod	13	4350	- 8 %
Haddock	12	6850	- 61 %
Whiting	17	15250	- 55 %
Plaice	16	12100	- 27 %
Lemon sole	11	2050	- 65 %

RESULTS

FLEXSELECT did not affect Norway lobster catch, while showing a significant reduction in bycatch of all fish species. The intensity of the effect varied among species and was strongly length-dependent for most roundfish species.

FURTHER INFORMATION

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DTU

DiscardLess

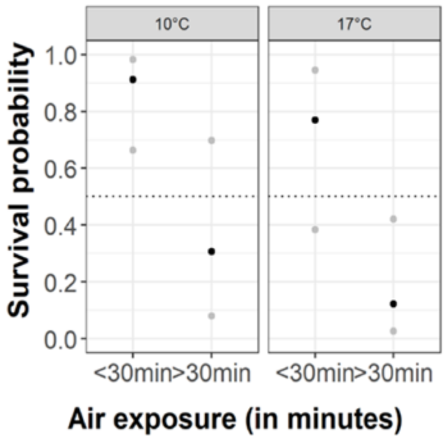
Discard survival of undersized plaice in the Danish seine fishery

AIM
To estimate the discard survival of undersized plaice in the Danish seine fishery.

TARGET SPECIES
European plaice (*Pleuronectes platessa*)

AREA, VESSEL
Skagerrak (ICES IIIa) on board S15 Vera-Marie (16.1 m, 142 kW)

FISHING OPERATIONS
A standard commercial Danish seine net with diamond mesh size of 125 mm (nominal) was fished.
The catch was sorted on deck following usual commercial practise. ~~and u~~ Undersized plaice that would previously have been discarded, were placed in specially designed holding tanks.



Discard survival as a function of air exposure and bottom temperature (black) with 95%-confidence intervals (grey).

RESULTS
On average 78% of 281 undersized plaice survived after 14 days in captivity.
The trials demonstrated that survival is better when the temperature on the sea bed is low and the exposure to air is short.

FURTHER INFORMATION
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DTU

COPE
DANMARKS FISKERIFORENING
Producent Organisation
Danmark og EU investerer i fiskeri og akvakultur

Discard survival of undersized plaice in the Danish bottom trawl fishery

AIM
To estimate the discard survival of undersized plaice in the Danish bottom trawl fishery.

TARGET SPECIES
European plaice (*Pleuronectes platessa*)

AREA, VESSEL
Skagerrak (ICES IIIa) on board S84 Ida-Katrine (15.1 m, 221 kW)

FISHING OPERATIONS
**A standard commercial twin rig trawl gear with nominal diamond mesh size of 90 mm was fished: (1) in summer targeting plaice, (2) in winter targeting plaice, and (3) in winter targeting Norway lobster.
The catch was sorted on deck following usual commercial practise. ~~and u~~
Undersized plaice that would have previously been discarded, were placed in specially designed holding tanks.**

RESULTS
The survival probability of undersized plaice after 14 days in captivity was:

(1) 44% of 333 fish when targeting plaice in summer.

(2) 75% of 142 fish when targeting plaice in winter.

(3) 41% of 123 fish when targeting Norway lobster in winter.

FURTHER INFORMATION
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DTU

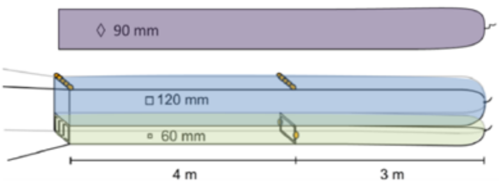
COPE
DANMARKS FISKERIFORENING Producent Organisation
Danmark og EU investerer i fiskeri og akvakultur
HAV & FISK

The effect of a divided codend on the discard survival of undersized plaice in the Danish bottom trawl fishery targeting Norway lobster

AIM
To estimate the discard survival of undersized plaice in the Danish bottom trawl fishery.

TARGET SPECIES
European plaice (*Pleuronectes platessa*)

AREA, VESSEL
Skagerrak (ICES IIIa) on board S84 Ida-Katrine (15.1 m, 221 kW)



GEAR MODIFICATION
A commercial twin rig trawl gear was fished. A standard 90 mm diamond mesh codend was attached to one net, and a horizontally divided codend with 120mm square mesh in the upper panel and 60mm square mesh in the lower panel was attached to the other.

FISHING OPERATIONS
The trials took place during the winter when targeting Norway lobster.
The catch was sorted on deck following usual commercial practise. ~~and u~~
Undersized plaice that would have previously been discarded, were placed in specially designed holding tanks.

RESULTS
There was no difference in survival probability of undersized plaice between the lower compartment of the modified codend and the standard codend after 14 days in captivity.
There was an indication of higher survival of undersized plaice in the upper compartment of the modified codend.

FURTHER INFORMATION
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DTU

COPE
DANMARKS FISKERIFORENING Producent Organisation
Danmark og EU investerer i fiskeri og akvakultur

developing a suction dredge in the Iceland scallop dredge fishery

AIM
to develop a harvesting method for scallops (*Clamys islandica*) to eliminate damage to seabed and both target and non-target species.

TARGET SPECIES
Iceland scallop (*Clamys islandica*)

PROTOTYPES AND TESTING
Experimental gear. Several prototypes were developed and tested in Icelandic coastal waters

GEAR MODIFICATION
After initial tests, suction was identified as the preferred harvesting method. Motors were used to suck seawater through piping mounted on a towed sled. They were then deposited in a retention bag.

RESULTS
Scallops were successfully lifted and retained. Little observable sediment displacement. Limited by-catch. There was no observed damage to target and non-target species.
Further work on vessel speed and operational parameters needed.

FURTHER INFORMATION
Georg Haney (georg@mfri.is)

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

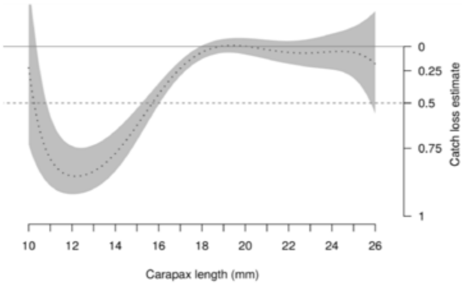
Reducing trawl length to improve size selection in the Northern shrimp fisheries

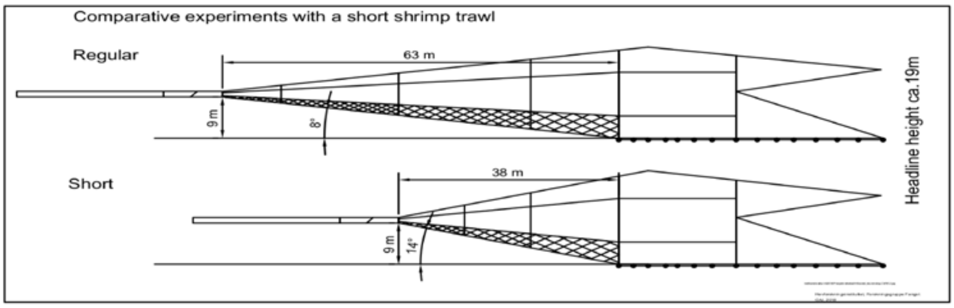
AIM
To reduce the capture of small Northern shrimp (*Pandalus borealis*) in a shrimp trawl by reducing the length of the trawl belly.

TARGET SPECIES
Northern shrimp (*Pandalus borealis*)

AREA, VESSEL
The trial took place in the Skagerrak (ICES IIIa) on board FV Tempo (28 m, 746 kW)

GEAR MODIFICATION
The trawl length, from fishing line to escape grid was reduced from 63 to 38 m by using steeper cutting rates. A regular and a modified trawl with 40 mm mesh sizes in the bottom panels were towed simultaneously and the catches were compared.





RESULTS
The two gears caught large (cooked) shrimp equally, catches of medium sized shrimp were reduced by 11% and undersized shrimp by 29%. No handling problems were experienced.

FURTHER INFORMATION
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Liz Kvalvik (liz.kvalvik@hi.no)

DiscardLess

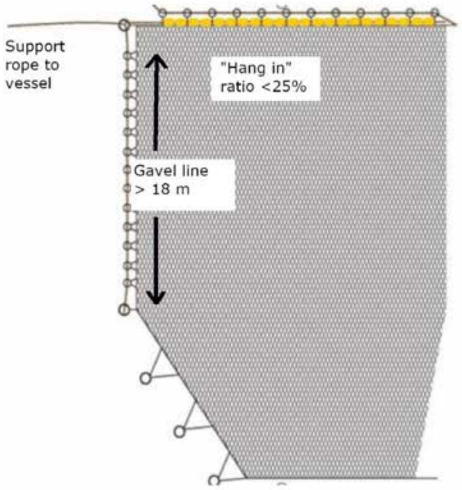
Best practice slipping from purse seines to increase survival of released fish

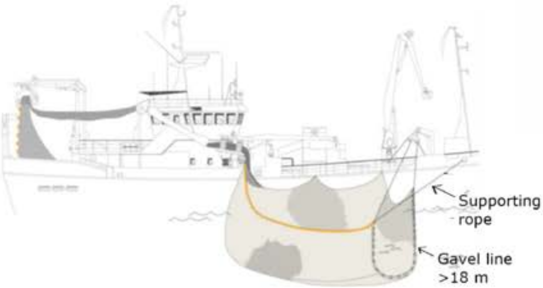
AIM
To develop standardized guidelines for good catch release methodology from purse seines that are acceptable to fishers and managers.

TARGET SPECIES
Herring (Clupea harengus), Mackerel (Scomber scombrus)

AREA, VESSEL
North Sea and Norwegian Sea.
Fiskebas (64 m) and Sjarmør (36 m)

GEAR MODIFICATION
The gavel line at the bunt end must be a minimum of 18 m long and also be long enough to ensure that the hanging ratio (E) along the gavel is greater than 80% ("hang in" ratio < 25%) of the stretched mesh size. There must also be a supporting rope from the vessel to the junction between the float line and the gavel. This rope is used to adjust the size of the escape opening.





RESULTS
- The method works well for small and medium sized catches.
- When large catches are released the size of the escape opening should be further increased to allow for fish to swim out freely.

FURTHER INFORMATION
Aud Vold (aud.vold@hi.no)
http://www.imr.no/filarkiv/2017/05/hi_nytt_1_2017.pdf/nb-no
https://brage.bibsys.no/xmlui/bitstream/handle/11250/2441258/HI-rapp_6-2017.pdf?sequence=1&isAllowed=y

Institute of Marine Research
FHF Fiskeri- og havbruksnæringens forskningsfond

trials with square and diamond mesh codends to increase escapees and reduce discards in the Mediterranean bottom trawl fishery

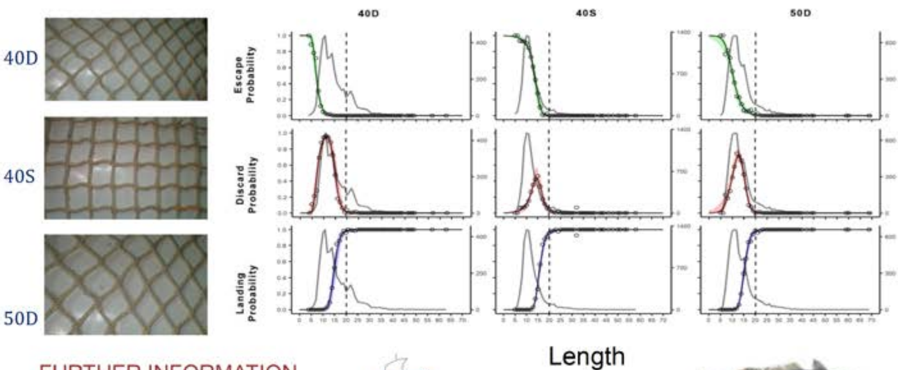
AIM
To compare the overall selectivity (gear and fisher) on the total hake (*Merluccius merluccius*) population entering the bottom trawl codend.

TARGET SPECIES
Hake (*Merluccius merluccius*)

AREA, VESSEL
The trial took place in the Southern Aegean Sea (Eastern Mediterranean) on board Takis-Mimis NX 411 (29m, 357 KW)
NX 411 (29m, 357kW) during 2015.

GEAR TRIALS
A comparison was made of the catching performance of trawl codends made of
(i) 40 mm diamond mesh (40D)
(ii) 40 mm square mesh(40S) and
(iii) 50 mm diamond mesh (50D)

RESULTS
40S square mesh showed a larger amount of escapees and a lower amount of discards compared to the diamond 40D & 50D. Similar selection behaviour by the fisher was defined for landings



FURTHER INFORMATION
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hcmr

DiscardLess