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ICES–FAO Working Group on Fishing Technology and Fish Behaviour

Report of the

2016 Symposium on Technology Development and Sustainable Fisheries

Merida, Mexico, 25–29 April 2016

Cover photograph: ©FAO/Raymon van Anrooy. Long line fishing vessels in Grenada's main harbour (2017)

ICES–FAO WORKING GROUP ON FISHING TECHNOLOGY AND FISH BEHAVIOUR

Report of the

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THE DOCUMENT

This document is the final report of the Symposium on Technology Development and Sustainable Fisheries, organized by the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB), and held from 25 to 29 April 2016 in Merida, Mexico. The document was prepared by Dr Steve Eayrs (Gulf of Maine Research Institute, USA) and Dr Petri Suuronen (Fishing Operations and Technology Branch, Food and Agricultural Organization of the United Nations [FAO]) on behalf of the ICES-FAO Secretariat to the Symposium.

This document was technically reviewed by Dr Raymon van Anrooy and Ms Amparo Pérez (FAO) before publication. The document has attempted to capture the issues raised by each presenter faithfully. The summaries of the presentations are made available in Appendix 3 of this report have been reproduced as submitted. The editors apologize for any misrepresentation that may have arisen in their summation.

This Symposium was the second collaborative WGFTFB meeting hosted by FAO, and the second meeting of the Working Group hosted outside of the ICES Member countries. The preparation, coordination, and planning for this Symposium was extraordinary, and the efforts of Professor Juan Carlos Seijo (Universidad Marista de Mérida, Mexico) in supporting the preparations and execution of this Symposium deserve special acknowledgment. FAO would also like to acknowledge the efforts of the WGFTFB co-Chairman, Dr Pingguo He (School for Marine Science and Technology, University of Massachusetts Dartmouth, USA) for his contribution to the organization of the Symposium. Last but not least, the FAO-ICES Secretariat to the symposium would like to acknowledge the important contributions of scientists, fishing technology experts and other experts of ICES and FAO Member States to the work of the ICES-FAO Fishing Technology and Fish Behaviour Working Group.

ABSTRACT

The 2016 annual meeting of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) was held from 25 to 29 April 2016 in Merida, Mexico. The meeting was hosted by FAO in close collaboration with the Universidad Marista de Mérida. More than 85 fishing technologists, scientists and other stakeholders, representing 23 countries from Europe, North America, Latin America and the Caribbean, and Asia, attended this meeting.

This report summarizes the three-day symposium, on "Technology Development and Sustainable Fisheries", which was part of the 2016 annual meeting of the ICES-FAO WGFTFB. The symposium comprised six thematic sessions: (i) challenges and advantages in static fishing gears; (ii) encouraging technological change in capture fisheries; (iii) energy and greenhouse gas (GHG) reduction in capture fisheries; (iv) technology and practice for managing bycatch and reducing discards; (v) innovative technologies for observing fish and fishing gear; and (vi) fishing technology to eliminate vaquita bycatch from fisheries in the Upper Gulf of California (UGC). A summary of the ICES topic groups, country reports and a general business session can be found in the 2016 ICES Working Group report. Session 1, on "Challenges and advantages of static fishing gears", featured research using a variety of static gears, including set nets, cod pots, pontoon traps and whelk traps. Most presentations focused on issues related to gear selectivity. In Session 2, on "Encouraging technical change in capture fisheries", the presentations focused on various techniques to facilitate change, including the application of organizational change management theory and principles, the application of a risk assessment matrix, sustainability assessment tools, and industry-led gear testing programmes. In Session 3, on "Energy and greenhouse gas reduction in capture fisheries", presenters focused on techniques used to measure energy consumption and associated remedial action, including energy audits and waste heat recovery from combustion processes. Session 4, on "Technology and practice for managing bycatch and reducing discards", included presentations of research carried out on a variety of fishing gear types. The overarching theme of this session was the challenge of excluding or avoiding bycatch species without loss of the target catch. Session 5, on "Innovative technologies for observing fish and fishing gear", provided a snapshot of initiatives to better understand fish behaviour in relation to the use of certain fishing gears and to evaluate fishing gear performance, particularly with the aim of reducing bycatch. Several new technologies were described as having the potential to contribute significantly to bycatch reduction. Session 6, on "Fishing technology to eliminate vaquita bycatch from fisheries in the Upper Gulf of California (UGC)", featured several presentations describing initiatives to reduce the bycatch of vaquita and other marine mammals.

This symposium provided an opportunity for fishing technologists and other experts from ICES member countries to exchange knowledge and ideas with contemporaries from around the world, especially from non-member countries in South America and Asia. A priority research subject that emerged from this symposium was to further reduce bycatch without loss of target catch. Greater efforts are required to understand fish behaviour. This will assist fishing technologists to develop more effective gears and technologies to reduce bycatch. Awareness raising and capacity building on new fishing gears and technologies that reduce bycatch and lead to more efficient fishing operations was considered essential to increase uptake and compliance with new fishing gears by fishers.

CONTENTS

ABBREVIATIONS AND ACRONYMS

BRD	Bycatch reduction device
CDD	Chronic degenerative diseases
COP	Carbon monoxide poisoning
DCS	Decompression sickness
ICES	International Council for the Exploration of the Sea
GHG	Greenhouse gas
GPS	Global positioning system
FAO	Food and Agriculture Organization of the United Nations
MSY	Maximum Sustainable Yield
PA	Polyamide (nylon)
PE	Poly ethylene
TED	Turtle excluder device
VCR	Video recorder
WGFTFB	Working Group on Fishing Technology and Fish Behaviour

I. INTRODUCTION

1. From 25 to 29 April 2016, the Food and Agriculture Organization of the United Nations (FAO) hosted the annual meeting of the ICES–FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) at the Hyatt Regency, in Merida, Mexico, in close collaboration with the Universidad Marista de Mérida. This meeting included a three-day symposium on the development, introduction, and challenges associated with new technology in capture fisheries. Topics included research into static gears, efforts to introduce technological change in fisheries, energy and greenhouse gas (GHG) reduction in fisheries, selective fishing gear design, innovative monitoring of fish and fishing gear, and recent efforts to eliminate vaquita bycatch in the Upper Gulf of California. More than 85 fishing technologists, scientists and other stakeholders, representing 23 countries from Europe, North America, South America and Asia attended this meeting.

2. The ICES–FAO WGFTFB r was established in 2002. Prior to this time, the working group was comprised primarily of individuals from the member countries of the ICES (International Council for the Exploration of the Sea) in Europe and North America. However, after many years of close collaboration between ICES and FAO on a variety of activities and issues, the forging of a new, combined working group with a global mandate was viewed as an important development and extension of this relationship. One of this joint working group's primary objectives is to foster dialogue and collaboration between member countries of ICES and FAO in order to address all aspects of fishing technology and fish capture, and to contribute to the sustainable exploitation of global fisheries resources.

3. In 2011, ICES and FAO further defined the purpose and methods of collaboration at the WGFTFB, with the subsequent outcome that FAO would co-chair the annual meeting and host it every third year at a location chosen by FAO. The inaugural meeting hosted by FAO under this new arrangement was held in Bangkok, Thailand, from 6 to 10 May 2013[1].

4. The objectives of the 2016 annual meeting of WGFTFB were to:

   a) Provide a forum for global synthesis of the scientific knowledge of fishing technology and its effective use.

   b) Evaluate the role and potential for capture technologies and practices to reduce fishing impacts on the environment and energy use.

   c) Review and discuss advances in technology and analytical methods used to study these impacts.

   d) Provide a forum for discussion on how the perceptions and decisions of fishers and resource managers affect the success of achieving sustainable use and successful management of fishery resources.

   e) Foster new partnerships between scientists and technologists from developed and developing economies to minimize the impact of fishing in the environment.

5. The WGFTFB meeting included the three-day symposium, "*Technology Development and Sustainable Fisheries*" and ICES topic group break-out sessions, as well as a general business session.

[1] The report of this meeting is available at: www.fao.org/3/a-i4384e.pdf.

6. The three-day symposium included the following six sessions:

    a) Challenges and advantages in static fishing gears.

    b) Encouraging technological change in capture fisheries.

    c) Energy and GHG reduction in capture fisheries.

    d) Technology and practice for managing bycatch and reducing discards.

    e) Innovative technologies for observing fish and fishing gear.

    f) Fishing technology to eliminate vaquita bycatch from fisheries in the Upper Gulf of California (UGC).

7. A summary of presentations from the symposium are provided in Appendix 3, while details of the ICES topic groups, country reports and a general business session can be found in the 2016 ICES Report of the WGFTFB[2].

II. SUMMARY OF SYMPOSIUM

SESSION 1: Challenges and advantages of static fishing gears

8. The primary focus of this session was to explore the challenges and relative advantages of static fishing gears as compared to mobile or active fishing gears. This session was chaired by Dr Daniel Aguilar-Ramirez (Instituto Nacional de Pesca, Mexico) and Dr Pingguo He (University of Massachusetts Dartmouth, USA).

9. The session comprised seven presentations from six countries. The keynote presentation by Dr Juan Carlos Seijo (Universidad Marista de Mérida, Mexico) was entitled "Selecting from alternative fixed gear technologies under behavioural uncertainty: A decision theory approach".

10. The keynote presentation argued that improvements in fishing gear selectivity are challenged by uncertainties associated with the behaviour of fish and other animals in response to the gear, as well as uncertainties in fisher behaviour. The application of a decision theory approach allows the modelling of fishing gear scenarios involving various fish and fisher responses, as well as a subsequent evaluation of the relative pay-offs or opportunity costs associated with these uncertainties over modifications to improve gear selectivity. This evaluation can be used to make statements about the potential uptake of selective fishing gear by fishers.

11. Other presentations in this session covered a variety of static gears, including set nets, cod pots, salmon pontoon traps, and whelk traps. Most presentations focused on issues related to gear selectivity. One presentation focused on trap loss and ghost fishing, and another on a decision theory approach to fishing gear adoption.

12. Despite the prevailing notion that static (or passive) gear is more selective than mobile gear, it was clear from presentations in this session that the selectivity of static fishing gear is not always adequate, and a significant body of research is focusing on improving the selectivity of this gear. However, while significant gains in gear selectivity have been achieved, monitoring the long-term behaviour of bycatch species in and around the fishing gear remains a challenge.

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[2] The 2016 annual ICES-FAO WGFTFB report is available at: http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/SSGIEOM/2016/WGFTFB/WGFTFB%202016.pdf#search=ICES-FAO%20Working%20Group%20on%20Fishing%20Technology%20and%20Fish%20Behaviour%202016

13. There were several other notable research outcomes presented during this session, including: the successful introduction of biodegradable twines in a whelk trap fishery to reduce ghost fishing; the successful tagging of tuna to monitor their behaviour inside a set net; the development of a secondary net (hose net) in a pontoon trap fishery to facilitate the separation of target catch from bycatch; and the testing of multiple trap and entrance funnel designs to prevent predation by seals and porpoise bycatch.

SESSION 2: Encouraging technological change in capture fisheries

14. This session focused primarily on ways to encourage fishers to change fishing practice or gear. It was co-chaired by Dr Steve Eayrs (Gulf of Maine Research Institute, USA) and Mr Michael Pol (Massachusetts Division of Marine Fisheries, USA).

15. The session comprised six presentations from four countries. The keynote presentation, presented by Dr Steve Eayrs, was entitled "What role can organizational change management play in encouraging change in capture fisheries?"

16. The keynote presentation argued that it is essential to view change from the perspective of recipients who experience the change. A survey including commercial fishers and some members of the WGFTFB indicated significant differences in perceptions regarding the reluctance of fishers to change, a surprising result given how close WGFTFB members work with fishers. Fishers reported resistance to change because they are concerned about a loss of control over their fishing operations, followed by mistrust and a perceived lack of opportunity, benefit, or reward from change. The application of the Kotter model was presented as a way of increasing the likelihood of successful change initiatives.

17. Other presentations in this session covered a variety of techniques to facilitate change, including the application of organizational change management theory and principles, the application of a risk assessment matrix, sustainability assessment tools and industry-led gear-testing programmes. One presentation described the development of an octopus fishery in Mexico.

18. Models or approaches to facilitate change include the use of risk assessment matrices to prioritize remedial action based on the perceived likelihood of an action or event, and the potential consequences of this action or event being a reality. Allowing industry to guide and test new fishing gear prior to scientific testing was described as a cost-effective step that also serves to encourage a sense of ownership among fishers. A novel approach was the application of trip specific evaluation of the sustainability of a fishing operation that included 14 indicators of sustainability including amongst others: profitability, remuneration, animal welfare, safety, and fuel efficiency.

SESSION 3: Energy and greenhouse gas reduction in capture fisheries

19. The focus of this session was primarily research to reduce energy consumption and GHG emissions in capture fisheries. It was chaired by Dr Antonella Sala (National Research Council, Italy) and Dr Liuxiong Xu (Shanghai Ocean University, China)

20. The session comprised three presentations from two countries. The keynote presentation, presented by Dr Antonella Sala was entitled, "Emerging issues on energy use in fisheries and development of low impact and fuel efficient fishing gears".

21. The keynote speaker described a variety of energy saving options, including fuel-efficient trawl doors, nets, and ground gear types, as well as propulsion systems. Types of data acquisition hardware and software were described as well, which can be installed on board in order for data

to be transmitted via wifi to a server when the vessel returns to port. The presentation further discussed the importance of training fishers in new, fuel-saving technology, as well as the challenges of uptake by fishers due to complacency, fear, and absence of leadership.

22. A variety of options exist for fishers to reduce energy consumption and GHG emissions. One presenter focused on the use of waste heat to produce electricity, which in turn can be used to power small capacity engines, pumps, refrigeration units, lighting or air conditioning. This process was being tested and initial results appeared promising. Another presenter focused on the application of energy audits in capture fisheries. Two case studies were described and a range of recommendations were discussed. It was noted that audit protocols are only used in a few instances for measuring performance standards, which hampers comparisons between vessels. The benefits of audits are that the impact of various combinations of fuel-saving options can be explored based on budget available, estimated energy saving target and estimated payback period.

SESSION 4: Technology and practice for managing bycatch and reducing discards

23. This session explored recent efforts to reduce bycatch and discards in capture fisheries. It was chaired by Dr Petri Suuronen (FAO).

24. The session comprised 15 presentations from 13 countries. The keynote presentation, presented by Dr Roger Larsen (The Arctic University of Norway) was entitled, “Effort to minimize unwanted bycatches in the northeast Atlantic trawl fisheries: A brief review of 40 years’ research and current status”.

25. The keynote speaker detailed the trials and tribulations of Norwegian efforts to improve selectivity in fish and shrimp trawl fisheries. This work has extended over 40 years and many codend and grid designs have been tested, some successfully and others less so. In the shrimp fishery, numerous grid configurations have been tested, including multiple grids, grids of different shape, exit windows in the side panels, and various guiding funnel designs; however, the Nordmøre grid, with its relatively simplistic design, has proven to be most effective and remains in use to this day.

26. Presentations in this session covered a variety of fishing gears, including demersal fish trawls, shrimp trawls and purse seines. In fish trawl fisheries a variety of techniques to reduce bycatch were presented including inclined grids, lateral openings in the extension piece, codend mesh size and orientation, and headrope extension. In many instances these modifications had proved successful, though it was clear that considerable research —including gear trials over many years— had preceded these achievements. One presenter described a highly innovative krill sampling trawl to overcome issues in mesh selectivity using full-size trawl gear; another described the utility of lights attached to the headrope to reduce bycatch; while another discussed recent technological improvements in holding tank design to test the survival of fish bycatch.

27. Presentations related to shrimp trawling focused both on tropical and temperate water shrimp fisheries. One presenter described efforts to introduce turtle excluder devices (TEDs) and bycatch reduction devices (BRDs) to reduce the capture of large animals and fish bycatch in a tropical fishery. A second presentation demonstrated a holistic approach to addressing bycatch in these fisheries that also explored need-based incentives, efforts to ensure engagement, and improved fishery management and compliance. The final presentation in this session described how yield per recruit can be influenced by different codend mesh sizes, and how the timing of the introduction of large mesh codends can influence the payback period of investments by fishers.

28. Several presentations related to non-trawl fisheries. One presentation focused on the relationship between the survival rate of discards and crowding time in the bunt of a purse seine, while another focused on the challenge of introducing measures to mitigate the capture and mortality of marine mammals. One of the most novel research presented in the symposium focused on the behaviour of sea turtles in a set net to design an escape device so as to reduce retention times and drowning rate. This modification allows sea turtles to follow a sloped roof in the set net and push through an opening in the top of the roof. Another presentation evaluated the influence of environmental variables, gear operation and hook depth to reduce the capture of bycatch in a pelagic tuna longline fishery.

SESSION 5: Innovative technologies for observing fish and fishing gear underwater

29. This session provided an opportunity for presenters to describe their recent efforts observing fish and fishing gear. It was chaired by Dr Daniel Stepputtis (Thuenen Institute of Baltic Sea Fisheries, Germany).

30. The session comprised four presentations from four countries. The keynote presentation, presented by Dr Barry O'Neil (Marine Scotland Science, UK) was entitled, "A review of technologies for observing fish and fishing gear underwater".

31. The keynote presentation highlighted the complexity of the discipline of fishing technology, including an understanding of fishing gear design, fish behaviour, and engineering performance. Related research requires application of a plethora of testing instruments, testing facilities, and sampling techniques. It was noted that much research relies on the participation of many others, including fishers, net makers, engineers, and statisticians. Several case studies were presented that highlighted the multidisciplinary and complex nature of what fishing gear technologists do, including the use of LED lights along the leading edge of horizontal separator panels or on inclined separator grids to illuminate openings for fish entry. The use of a sophisticated towing sled to explore the physical impact of gear components on the seabed was also presented at this session.

32. A variety of fishing gears were the focus of the presentations including fish, shrimp, and Nephrops trawl gear, and tuna purse seines. A novel research presented was the application of post-processing software that serves to count fish in an underwater video. Crowding and turbid water can be significant challenges to counting fish, and this software largely overcomes this problem as well as allows the trajectory of individual fish to be monitored. Another presentation focused on an improved technique to evaluate selectivity in trawl fisheries. The introduction of large-mesh panels, and how the use of these increases sinking time of purse seines and catching efficiency was discussed as well.

33. The general discussion was brief and was based on a request for greater time allocation at future meetings for presentation and discussion of fish behaviour studies.

SESSION 6: Fishing technology to eliminate vaquita bycatch from fisheries in the Upper Gulf of California (UGC)

34. The focus of this session was to explore techniques and methods to eliminate the bycatch of vaquita in fishing gear. This session was chaired by Mr Jeff Gearhart (U.S. National Marine Fisheries Service).

35. The session comprised five presentations from four countries. The keynote presentation, presented by Dr Daniel Aguilar-Ramirez (Instituto Nacional de Pesca, Mexico) was entitled, "Results of the experiments with alternative fishing gear in the Upper Gulf of California".

36. The keynote presentation described the importance of reducing vaquita bycatch and the related challenges. Several gear options have been tried including modified shrimp trawls, Suripera cast nets, shrimp pots, and fish traps. The use of shrimp trawls is actively being promoted for use by fishers using pangas gear; however, uptake rates remain modest. Currently there is no immediate gear solution to vaquita bycatch, although an existing gillnet ban extends to 2017.

37. A presentation in this session focused on efforts to support local coastal communities to find solutions to vaquita bycatch, including the introduction of new fishing gear, and an evaluation of the trade-offs associated with various vaquita protection measures, including closures and paying fishermen to leave the fishery. A similar presentation described a bottom-up process that provides fishers the opportunity to design alternative gears and options, and how a cash reward had been used to incentivize and encourage the submission of new ideas.

38. Other presentations highlighted the importance of fishers collecting spatial and temporal information regarding interactions with marine mammal, because this information can inform the design of closed areas and the best timing of opening and closure of these areas. The final presentation highlighted the importance of innovative and more risky projects in terms of outcomes, because they can often provide important insights, even if ultimately unsuccessful.

During the general discussion following the presentations several key points were made regarding vaquita bycatch:

- The use of pingers to deter vaquita that are approaching gillnets was not considered a viable option due to concerns that vaquitas would be displaced from their normal habitat by their sound.
- Poor monitoring, control and surveillance had enabled fishermen to use gillnets illegally, often longer than permitted by law. Moreover, given that the sale of totoaba swim bladders is highly lucrative, there is little incentive to change fishing behaviour.
- The time for effective action is getting very short: only 60 vaquita remain.
- Effective government actions would significantly enhance ongoing remedial measures.
- Communication and coordination between all stakeholders is key to success, though no coordinated mechanism exists to improve communication, particularly at the community level.

APPENDIX 1

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APPENDIX 2

AGENDA AND TIMETABLE

April 25, 2016 (Monday)

8:00 – 9:00	Registration
9:00 – 9:30	Welcome and general introduction of the meeting

Session 1: Challenges and advantages in static fishing gears

	Facilitators: **Daniel Aguilar-Ramirez**, Instituto Nacional de Pesca, & **Pingguo He**, University of Massachusetts Dartmouth
9:30 – 10:00	Keynote: Selecting from alternative fixed gear technologies under behavioral uncertainty: A decision theory approach. **Juan Carlos Seijo**
10:00 – 10:20	Fishing efficiency and bycatch rate of whelk trap depending on the shape of trap and net materials in the Uljin waters, Korea **Heui-Chun An**, **Jae-Hyun Bae**, **Pyung-kwan Kim**, **Seong-Hun Kim** and **Byoung-Sun Yoon**
10:20 – 10:40	Can we develop species selective fisheries using salmon pontoon traps? **Peter Ljungberg**, **Sara Königson**, **Sven-Gunnar Lunneryd** and **Maria Hedgärde**
10:40 – 11:10	Coffee break
11:10 – 11:30	Behavioral Observation of Young Bluefin Tuna *Thunnus orientalis* and Yellowtail *Seriola quinqueradiata* in the Set Net using an Ultrasonic Biotelemetry **Keiichi Uchida**, **Kohei Hasegawa**, **Hiromichi Ogawa**; **Seiji Akiyama**, **Hideki Noro** and **Yoshinori Miyamoto**
11:30 – 11:50	Development of cod pots as fishing tool to solve the conflict with seal depredation and harbour porpoise bycatch **Lotte Kindt-Larsen**, **Maria Hedgärde**; **Casper Willestofte Berg**, **Finn Larsen** and **Sara Königson**
11:50 – 12:30	Observations of fish behavior in and around passive fishing gear: an efficient tool in fishing gear development **Peter Ljungberg**, **Sara Königson**, **Maria Hedgärde** and **Lotte Kindt-Larsen**
12:30 – 12:40	General discussion
12:40 – 2:00	Lunch

Session 2: Encouraging technological change in capture fisheries

	Facilitators: **Steve Eayrs**, Gulf of Maine Research Institute, and **Mike Pol**, Massachusetts Division of Marine Fisheries
2:00 – 2:30	Keynote presentation: What role can organizational change management play in encouraging change in capture fisheries? **Steve Eayrs**

2:30 – 2:50	Health and socioeconomic effects of hookah diving fishing technology in small-scale fisheries: A qualitative risk assessment **Oswaldo Huchim** and **Juan Carlos Seijo**
2:50 – 3:10	Industry-led fishing gear selectivity improvements. How can we increase flexibility and ownership over the gears used while ensuring an effective introduction of the new EU Common Fisheries Policy? **Jordan Feekings**, **Ludvig Krag**, **Tiago Malta**, **Henrik S. Lund**, **Søren Eliasen**, **Clara Ulrich** and **Lars Mortensen**
3:10 – 3:30	Improving tropical shrimp fisheries through eco-labelling: experiences from the Suriname seabob fishery **Tomas Willems**, **Annelies De Backer**, **Magda Vincx** and **Kris Hostens**
3:30 – 3:40	Discussion
3:40 – 4:10	Coffee break
4:10 – 4:30	VALDUVIS: An innovative approach to assess the sustainability of fishing activities **Arne Kinds**, **Kim Sys**, **Laura Schotte**, **Koen Mondelaers** and **Hans Polet**
4:30 – 4:50	Fishing gear related to octopus behavior in the Octopus maya fishery of Yucatan shelf **Alvaro Hernandez**
4:50 – 5:00	General discussion

April 26, 2016 (Tuesday)

8:00 – 8:10	Messages, announcements, and logistics
Session 3: Energy and greenhouse gas (GHG) reduction in capture fisheries	
	Facilitators: **Antonella Sala**, National Research Council, Italy, and **Liuxiong Xu**, College of Marine Sciences, Shanghai Ocean University
8:10 – 8:40	Keynote: Emerging issues on energy use in fisheries and development of low impact and fuel efficient fishing gears **Antonello Sala**
8:40 – 9:00	Application and review of energy audit protocols in the commercial fishing industry **Steve Eayrs**
9:00 – 9:20	Efficientship: Fuel saving in fisheries through heat recovery from the main engine – a case study in Ireland **Emilio Notti**
9:20- 9:30	General discussion
Session 4: Technology and practice for managing bycatch and reducing discards	
	Facilitator – **Petri Suuronen**, FAO
9:30 – 10:00	Keynote: Effort to minimize unwanted by-catches in the North-East Atlantic trawl fisheries; A brief summary of the developments over the last 40 years and current status presentation. **Roger B. Larsen**

10:00 – 10:40	Employing a trawl-independent multi-compartment towing rig to study selectivity of crustaceans in trawl
	Ludvig A Krag, Bjørn A. Krafft, Arill Engås and **Bent Hermann**
10:40 – 11:10	Technology on board to improve discards survival on Basque purse seine fishery.
	Luis Arregi
11:10 – 11:30	Coffee break
11:30 – 11:50	Reduction of the shrimp bycatch from tropical trawling on the Colombian pacific
	Mario Rueda, **Alexander Girón** and **Jorge Viaña**
11:50 – 12:10	Illuminated area in front of a topless trawl in order to reduce bycatch in shrimp fisheries.
	Haraldur A. Einarsson, **Hjalti Karlsson** and **Einar Hreinsson**
12:10 – 12:30	One step beyond: identification of 'improved selectivity' using selectivity experiments and population models for brown shrimp (Crangon crangon) beam trawl fishery in the North Sea.
	Daniel Stepputtis, **Sebastian Schultz**; **Claudia Günther**, **Juan Santos**, **Jörg Berkenhagen**, **Marc Hufnagl**, **Axel Temming**, **Bent Herrmann**, **Eckhard Bethke** and **Thomas Neudecker**
12:30 – 12:40	Using fish behaviour to separate fish from Nephrops in a horizontally divided codend in the mixed trawl fishery
	Junita D. Karlsen, **Ludvig Krag**, **Bent Herrmann**, and **Henrik S. Lund**
12:40 – 1:00	General discussion
1:00 – 2:00	Lunch
2:00 – 2:20	A Global Analysis of Cetacean Bycatch and Mitigation Measures
	Aimee Leslie, **Damon Gannon**, **Leigh Henry**, **Rab Nawaz** and **Heidrun Frisch**
2:20 – 2:40	Development of a turtle releasing system (TRS) for set net fisheries
	Daisuke Shiode, **Maika Shiozawa**, **Keiichi Uchida**, **Seiji Akiyama**, **Yoshinori Miyamoto**, **Fuxiang Hu**, **Tadashi Tokai** and **Yoshio Hirai**
2:40 -3:00	Avoidance of Atlantic cod with a topless trawl in the New England groundfish fishery
	Michael Pol and **Steve Eayrs**
3:00 – 3:20	Be FLEXible; a simple and cheap flatfish BRD concept for roundfish trawl fisheries.
	Juan Santos, **Bernd Mieske** and **Daniel Stepputtis**
3:20 – 3:40	Trials and tribulations of halibut bycatch reduction in Alaska's Bering Sea trawl fleet
	Carwyn Hammond
3:40 – 4:10	Coffee break
4:10 – 4:30	Flatfish survival assessment carried out in 2014–2015.
	Pieke Molenaar
4:30 – 4:50	Effects of environmental variables on bycatch rates of Acanthocybium solandri in waters near Cook Islands
	Liming Song, **Zhihui Zheng**, **Kai Xie and Hailong Zhao**
4:50 – 5:10	Sustainable management of bycatch in Latin America and Caribbean trawl fisheries – transforming wasted resources into a sustainable future
	Petri Suuronen and **Carlos Fuentevilla**

5:10 – 5:30	Underwater observations of fish behavior related to bottom trawl codend in the Mediterranean **Chryssi Mytilineou**, **Chris Smith**, **Caterina Stamouli** and **Persefoni Megalophonou**,
5:30 – 5:40	General discussion

April 27, 2016 (Wednesday)

8:00 – 8:10	Messages, announcements, and logistics

Session 5: Innovative technologies for observing fish and fishing gear

	Facilitator: Daniel Stepputtis, Thünen Institute of Baltic Sea Fisheries
8:30 – 8:50	Discards mitigation in the trawl Nephrops fishery of the bay of Biscay: innovations, improvements and challenges **Sonia Mehault**, **Thomas Rimaud**, **Julien Simon**, **Fabien Morandeau**, **Jean Philippe Vacherot**, **Dorothee Kopp** and **Pascal Larnaud**
8:50 – 9:20	Keynote: A review of technologies for observing fish and fishing gear underwater **Barry O'Neill**
9:20 – 9:40	Automated images processing a tool for better understanding of fish escape behavior **Julien Simon**, **Benoît Vincent**, **Sonia Mehault**, **Dorothee Kopp**, **Pascal Larnaud, Mariane Robert**, **Fabien Morandeau** and **Jean Philippe Vacherot**
9:40 – 10:00	Field measurement of sinking characteristics of tuna purse seine of different mesh sizes and its effect of catch performance **Liuxiong Xu**, **Xuchang Ye**, **Guoqiang Xu**, **Hao Tang** and **Cheng Zhou**
10:00 – 10:20	New method to identify the optimal bar spacing for grids in shrimp trawl fisheries: the case of the deep water shrimp (Pandalus borealis) in the North-East Atlantic **Bent Herrmann**, **Manu Sistiaga** and **Roger B. Larsen**
10:20 – 10:30	Discussion
10:30 – 11:00	Coffee break

Session 6: Fishing technology to eliminate vaquita bycatch from fisheries in the Upper Gulf of California (UGC)

11:00 – 11:20	Results of the experiments with alternative fishing gear in the Upper Gulf of California **Daniel Aguilar**
11:20 – 11:40	Participation of Civil Society Organization for developing new gear to substitute gillnets from the Upper Gulf of California **Enrique Sanjurjo**
11:40 – 12:00	Experiences in the Baltic Sea for developing alternative fishing gear for gillnet fisheries in the Sea of Cortez **Sara Königson**, **Peter Ljungberg** and **Sven-Gunnar Lunneryd**
12:00 – 12:20	A bottom-up social process to find fishing gears different from gillnets to reduce vaquita bycatch **Sergio Alejandro Perez Valencia and Peggy Turk Boyer**
12:20 -12:40	Initiatives to protect porpoises in Denmark **Lotte Kindt-Larsen** and **Finn Larsen**

12:40 – 1:00	Discussion - Moderator: **Michael Osmond**
1:00 – 1:30	End Symposium remarks – **Petri Suuronen**
1:30 – 10:00	Fieldtrip and dinner

April 28, 2016 (Thursday)

8:50 – 9:00	Messages, announcements, and logistics
9:00 – 10:40	Topic group meetings
10:40 – 11:00	Coffee break
11:00 – 12:30	Topic group meetings
12:30 – 2:00	Lunch
2:00 – 3:30	Topic group meetings
3:30 – 4: 00	Coffee break
4:00 – 5:30	Topic group meetings
6:00 – 8:20	Visit Marista University of Merida

April 29, 2016 (Friday)

8:50 – 9:00	Messages, announcements, and logistics
9:00 – 9:30	Country report summary. **Barry O'Neill**
9:30 – 10:40	Topic group reports
10:40 – 11:10	Coffee break
11:10 – 12:30	Topic group reports, conclusions and recommendations
12:30 – 2:00	Lunch
2:00 – 4:00	Election of FTFB chair, Location of FTFB/FAST joint session, New TORs, 2017 ICES ASC proposal, Other business
4:00	End

APPENDIX 3

INDIVIDUAL PRESENTATION SUMMARIES

SESSION 1: Challenges and Advantages in Static Fishing Gears

Selecting from alternative fixed-gear technologies under fish and fisher behavioral uncertainty: A decision theory approach. *(by* Juan Carlos Seijo. Universidad Marista de Merida*)*

While technological development has facilitated substantial improvements in fishing gear selectivity, selecting the right approach to improve selectivity is challenged by uncertainties associated with fish behavior, including reproductive condition, feeding behavior, migratory behavior, response to predators, and fish cognition. In addition, the development and adoption of selective fishing gear is hampered by fisher behavior associated with costs of gear modification, loss of catch, compliance with new gear regulations, and response by fishers to change itself.

To address the issue of uncertainties in fish and fisher behavioral, with respect to species and size selective fixed gear technology, a decision theory approach to fisheries has been applied (Figure 1). The decision theory approach can be used to explore the pay-off or loss of opportunity of various scenarios or fixed gears (Table 1). It accommodates multiple states of nature (fish behaviours and/or fisher responses), and numerical output is used to identify potential benefits of using selective fishing gear, including profitability, and to compare benefits between fishing gear.

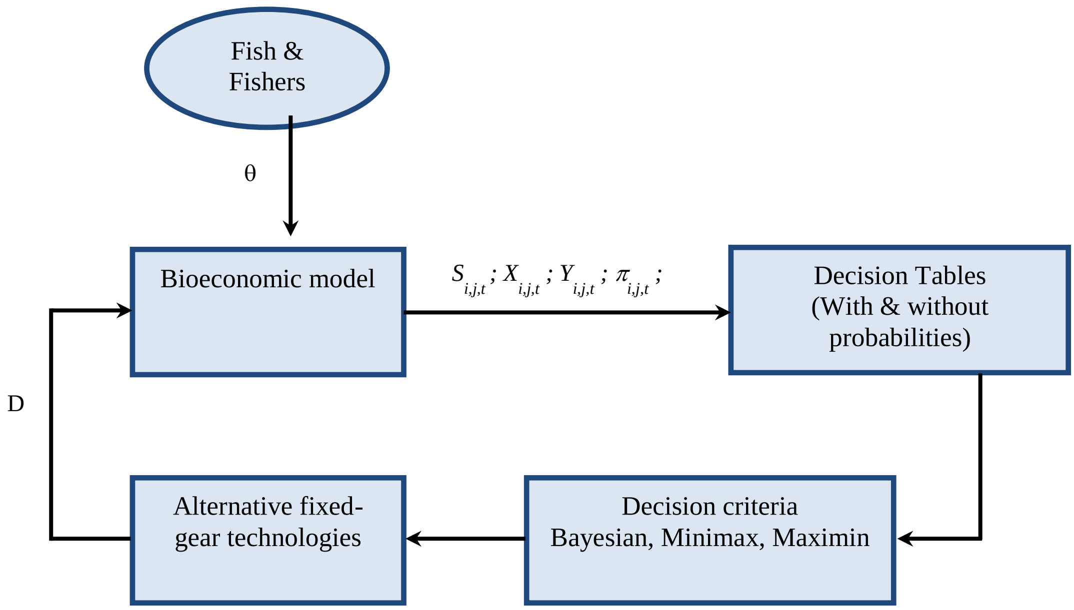


Figure 1. Decision theory approach model. Nomenclature: S = escapement; X = biomass; Y = yield; π = profit; NPV = net present value; i = species; j = size (length); t = time; D = decision

Table 1. Pay-off matrix evaluating fixed gear technologies and possible states of nature (fish behaviour responses) to the gear. Numeric values are for example only.

Fishing technologies to reduce bycatch	**Fish behavior (*θ₁*)**	**Fish behavior (*θ₂*)**	**Fish behavior (*θ₃*)**	**Maximin Criterion Max (Min S_{ij})**
Fixed gear Technology X	0.8	0.15	0.05	0.05
Fixed gear Technology Y	0.5	0.2	0.3	0.2
Fixed gear Technology Z	0.3	0.1	0.6	0.1

Fishing efficiency and bycatch rate of whelk traps depending on the shape of trap and net materials in the Uljin waters, Korea (by Heui-Chun An, Jae-Hyun Bae, Pyung-kwan Kim, Seong-Hun Kim, and Byoung-Sun Yoon)

In the Republic of Korea trap fisheries are responsible for just over 6% of total marine fisheries production. However, an estimated 10% of traps are abandoned, lost, or discarded at sea, many of which presumably continue to ghost fish for a significant period of time. This study attempted to estimate the potential of biodegradable whelk traps to avoid problems associated with trap loss and ghost fishing while retaining commercial landings of whelks.

The performance of two traps (Figure 2) was compared in 2014 (Table 2). A total of 100 traps (50 of each type) were attached in an alternating sequence (A-B-A-B) to a longline and fished a total of 6 times for 8 – 13 days. Water depth was 105 – 113 m. For each trap type, the body was constructed using polyethylene or polybutylene succinate biodegradable twine. The traps were baited with mackerel or other fish.

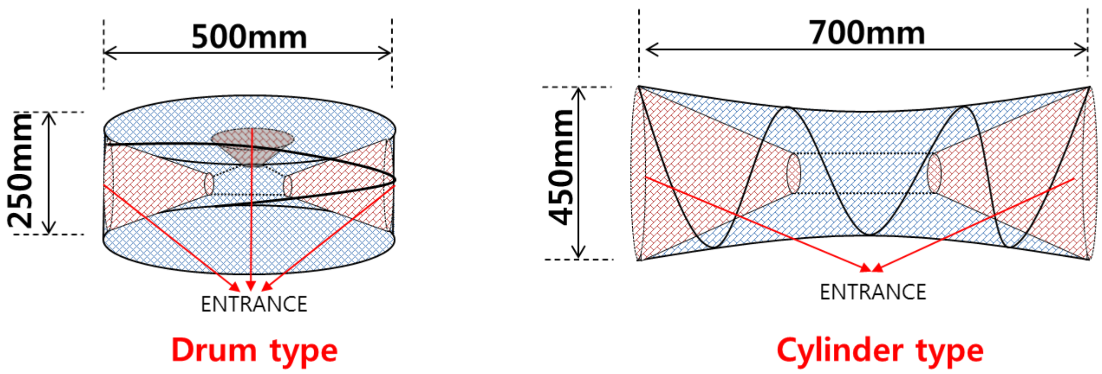


Figure 2. Two trap designs used in the experiment. The drum trap has three funnels and the cylinder trap has only two funnels. The cylinder trap is the traditional design used by fishers.

The drum trap caught substantially more whelk than the cylinder trap. However, in the drum trap substantially less octopus and snow crab (which are a bycatch and discarded) were retained, possibly due to smaller internal volume in the drum trap compared to the larger cylinder trap. In a second experiment only the drum trap was tested, although with different material in the body and funnel. A longline of 100 drum traps was fished 14 times for 9 to 15 days in 112 – 127 m of water. The drum trap was tested in five configurations: PBS body + PE funnel; PE body + PBS funnel; PBS body + PBS funnel; PE body + PA funnel, and; PE body + PE funnel. The traps constructed with the PBS body + PE funnel caught the most whelks (23, 414 g) and those constructed with PE body + PE funnel the least (17,952 g). Comparison between each configuration was not statistically significant, which implies the use of biodegradable twine is a viable option in the fishery, although it is approximately 4 times the costs of existing twines and requires replacement in 1 – 2 years.

Table 2. Catch results. All weights are in grams (g). Nomenclature: PE – polyethylene; PA – nylon: PBS – polybutylene succinate biodegradable twine.

Common name (Scientific name)	**Trap type**				**Total**	
	Drum type		**Cylinder type**			
	PE body + PA funnel	**PBS body + PE funnel**	**PE body + PE funnel**	**PBS body + PBS funnel**	**Weight (g)**	**Rate (%)**
Whelk	56974	52921	32062	31304	173261	48.69
Giant octopus *(Enteroctopus dofleini)*	3366	2128	17600	8668	31762	8.93
Snow crab *(Chionoecetes opilio)*	29398	13704	38342	61543	142987	40.18
Others	676	1131	2569	3, 446	7822	2.20
Total	*90414*	*69884*	*90573*	*104961*	*355832*	*100.00*

Can we develop species selective fisheries using salmon pontoon traps? (by Peter Ljungberg, Sara Königson, Sven-Gunnar Lunneryd and Maria Hedgärde)

The introduction of the EU Common Fisheries Policy Landing Obligation in 2015 is a significant driver urging the development of more selective fishing gear. In Sweden, small-scale coastal fishermen are struggling with a plethora of issues affecting their profitability in addition to the landing obligation, such as the impact of seal on catches in static gear, bycatch of seabirds, marine mammals, non-target fish species, and low income. Consequently, there is considerable interest in the development of alternative static (passive) gear that can overcome these issues.

An important recent development has been the use of pontoon traps with a hose-net to allow sorting of the catch and release of bycatch. A pontoon trap is a large static gear consisting of multiple chambers that is designed to retain and ultimately guide whitefish, salmon, and other species toward a holding chamber. There are currently 300 of these traps in existence. The holding chamber is designed to keep fish alive and prevent seal depredation. However, as the chamber is hauled onboard it is difficult to release bycatch alive without first collecting the catch; subsequently, pontoon traps are presently banned when the salmon season is closed to avoid mortality of salmon bycatch.

Two options were designed to reduce pontoon trap bycatch (Figure 3). One option is to install closing nets at the mouth of the trap which prevents salmon ingress (when the salmon season is closed) but not that of whitefish, while the other option is the use of selection panels to filter the catch and prevent the ingress of seals and salmon into the holding chamber. After field testing both methods were found to successfully reduce salmon catch, but also the catch of whitefish.

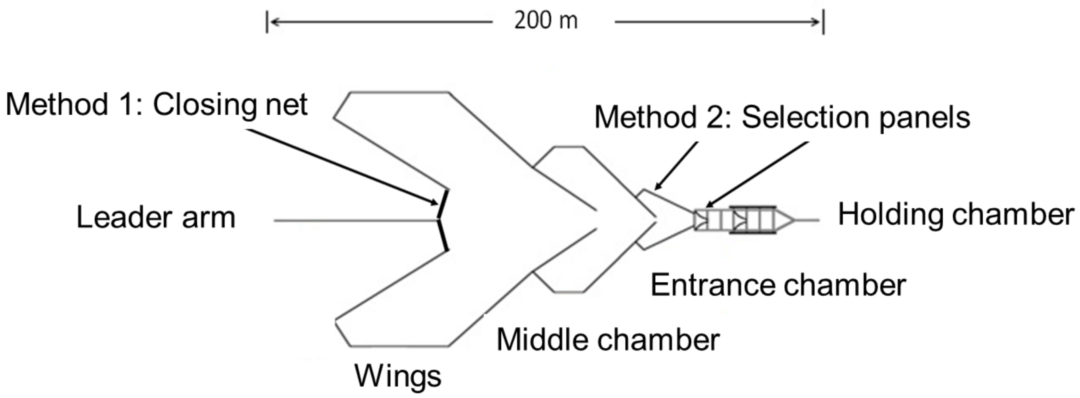


Figure 3. Pontoon trap with two methods of reducing bycatch indicated.

Fishermen then developed a hose-net for use during the salmon fishing season. The hose-net is a small codend with a larger selection mesh section to allow fish escape (Figure 4). As the holding chamber is lifted towards the surface, caught fish enter the hose-net. The hose-net is then lifted toward the surface. White fish can then escape through the selection mesh while salmon are retained. The hose-net is currently being tested in coastal pontoon trap fisheries for Atlantic cod.

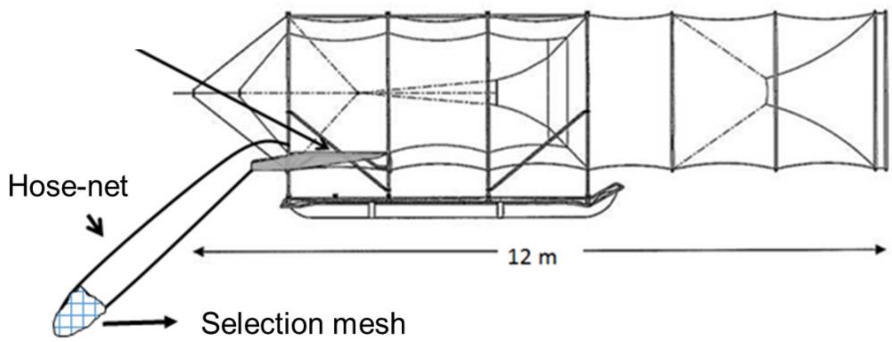


Figure 4. The hose-net is used to facilitate the escape of bycatch from the holding chamber.

Behavioral observation of Young Bluefin Tuna Thunnus orientalis and Yellowtail Seriola quinqueradiata in aSet Net using an ultrasonic biotelemetry (by Keiichi Uchida, Kohei Hasegawa, Hiromichi Ogawa; Seiji Akiyama, Hideki Noro and Yoshinori Miyamoto)

As a result of historic low abundance of Pacific bluefin tuna, a catch limit has been applied to total landings of immature individuals weighing less than 30 kg in the Japanese coastal set net fishery. When catches of these fish reach 95% of the catch limit the fishery is closed.

In this fishery almost 600 large set nets are used to land a variety of pelagic species, and bluefin tuna have historically comprised around 1% of total landings. The challenge for this fishery is how to conserve the bluefin tuna resources, while allowing the fishery to continue. Greater understanding of tuna behavior is therefore necessary to seek options to avoid tuna catch without impacting landings of other species.

In this experiment immature bluefin tuna were fitted with an AqusSound acoustic tag and their behavior observed inside a set net. Four receivers were strategically located around the set net (Figure 5). Each receiver receives an acoustic signal from the tagged fish and by comparing differences in signal receiving time between pairs of receivers the precise location of the fish is determined. A total of 10 fish were tagged although data was received only from 4 bluefin tuna and 2 yellowtail tuna.

The acoustic tags allow the depth profile of each fish to be observed as well as horizontal movement (Figure 6). Yellowtail seemed to more readily enter the smaller confines of the final trap compared to bluefin tuna, while bluefin tuna spent more time swimming between the first and second bag nets. Observation of behaviour was hampered by the low number of tagged fish and limited duration of observations.

This experiment has confirmed the feasibility of acoustic tagging to observe fish in a set net, and over time and with a greater number of tagged fish it should be possible to document definitive trends in behavior. Future work could also observe the effect of an external stimulus on tuna movement in the set net, with a goal of preventing bluefin tuna from entering the final trap and facilitating their escape.

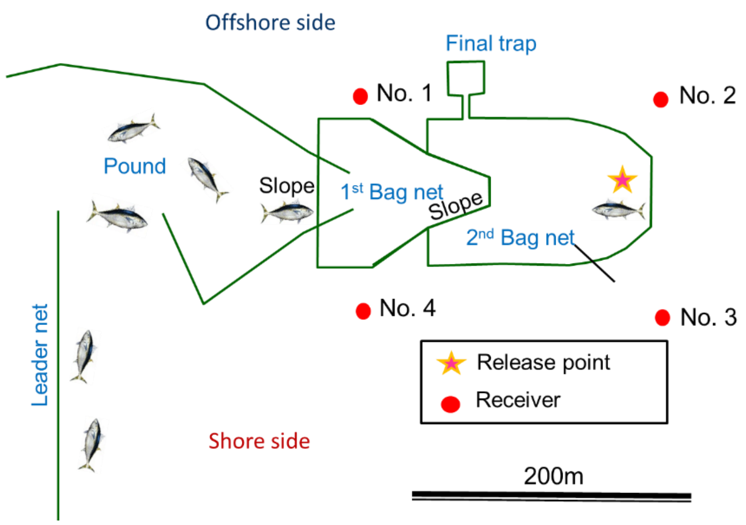


Figure 5. Arrangement of acoustic receivers adjacent a set net.

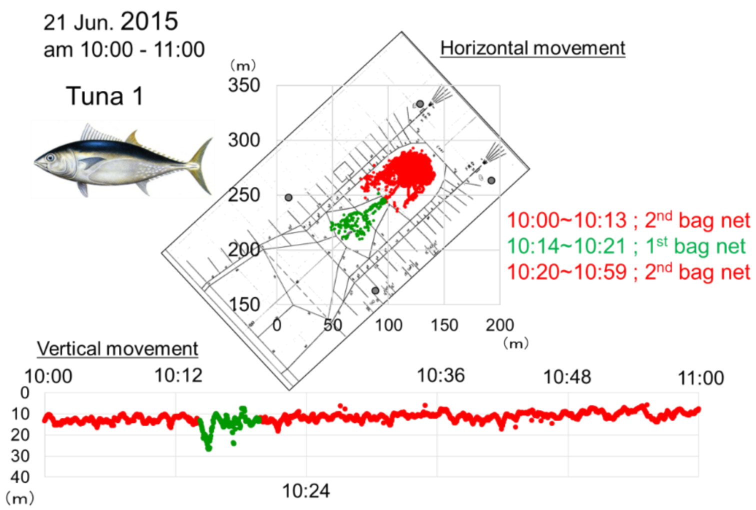


Figure 6. Horizontal and vertical movement of a Bluefin tuna inside a set net.

Development of cod pots as fishing tool to solve the conflict with seal depredation and harbour porpoise bycatch (by Lotte Kindt-Larsen, Maria Hedgärde, Casper Willestofte Berg, Finn Larsen and Sara Königson)

The bycatch of endangered harbor porpoise in commercial fishing operations and the depredation of catch by grey and harbor seals is a growing concern in the Baltic Sea gillnet fishery. In recent years the seal population has increased significantly, in some regions by eightfold or more. Subsequently, a collaborative effort between researchers, gear manufactures, and fishers has been attempting to design pots to catch cod and avoid interactions with porpoise and seals.

Four pot designs were tested: Little Sara; Big Sara; Lotte-round, and: Carapax (Figure 7). All are floating pots except the Lotte-round and Carapax, and all have a single entrance with the exception of the Lotte-round which has three entrances. Ten pots of each design were tested and preliminary results indicated the round lotte caught more slightly cod (<38 cm; >38 cm) than the remaining pots.

Additional tests included using the Little Sara as a control and several modifications were then completed, including adding cable ties to the funnel to prevent mammal depredation (SUN entrance), removal of the internal chamber, and chamber turned around. The Lotte-round, a smaller Lotte-round, a Swedish designed (square) pot called Olle, and a Sara prototype pot were also compared during these additional tests. All traps were first tested in a flume tank to observer orientation and height above the seabed. Seven traps of each design were tested and the Lotte-round, the Olle and the Sara prototype were most effective (Figure 8). Future work will include exploring the impact of different baits and funnel designs.

Figure 7. Trap designs. a) Little Sara b) Big Sara c) Lotte-round d) Olle e) Sara SUN entrance f) Low Sara with chamber the other way, from horizontal to vertical.

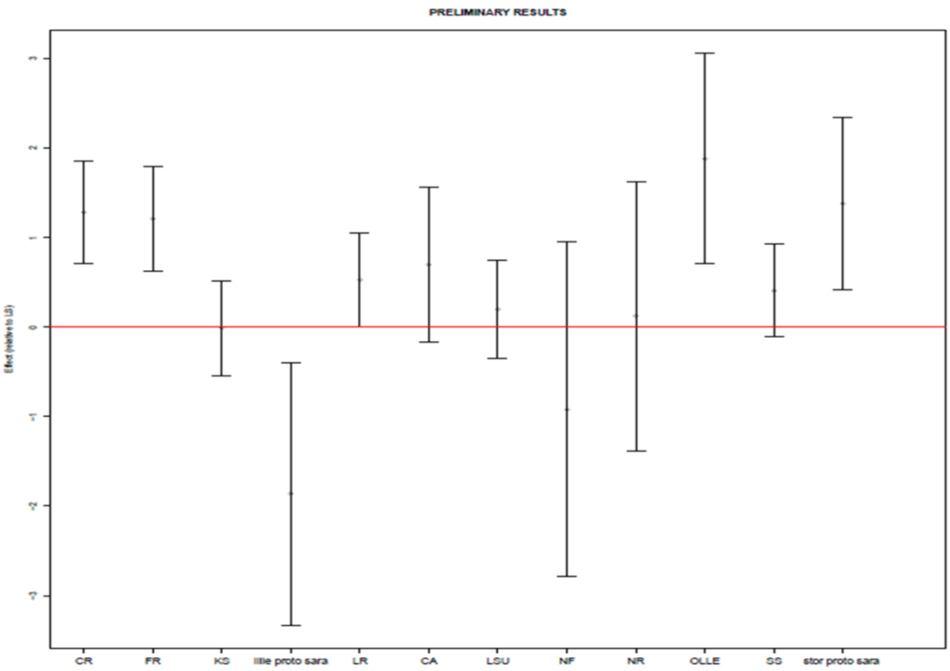


Figure 8. Cod catch by trap type relative to Sara round (red horizontal line).

Observations of fish behaviour in and around passive fishing gear: an efficient tool in fishing gear development (*by Peter Ljungberg, Sara Königson, Maria Hedgärde and Lotte Kindt-Larsen**)*

There is an increasing need to find solutions to catch depredation by seals in the Swedish coastal gillnet fishery, especially in southern waters. The development of efficient cod pots is an obvious choice. A need was identified to observe fish responding to cod pots, understand the function of the catch chamber (is it to prevent pot saturation, to decrease escape, or retain fish circling around the bait bag, or all three?), and investigate the factors affecting cod entrance behaviour.

To observe behaviour in and around the pot a GoPro camera connected to two power packs was used. To record observations for 30 hrs a 124 GB memory card was used. The camera and battery packs were fitted to a housing rated to 100 m and the field of view was illuminated by 1500 lumen LED lights. Observations were then made on several pots including floating and bottom standing pots (see previous presentation for description).

To understand the function of the catch chamber a comparative experiment was completed with two pot designs (floating pots with single entrance and bottom pots with three entrances), each configured with or without a catch chamber and with an open entrance or a closed (tapered) entrance (Figure 9). The floating pot with the open entrance and catch chamber was the control against which cod catch rates of all pot types were compared.

There was no significant difference when the chamber was removed or the open entrance replaced with a tapered entrance when the floating pot was used. The bottom pot with open entrance caught significantly fewer fish while the catch of the other bottom pots was insignificant. Evidence indicating that chambers influence pot saturation was inconclusive, although the closed entrances appeared to successfully retain more cod than open entrances. A generalized additive model was used to explore cod behaviour around pots and factors that appear catch rates. The number of fish already inside the pot did not have an impact on the number of fish entering the pot, although time of day did affect catches with peak catches at night time (although this may have been due to light induced effects). Cod activity around the pots (# that entered the pot) was found to increase with time and was greater with the bottom standing pot with three entrances. However, in the bottom standing pot most of the fish were not retained and escaped.

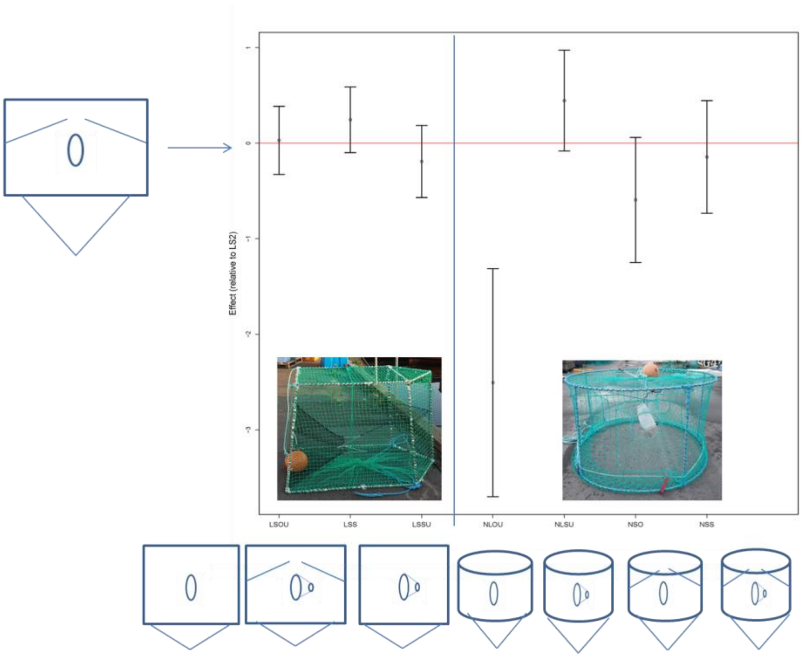


Figure 9. Relative catching performance of floating and bottom standing cod pots.

General discussion of the session 1.

A question was asked if the Didson acoustic camera might be a suitable option to avoid the problem of video work with lights. In response it was suggested that such a camera can be a suitable replacement, although it was also pointed out that this camera is very expensive. An alternative is to use lights that alternate between being turned on and off.

A question was asked regarding the time before the cod traps tested could be used for commercial purposes. Fishermen and the fishery managers determine application, although some traps are being made available to fishermen to test for free so they can try them.

Another question related to the use of pots to catch shrimp. In Norway some fishermen have tested pots to catch Norwegian lobster and shrimp, using pots from Maine and elsewhere. A locally designed pot was most successful, and catches were profitable. The pots were baited with herring. Bycatch was only around one fish per pot, and efforts are being made to continue the research work for another year, including testing of the use of light and monitoring the behaviour of shrimp in and out of the pots.

SESSION 2: Encouraging Technological Change in Capture Fisheries

What role can organizational change management play in encouraging change in capture fisheries? (by Steve Eayrs*)*

To set the scene it was pointed out that despite this session seeking presentations that focus on i) efforts to facilitate change in fisheries, ii) responses by fishermen to change, and iii) change initiatives that did not achieve anticipated outcomes, almost all presentation abstracts suggest a focus on i) with little evidence of consideration of ii) or iii). The question was asked does this reflect a bias in our research or that we are simply more comfortable talking about our own successful work rather than the behavior of others or why some initiatives failed.

Organizational change management was defined as a process of continual refinement of an organization's direction, structure, and capabilities to serve ever-changing needs of internal and external customers. Several personal examples were presented highlighting the challenges of change in commercial fisheries including restrained uptake of free fuel flow meters by fishers despite their recognition of annual fuel savings and use of TEDs and BRDs that were provided at no cost prior to their mandatory use. It was posited that their reluctance is described as a paradox, because fishers respond consistently to inherent work-place change but are reluctant to change otherwise. This is the paradox of fishermen.

Fishers in Australia and the USA were questioned regarding their appetite and attitude to change and the efficacy of industry groups designed to facilitate change on their behalf. Members of the WGFTFB were also questioned regarding their perceptions of fishers' appetite and attitude to change. A highly significant difference between fishers and the WGFTFB was found regarding fisher appetite and attitude to change (Table 3). There was also substantial difference between fishers and the WGFTFB in response statements explaining why fishers are reluctant to change (Table 4), and fishers clearly value the importance of incentives or subsidy differently to WGFTFB members. The Kotter change management model was presented and fishers were required to respond to questions related to each step of the model (Figure 10). The model was described, but only major findings related to the first few steps were provided. These included:

- While most fishers joined their industry group after identifying an urgent need to change, not all fishermen agreed on the type of change that was necessary or how the changes would be introduced.

- Vision statements to guide change are seldom used and many fishers were not aware of the vision in their industry group or if they agreed with the vision, and few are aware of a strategy for change. Few agreed the vision statement was communicated and that others behaved consistently with the vision.

Overall it was recommended that WGFTFB members give greater consideration to the application of their research by fishers, that change should be considered from the perspective of fishers, and that appropriate change management theory and principals can be applied that may increase the likelihood of a successful outcome.

Table 3. Responses by fishers and WGFTFB members regarding acceptance of change by fishers.

Statement	Case study	
	Fishers (n = 37)	WGFTFB (n = 45)
I/They readily/enthusiastically embrace and accept significant change in my/their fishery	9	1
I/They sometimes embrace and accept significant change in my/their fishery	26	21
I/They do not like and rarely/reluctantly and accept significant change in my/their fishery	2	23

Table 4. Top five ranked statements (there were 10 in total) by fishers regarding their reluctance to change. The statement regarding incentives is included because of the large ranking between both groups.

Statement (n = 10)	Fishers (n = 40)	WGFTFB (n = 38)
Perceived loss of control over their fishing operation and/or fishing business	1	3
Mistrust of individuals responsible for bringing about change, including their motivation ($p<0.05$)	2	7
Perceived lack of opportunity, benefit, or reward from change	2	5
Concerns that change will be costly or painful	3	1
Concerns that change will have a ripple effect and more changes will be introduced	4	9
Perceived lack of incentives to offset any catch loss	9	2

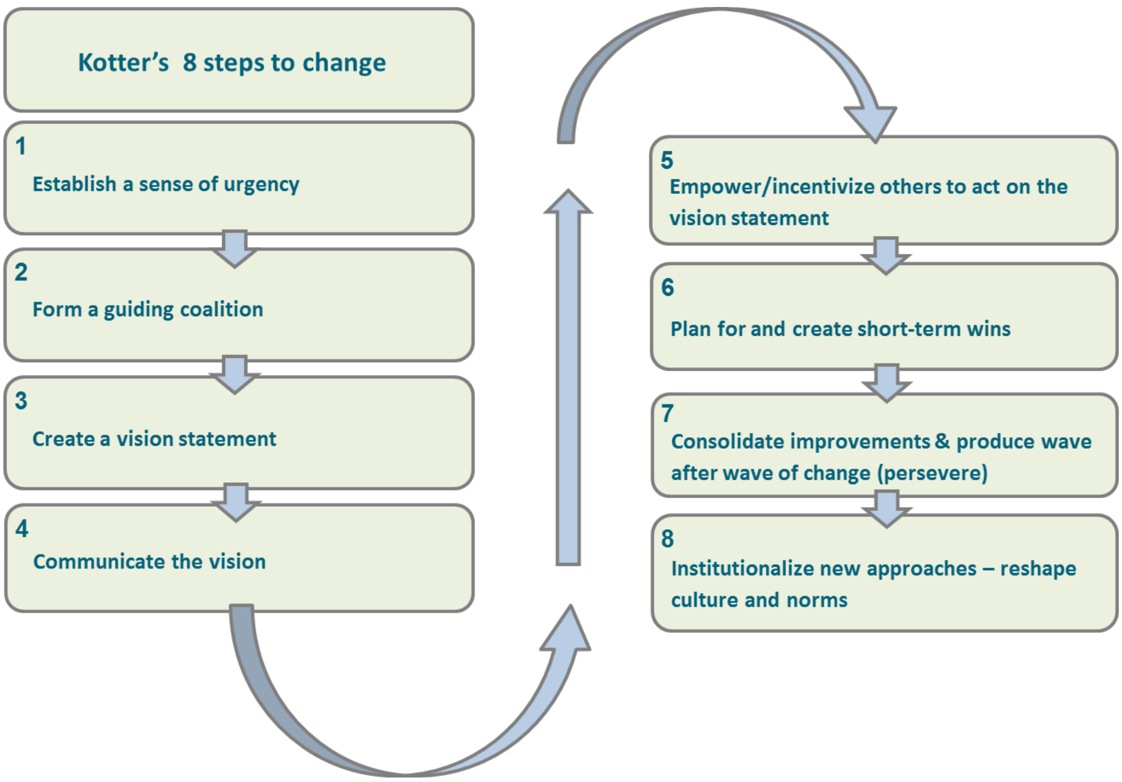


Figure 10. The 8-step Kotter model. All steps are required to reach a success outcome.

Health and socioeconomic effects of hookah diving fishing technology in small-scale fisheries: A qualitative risk assessment *(*by Oswaldo Huchim and Juan Carlos Seijo*)*

On the Yucatan coast around 1300 fishers participate in hookah diving for spiny lobster and sea cucumber. A significant health risk from hookah diving is decompression sickness (DCS) and carbon monoxide poisoning (COP), and since 2003 at least 100 lobster fishers per year are treated with hyperbaric oxygen therapy.

A qualitative risk analysis framework was applied to evaluate the consequence levels of risks to health using hookah gear (Table 5). Based on a likelihood/impact matrix filled with perceptions from fishers, the health risks of hookah diving were evaluated. The perceptions of fishers were obtained from their responses to an eleven question survey related to their wellbeing and a range of health threats such as CDS, COP, and chronic disease

Each fisher indicated the perceived consequence level and likely level of impact to each question. These scores were multiplied to identify a risk category (Table 6); each category relates to a potential management response. The risk values of each consequence were then summed to produce an impact value, and by repeating this for each question the relative importance of each question can be determined (Table 7).

As a result of this risk analysis prioritization of relative health issues has been possible, which not only raises awareness by fishers and others, but helps prioritize limited resources.

Table 5. Consequence levels of potential risks to health using hookah gear.

Level	Score	Consequence				
		Wellbeing of Fishermen	**DCS**	**COP**	**Non-fatal injuries**	**CDD**
Negligible	0	There is no risk of negative impact on wellbeing.	There is no risk of DCS.	There is no risk of COP.	There are no injuries related to diving.	CDD are not related to the diving activity
Minor	1	Good catches with minimal negative impact on health status	Minor risk to get DCS and if does symptoms were self- treated with pain relieve.	Probabilities of COP are minimal.	Probabilities of injuries are minimal.	CDD could be related to diving accidents but not know which ones.
Moderate	2	Incomes above the community average but households remain vulnerable	HBOT is needed to relieve symptoms but sequelae risk is minimal.	Chances of COP while diving are important	If injuries are present they are not severe.	CDD are related to some diving accidents but not increasing the probabilities to have it.
Severe	3	Bad yields but job satisfaction worth it and wellbeing perception is not affected	HBOT and hospital stay is needed to relieve symptoms with risk of sequelae.	Symptoms due to DCS are minor and disappear few hours before diving	Injuries related to diving can be cause of disabilities.	CDD are related to diving accidents and increasing the probabilities to have it.
Major	4	Wellbeing is compromised due to overexploitation of resources and hence incomes will be reduced.	DCS cause disabilities in divers despite the HBOT	Symptoms don’t disappear so HBOT is needed.		CDD related to diving is a cause of disabilities among divers.
Catastrophic	5	Decrease of incomes and ineffective management policies linked to resources overexploitation compromised wellbeing	DCS is the cause of death among divers	COP is a cause of death among divers.		CDD related to diving is a cause of death.

Table 6. Level of impact associated with the likelihood of an event occurring, and risk category and associated likely management response.

Level of Impact	Score	Description	Risk Category	Value	Likely management response
Likely	6	It is expected to occur	Negligible	0	No direct management needed.
Occasional	5	May occur sometimes	Low	1–6	No specific management actions needed.
Possible	4	Some evidence suggest that this is possible to occur locally	Moderate	7–12	Specific management needed
Unlikely	3	Uncommon but has been known to occur someplace else.	High	13–20	Increases to current management activities probably needed.
Rare	2	May occur in exceptional circumstances	Extreme	20–30	Significant additional management activities needed
Remote	1	Never heard, but not impossible			
Negligible	0	Impossible to occur			

Table 7. Risk perception analysis related to the question regarding the consequences of diving as a fishing method.

Consequences of diving as fishing method to the fishermen wellbeing	Impact Value	Consequence Level	Qualitative Likelihood	Risk Category
Do you think diving as fishing method has impacts on your wellbeing?	8.57	Moderate	Possible	Moderate
Are there possibilities of get injured because of hookah diving?	9.95	Severe	Possible	Moderate
Are chronic degenerative disease (CDD) related to the diving activity?	3.85	Severe	Improbable	Low
Is there a risk of DCS because of diving as fishing method in artisanal fisheries?	12.57	Major	Possible	High
Diving with HDS could COP?	8.27	Minor	Improbable	Moderate

Industry-led fishing gear selectivity improvements. How can we increase flexibility and ownership over the gears used while ensuring an effective introduction of the new EU Common Fisheries Policy? *(*by Jordan Feekings, Ludvig Krag, Tiago Malta, Henrik S. Lund, Søren Eliasen, Clara Ulrich and Lars Mortensen*)*

In Denmark and the wider EU, the traditional way in which fishing gear has been implemented is via a top-down prescribed approach where regulations define minimum requirements, such as minimum mesh size, use of grids or panels, and even twine thickness. This approach, akin to micro-management, relies upon fishery managers first identifying a problem, followed by testing and evaluation by scientists and others collaborating to seek for a solution, followed by implementation by fishers. This is a slow and inflexible approach that may take several years to complete; furthermore, simple gear changes can substantially affect selectivity and negate to a greater or lesser extent anticipated benefits of regulation. In response, technical regulations often get longer and more cumbersome in an attempt to control the impact of these changes made by fishers. This approach typically results in a one-size-fits-all, inflexible outcome where fishers have little sense of ownership over their fishing activity and resource.

An alternative approach, one that is more bottom-up, is necessary because it utilizes industry knowledge, much of it unique. It also gives industry a change to play an active role in the change, and it subsequently provides them a sense of ownership over the change. It is important that this approach is acted upon because the EU Common Fishery Policy (CFP) requires unwanted species must be landed, which count against quotas, and fishers now have an economic incentive to improve their selectivity to the greatest extent practicable. Subsequently, there is a need to fast-track the process of gear change (Figure 11).

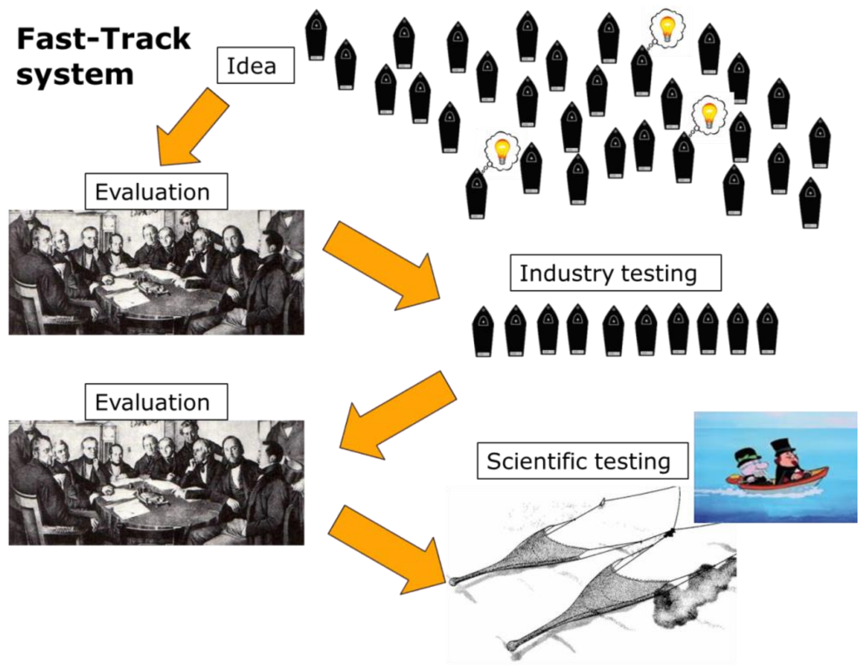


Figure 11. Proposed bottom-up fast-track system for promoting gear change.

One option is to allow industry to formulate the idea/identify a need for change. The idea/need is then briefly evaluated by a core group of scientists and fishers who then arrange for industry testing if the change is deemed meritorious. The results of the testing are evaluated by the core group, including the impact of small modifications and refinements, and if deemed successful scientific testing may follow under appropriate scientific conditions. This latter step provides sufficient rigor to enable the development of effective regulations. This approach is deemed particularly well suited to accommodate the CFP because fishers will need to continuously minimize discarding to improve quota utilization, increase responsiveness, and allow greater application of vessel-specific solutions. Moreover, multiple tests can occur simultaneously, on multiple vessels, and at relatively low cost, so a greater number of gear modifications can be tested in a short period.

***Improving tropical shrimp fisheries through eco-labelling: experiences from the Suriname* seabob fishery** (*by Tomas Willems, Annelies De Backer, Magda Vincx and Kris Hostens*)

The Suriname seabob (shrimp) fishery was certified as sustainable by the Marine Stewardship Council in 2011. The first tropical shrimp fishery to be certified. Seabob are landed using small trawlers in coastal waters and are typically exported to Europe. The bycatch in this fishery includes a variety of species, including sea turtles, elasmobranchs, small fish and others. The bycatch to shrimp ratio was around 10:1 by weight.

In 2007 there was no seabob stock assessment, a vague fishery management plan (that had been in a draft stage for the preceding 8 years) and no transparent decision making processes. While there was a requirement for fishers to use TEDs, there was only weak monitoring and control at sea. A plan was established in 2007 to bring about significant fishery improvement. With a timeframe of five years, steps were taken to monitor fishing effort and spatial fleet distribution, conduct format stock assessments of the seabob stock, introduce harvest control rules and bycatch reduction strategies, build fishery governance, and establish a fishery management plan. Ultimately these improvements resulted in certification of the fishery. Without the lure of this outcome it is unlikely that efforts would have been made toward fishery improvement. A seabob working group has also been established, comprising fishery officials, fishers, NGOs, and researchers, who meet monthly to evaluate progress against a fishery R & D plan.

VALDUVIS: An innovative approach to assess the sustainability of fishing activities (by Arne Kinds, Kim Sys, Laura Schotte, Koen Mondelaers and Hans Polet*)*

To promote a sustainable Belgian fishing fleet and overcome issues associated with environmental impacts of beam trawling, dredging, and other fishing gears, two projects are currently ongoing. These projects are Vistraject, which is developing goals and actions for a sustainable fishery by 2020, and VALDUVIS, an indicator based sustainability assessment tool.

To shape change in the fleet, these projects are applying a holistic approach using an integrated sustainability approach that includes a cyclic, step-by-step approach. This approach starts by envisioning a sustainable future (outcome) and then working backwards to identify relevant steps to achieve the desired outcome in partnership with multiple stakeholders (Figure 12).

This approach was applied to the Belgium beam trawl fishery. Consideration was given to using alternative gears such as Sumwing or twin trawling as replacement gears given their superior selectivity, positive effects on fuel consumption, and reduction in seabed contact. The application of new gears is often slow, so a new approach was applied, that of individual assessments. This approach (VALDUVIS) involved daily sustainability assessments of individual beam trawl fishers to provide a baseline to measure future performance and to provide fishers insights into their sustainability against multiple criterial. This information can also be used in association with efforts to gain market recognition and access.

Substantial data for these assessments was collected using an electronic reporting system (e-catch), an important process for evaluating individual sustainability. A total of 14 sustainability indicators have been established, related to economic, social, and environmental performance metrics (Figure 13).

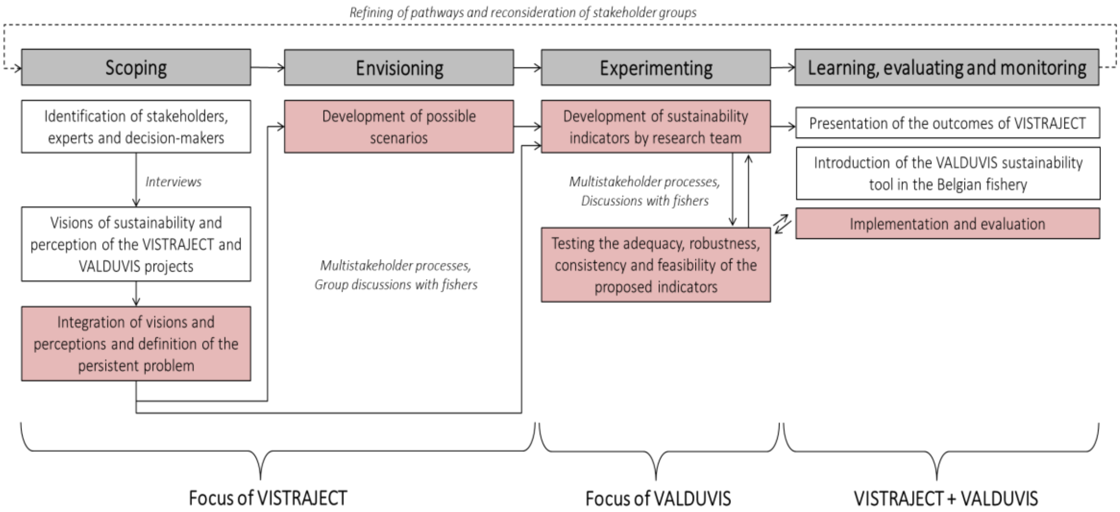


Figure 12. The framework used in the VALDUVIS project.

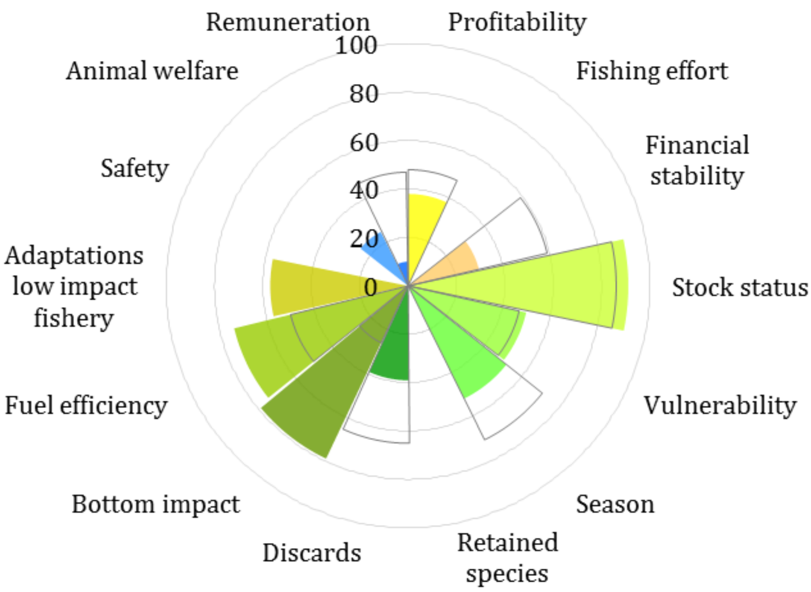


Figure 13. Visual representation of sustainability of an individual fishers' fishing trip. Fourteen indicators are used, scored between 0 (worst practice) – 100 (best practice). Grey lines represent internally developed performance benchmarks.

Fishing gear related to octopus behavior in the Octopus Maya fishery of Yucatan shelf (by Alvaro Hernandez)

In Yucatan more than 29 000 tonnes of octopus were landed in 2012. This fishery is currently exploited at Maximum Sustainable Yield (MSY), however, concern has been raised regarding fishing for octopus during the reproductive season. Octopus are caught using a pole with a live crab tied to the end of the line from drifting fishing boats. Despite regulations designed to avoid overfishing, such as closed seasons and minimum landing size, there are concerns due to illegal fishing gear and momentum to commence the season earlier.

General discussion of the session 2.

A comment was made regarding the use of habitat maps to define where the seabob fishery takes place, so the extent and possible impact of trawl induced seabed impact could be evaluated.

A question was asked regarding different responses between fishermen and the WGFTFB, and if stated beliefs and preferences might not differ from actual beliefs and preferences. The response confirmed this might be the case, and that an issue with questionnaires is that stated beliefs and preferences might actually vary on a daily basis. It is very difficult to capture this variation.

It was noted that when users are well informed their decisions can be better as they internalize the perceived costs of their behaviour. It was added that scientists need to spend time keeping fishers and all other stakeholders well informed.

The sustainability of the red octopus fishery was questioned; Seafood Watch indicated that this fishery is not sustainable due population decline, an unknown state of common octopus species, and lack of proper fisheries management. In response it was claimed that octopus fishing, even during the octopus reproductive period, which now had been ongoing for 30 life cycles (they reproduce only once), demonstrated stable catch rates over this time.

SESSION 3: Energy and greenhouse gas reduction in capture fisheries

Emerging issues on energy use in fisheries and development of low impact and fuel efficient fishing gears (by Antonello Sala)

Energy consumption and GHG emissions are an emerging issue confronting the fishing industry. Currently 3 standards exist related to emission of GHG, ISO/TS 14067, a British standard PAS 2050–2:2012, and a Norwegian standard NS9418. The British standard contains requirements for the life cycle assessment GHG emissions, and it identifies various inputs and outputs of various stages of the seafood product cycle, from fishing to transport and distribution, and evaluates their potential relative contribution to GHG emissions.

In Italy, energy audits in fisheries first commenced several years ago, to define the energy profile of fishing vessels, to identify potential technological improvements, and to evaluate the technical and economic benefits of these improvements (Figure 14). Data acquisition software was developed at CNR-ISMAR that acquires data from several sources including shaft power, drag during fishing, fuel consumption, hydraulic power, electric power, and vessel position and speed. Hardware included a CorFu meter comprising two flow sensors, a multi-channel recorder, and a global positioning system (GPS) logger. This data is then downloaded to a server when the vessel reaches a wifi region.

Semi-pelagic doors are emerging as a viable low fuel alternative to traditional doors, and fuel savings up to 18% have been realized, with payback times in some circumstances as little as four months. Another fuel saving option is the experimental W-trawl, comprising two headropes rather than a large single headrope. This trawl design places less load on the wings of the trawl so smaller doors can be used. A move to twin trawls can also produce significant fuel savings, as can improved trawl design and rigging, as well as high strength twines which can reduce fuel consumption by 5% or more with payback of less than 3 months.

A suite of vessel innovations are also available to reduce fuel consumption. Hull optimization has been shown to reduce resistance by over 50% under certain conditions. Electromagnetic devices for reducing fuel viscosity have been shown to reduce fuel consumption by around 4% and heat recovery from the main engine to generate electricity can contribute another 5-8% saving. Hull cleaning and use of antifouling paint can avoid marine growth and reduce fuel consumption by 6-8%.

Facilitating the adoption of fuel efficient fisheries requires developing acceptable technology and incentives, realistic objectives, training and assistance and involvement by all stakeholders, redirecting fuel subsidies to encourage development of energy saving practices.

Finally, the reluctance of fishers to use this new gear should be considered. Despite the availability of new technology, fishers do not always readily adopt this gear. A variety of reasons exist explaining their reluctance to change, from complacency and lack of urgency, inability to overcome fear, absence of leadership, vision, and strategy, lack of communication and failure to celebrate short term wins. However, given this reluctance, sometimes it takes time for technological uptake and our timeframe is too short to see long term, permanent change. Moreover, many issues we are tackling today have a long history and still have not been adequately overcome.

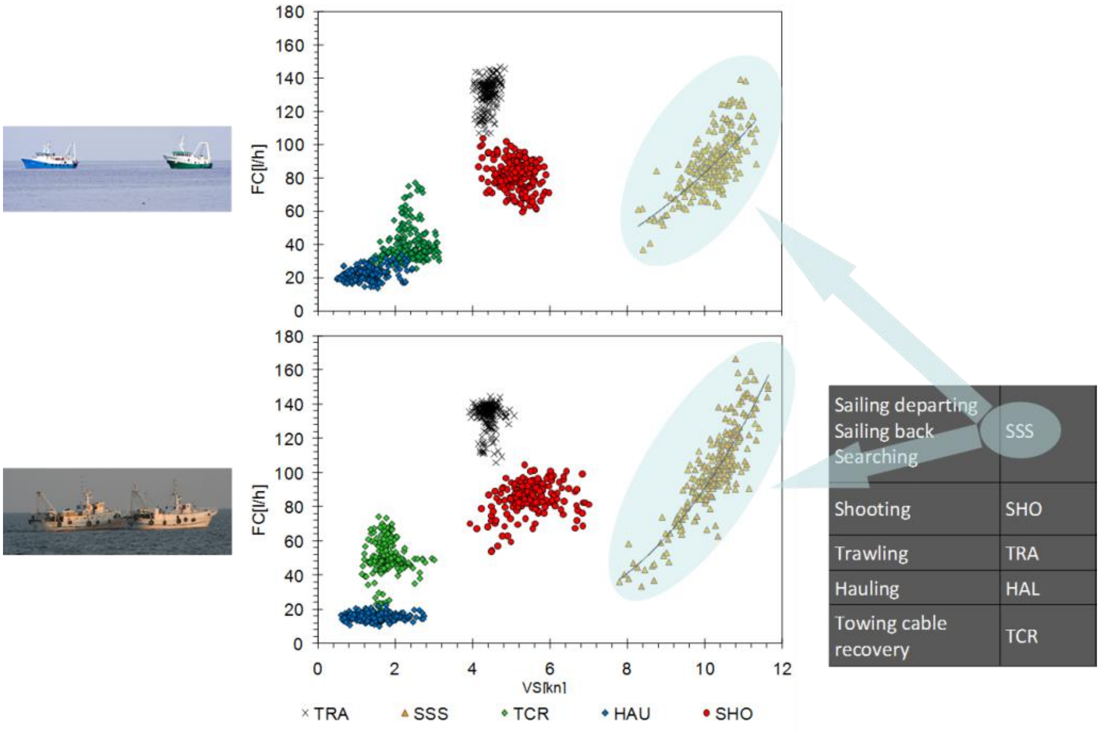


Figure 14. Relationship between fuel consumption and towing speed for two pair trawling operations.

Application and review of energy audit protocols in the commercial fishing industry
(by Steve Eayrs)

The methodology, outcomes, and utility of energy audits in the New England groundfish fishery, USA, and the Thai trawl fishery was described. In New England 4 trawlers were audited by Canadian company TriNAV Fisheries Consultants. They interviewed the captains of each trawler to collect information regarding operation and performance of the vessel and fishing gear, followed by site inspections to record important deck and hull measurements, machinery design and specification, etc. This process took approximately half a day per vessel. A variety of fuel saving recommendations were suggested for each trawler, with estimated outlay costs, annual fuel savings, and return on investment (payback periods). This information was then used to explore relative fuel savings under a variety of scenarios (Table 8).

Table 8. Examples of questions that could be asked of a fishing operation once an energy audit is completed.

What if I want to purchase a fuel saving option, pocket the savings to recover the cost, before making another purchase? Total budget - $5500

Recommendation	Cost ($)	An. fuel ($)	Fuel savings (%)	An. savings ($)	An. fuel - An. Savings ($)	Cum. savings (%)	Time to save (mths)
Fuel meter	3 000	30 000	15	4 500	25 500	15.00	8.0
Upgrade rudder	2 000	25 500	5	1 275	24 225	19.25	5.3
Fairing pieces	500	24 225	5	1 211	23 014	23.29	1.0
Total	5 500			6 986		23.29	14.3

Or, what if I saved fuel and used the savings to purchase each recommendation incrementally up to $5500?

Recommendation	Cost ($)	An. fuel ($)	Fuel savings (%)	An. savings ($)	An. fuel - Ann. Savings ($)	Cum. savings (%)	Payback period (mths)
Fuel meter	3 000	30 000	15	4 500	25 500	15.00	8.0
Upgrade rudder	2 000	25 500	5	1 275	24 225	19.25	4.2
Fairing pieces	500	24 225	5	1 211	23 014	23.29	0.9
Total	5 500			6 986		23.29	13.1

In Thailand a different approach was used. A total of 150 fishermen were interviewed by SEAFDEC staff; 50 captains from small vessels (<14 m), 50 captains from medium vessels (14-18 m), and 50 captains from large vessels (>18 m). Each captain was asked about trip expenses including crew salary, food, lube oil, ice, and fuel. This was followed by at sea measurement of fuel consumption, vessel operations, speed over ground, and heading. Four cameras were used to film instantaneous fuel consumption, GPS display, engine rpm display, and weather display, with each display recorded using a digital video recorder (VCR) (Figure 15). At the end of a trip this footage was collected and analyzed. Catch and fishing cost information was also collected. Data was collected while the vessel was steaming and fishing; efforts were made to collect data over a range of steaming speeds and fishing speeds so optimal speeds could be determined.

In New England a range of potential fuel saving options exist, including fuel efficient otter boards and nets. In addition, improving optimal steaming speeds was viewed as a simple and cost effective fuel saving option. A fuel flow meter was considered ‘low hanging fruit’ because of its relative cost effectiveness. In the Thai fishery many gear options such as fuel efficient (steel) otter boards and larger mesh netting were not considered suitable because of their impact on the fishing operation or catch. Instead, a fuel flow meter was considered an effective option, coupled with improved trip planning. Regular hull cleaning was also suggested an important low-cost option to reduce fuel consumption.

The interviews of fishermen provided a general guide of sources of fuel consumption and vessel behaviour. Recollection of costs by fishermen was not always accurate and should be confirmed through inspection of logs or records. Furthermore, many fishermen were not interested in fuel saving, particularly now that fuel costs have decreased in recent years.

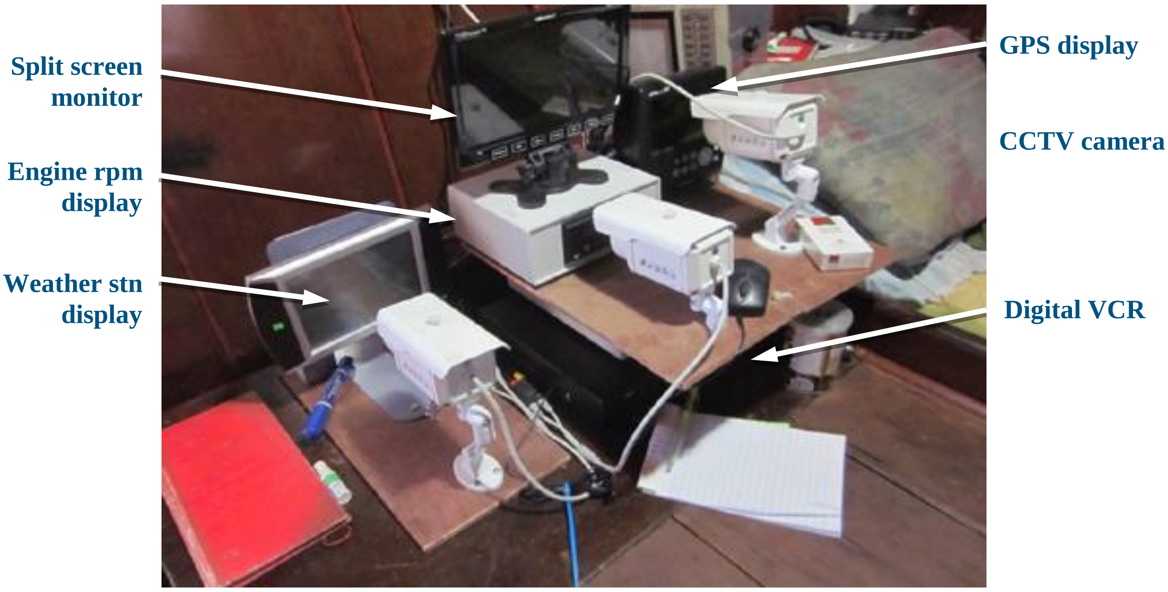


Figure 15. Energy audit data collection system developed by SEAFDEC.

The data collection approach applied by SEAFDEC is a portable, relatively cheap, simple, easy to use system that can be left on board to collect data over long time periods in the absence of a researcher. The down side of this system is the considerable post-trip video and data evaluation that is required. Presently, energy audit protocols for the commercial fishing industry do not exist. There are no minimum performance standards, hampering comparison between individual vessels or fishing fleets. The collection of historical catch and expense data from fishermen hampers first order evaluation of their fishing operation. Logbooks may be an option in the future; meanwhile, reliance on historical records is the best available option.

Efficient ship: Fuel saving in fisheries through heat recovery from the main engine – a case study in Ireland (by Emilio Notti)

This was a collaborative project between CNR (Italy), KFO (Ireland), ENOGIA (France) and IFPEN (France) that attempted to demonstrate the feasibility of applying Organic Rankine Cycle (ORC) technology to reduce fuel consumption and GHG emissions from fishing vessels, evaluate the suitability of the ORC technology, and improve efficiency and reduce environmental impact of European fisheries. This project adopted a multi-stage approach i) identification of demonstrative vessel, ii) assessment of energy profile, iii) monitoring of fuel consumption, iv) design and installation of ORC technology, and v) evaluation and impact of ORC technology.

The ORC involves converting waste heat from thermal engines into electric energy (Figure 16). A case study vessel was selected and its operational/energy profile was then documented. The vessel selected was a crabber, measuring just over 25 m propelled by a 484 kW Caterpillar engine. Two auxiliary engines are present, both 95kW Caterpillar engines.

Specialized data acquisition software was used to collect data on fuel consumption, hull drag resistance, engine power, hydraulic power, electric power, and vessel location. Based on an energy profile assessment, up to 265 kW of recoverable thermal energy is available from the exhaust gasses of the vessel while sailing, and 86 kW while fishing. Three water pumps used have a constant 21 kW electrical demand, the hydraulic pumps require up to 24 kW, while refrigeration, lights, and other sources of demand results in a total constant demand of 34 kW plus a variable demand up to an additional 36 kW. Monitoring of fuel consumption has only just commenced, and data are preliminary. However, it is anticipated that the electrical demand for the three water pumps can be met by utilizing recoverable thermal energy from the main engine. Predicted payback period for this vessel could be 8 years or more, although this period is predicted to be reduced by half if the vessel would be converted for trawling because of a substantially higher period under high load conditions (Figure 17).

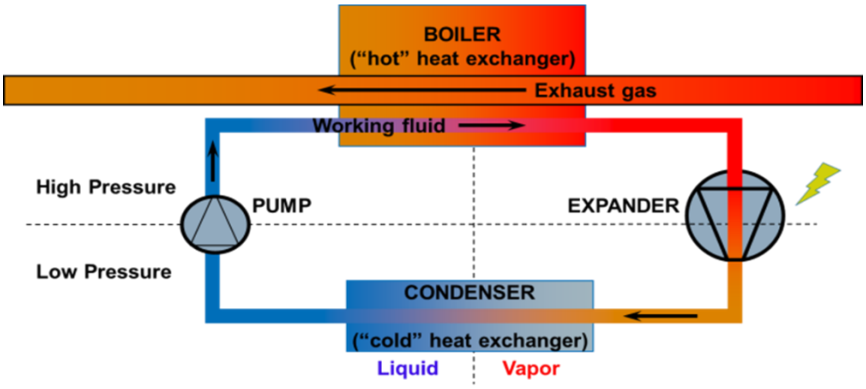


Figure 16. The Organic Rankine cycle, converting heat from exhaust gas to electrical energy.

Nominal consumption onboard

Genets': Caterpillar 3304B - 106kVa: 50A constant load ⇔ 9.7L/h ⇔5.6€/h (0.58€/L)

Vessel profile: 7500 hours/year

High-low load distribution: 80% / 20%

Economic saving: 11,000 €/year

CBA			
Fuel consumption		9.70	l/h
Fuel cost		0.58	€/l
Working hours		7,500	h/y
High load	80%	6,000	h/y
Low load	20%	1,500	h/y
Hourly cost		5.63	€/h
Fuel cost at high load		33,756	€/y
Money saving		11,000	€/y
Investment		50,000	€
ROI		22.00	%
PBP		4.5	y

Figure 17. Predicted fuel saving and return on investment using the ORC technology.

SESSION 4: Technology and Practice for Managing Bycatch and Reducing Discards

Efforts to minimize unwanted by-catches in the North-East Atlantic trawl fisheries; A brief summary of the developments over the last 40 years and current status (by Roger B. Larsen)

The Northeast Atlantic (NEA) has a long history of research attempting to reduce bycatch in trawl fisheries. The NEA, which extends along the Norwegian and Russian coast and into the Barents Sea, is a highly productive region and the total allowable catch of cod, haddock, and saithe is 805 000 tonnes, 223 000 tonnes, and 140 000 tonnes respectively. A shrimp fishery also extends over much of this region.

Efforts to reduce bycatch in the NEA commenced in the late 1960s in the shrimp fishery and involved study into optimum codend mesh size. Four codend mesh sizes were studied, 30, 35, 40, and 41 mm with the goal of reducing the catch of undersize shrimp while retaining legal sized shrimp. The L50 for shrimp retained in the 35 mm mesh was 16 mm (carapace length), which was close to the minimum landing size (MLS) of 15 mm. This mesh is still deemed optimal by fishers to this day. Around this time, efforts to reduce fish bycatch included a trawl with a sorting panel at the trawl mouth that helped guide fish through exit openings in the upper and lower panels. While fish were excluded successfully, shrimp loss was 30%-75%, and this trawl was not adopted by fishers. Various soft panel excluders were tested a little while later, including 60 and 80 mm mesh vertical side separator panels (35 m^2 each; 4-14% fish reduction), a 69 mm mesh panel across the trawl mouth (60 m^2; 44% fish reduction, large reduction in shrimp), an oblique separator panel in the trawl mouth (60 m^2; 50% fish reduction, low reduction in shrimp), and an oblique HH separator panel at the aft of the belly constructed from 40-60 mm mesh (6 m^2; 80-90% fish reduction, 25% reduction in shrimp). The size of the panels at or near the trawl mouth was a major impediment to their uptake, and the use of the HH panels became mandatory in the early 1980s.

In the 1980s the Siamese twin trawl was developed for the purpose of excluding fish bycatch. This trawl in effect consisted of two trawls mounted to the same headrope and footrope, with a large space in between for fish to escape. This trawl caught 12% fewer shrimp, 54% less haddock, and 11% less cod. It was not adopted by the fishing industry. Around this time efforts were made to test the efficacy of a dual funnel system connected by longitudinal rib lines in the extension of the trawl. Each funnel served to concentrate the catch into the center of the extension. Haddock and other fish could then move laterally and swim through the rib lines and escape. High shrimp loss resulted in this design being rejected by fishermen. Another device, the radial escape section, used funnels to filter small shrimp from the trawl and while it reduced the catch of small shrimp by up to 80%, this too was not adopted by fishers. Square mesh codends were tested in the shrimp fishery in the 1980s, including 35 mm square mesh, and while up to 90% of undersized shrimp were excluded, too many legal sized shrimp were also lost and so these codends were also not adopted by fishers. A mix of visual and audible stimulators were tested in the trawl mouth, but their results were inconclusive. In the late 1980s the Nordmöre grid was first tested. Following promising testing, including a variety of shapes and materials, fishers soon found the grid not only reduced onboard sorting time but improved catch quality as well. Despite numerous subsequent tests with different configurations, including multiple grids, grids of different shape, exit windows in side panels, and various funnel designs (Figure 18), the fishery currently uses a single Nordmöre grid with a 19 mm bar spacing and a codend with a 35 mm mesh size.

Norwegian efforts to reduce bycatch problems in the NEA groundfish fishery initially focused on modifications to the codend and later, the extension piece. Up until 1972 codend mesh size was 110 mm. In the 1980s it was increased to 125 mm and then 135 mm, and by 1997 a sorting grid with a minimum bar spacing of 55 mm was an additional mandatory requirement. In 2011 mesh size was reduced to 130 mm while the grid requirement remained intact; these are required in this fishery today. Square mesh codends were thoroughly tested in the 1980s, including 120 mm knotless PA square-mesh and double 135 mm PA square-mesh. While the results were generally successful, catch loss, knot slippage, and deck handling problems remain. Various codend lengths have also been tested, including “roped” codends using lastridge ropes to shorten codend length by up to 15%. This had the effect of reducing mesh tension so meshes could remain open. These codends successfully retained less small fish compared to a square-mesh codend of similar mesh size.

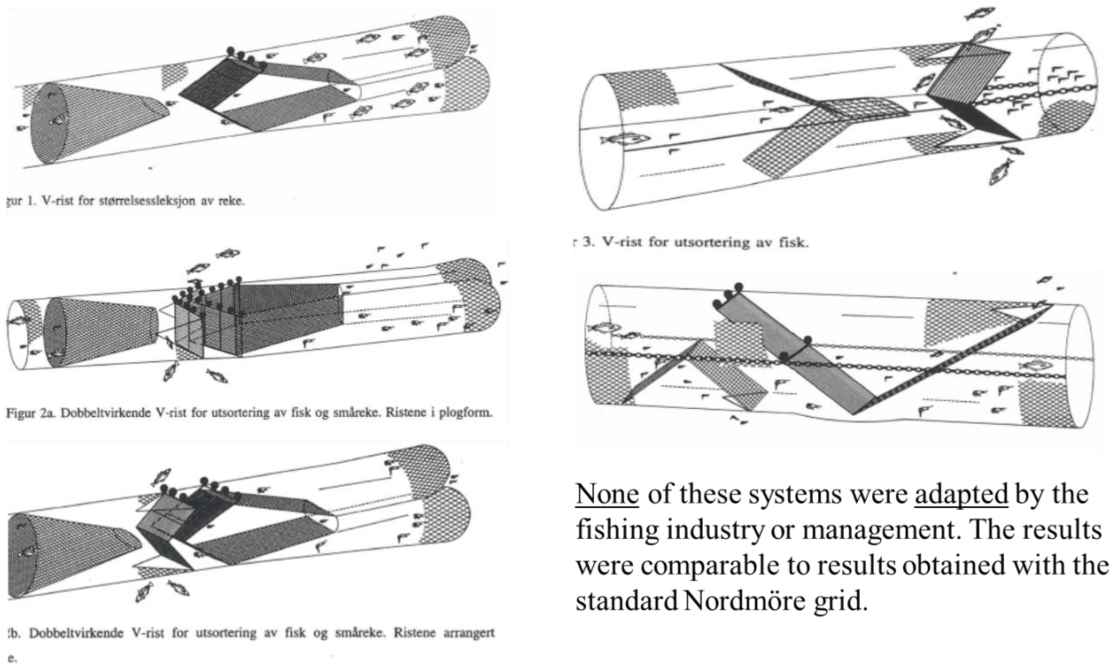


Figure 18. A variety of grid systems tested in the early 1990s to improve shrimp trawl selectivity.

Size selective grids were also introduced in the groundfish fishery (Figure 19). The original Sort-X grid was successful and provided fishermen an opportunity to access closed areas providing the grid was used. Bar spacing was 55 mm. The Sort-V is a double grid successfully reduced small cod and was approved for use in 2000. Several additional variations of grids have been tested including plastic grids to reduce grid weight and improve safety.

In 1987 a discard ban was introduced in the NEA fisheries. Recent evaluation of mean age at landing (years) and mean weight at landing (kg) suggests this ban has been very successful, with both metrics being at highest levels since the late 1940.

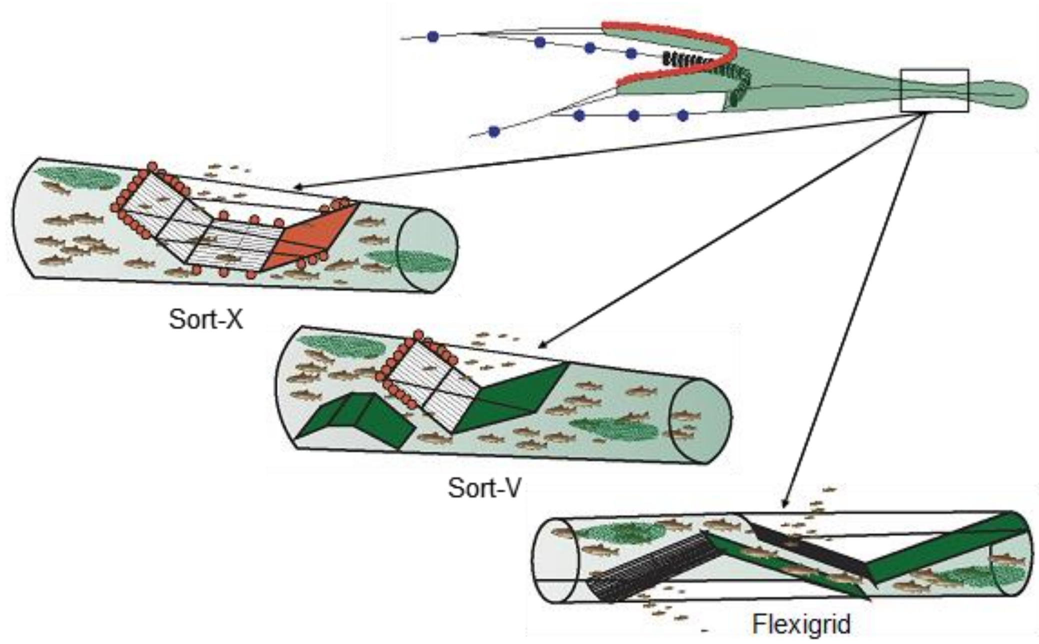


Figure 19. Grids systems designed to improve the selectivity of groundfish trawls.

Employing a trawl-independent multi-compartment towing rig to study selectivity of crustaceans in trawl (by Ludvig A Krag, Bjørn A. Krafft, Arill Engås and Bent Hermann)

There is increasing interest in commercial trawl fishery for Antarctic krill however there is little knowledge of the selectivity of krill trawls or if escaping krill survive selection from the trawl. The biomass of krill is estimated to be around 200 million tonnes. Krill measure between 2-7 cm in length when caught using 15–16 mm meshed codends.

The initial perception was that krill trawls were unselective, although comparison between a commercial trawl with 16mm codend mesh against a survey trawls with 3 mm mesh found a degree of selectivity with the commercial trawl, and determined an L50 value of approximately 35 mm. However, measuring selectivity and relating the outcomes to the fishing fleet is challenged by inconsistency in trawl designs, including mesh size. Krill trawls are also shallow tapered designs, and codend meshes can easily become masked by the codend cover/retaining bag. Full scale selectivity experiments are also expensive and place high demand on limited resources. There is uncertainty with respect to the extent that krill behaviour plays in selectivity, or the extent it is a passive sieving process through trawl meshes.

An innovative beam trawl was designed to evaluate the selectivity of multiple mesh sizes simultaneously and to overcome the difficulties of measuring selectivity in a challenging environment. Behind the beam were five compartments measuring 50 x 50 cm (Figure 20). These compartments were angled to the direction of tow to simulate the operating angle of panels of netting in the trawl, and some had a panel of 16 mm mesh extending across the mouth of the compartment. All compartments with the exception of compartment E had a 3 mm collecting bag to retain all krill.

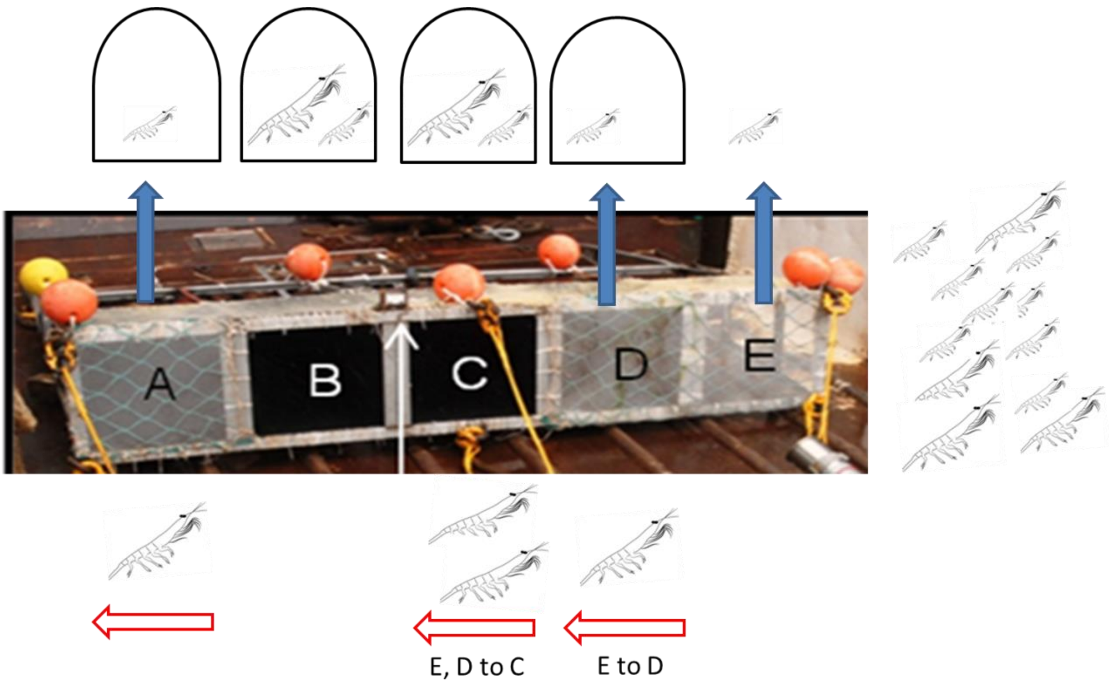


Figure 20. The krill sampling trawl.

The krill population encounters all compartments. However, small krill that encounter compartment E may pass through the 16 mm mesh panel and escape while large krill are guided by the panel to compartment D. Here, some small krill will pass through the 16 mm mesh panel and are retained, while large krill are guided to compartment C. This compartment has no small mesh panel, so retained krill will consist of those guided from compartments E and D as well as individuals that directly encounter this compartment. Compartment B will retain individuals from the population that directly encounter this compartment, and not individuals guided from compartments C, D, or E. Compartment A will retain only individuals small enough to pass through the small mesh panel.

The beam was used for 10 hauls on commercial fishing grounds. The retention rates of krill of each length were recorded and analyzed. The selectivity curves were similar to that recorded using in the 16 mm *versus* 3 mm trawl study. This trawl was deemed to provide realistic selectivity estimates although it was not possible to determine if selectivity was based on active behavior or passive filtration. Still, the potential for applying trawl-independent towing devices was deemed a success.

Technology on board to improve discards survival on Basque purse seine fishery (by Luis Arregi, Inigo Onandia, Esteban Puente, Oihance C. Basurko and Raúl Prellezo)

The Basque purse seine fishery targets anchovy, mackerel, horse mackerel, and sardine. However, when the quota for these species is reached they are usually discarded. From 1January 2016, these discards must be retained and counted against the quota, hence there is strong interest in assessing the survival of discarded fish once they have been pumped onboard and passed through a sorting machine before their release. Additionally, there is interest in the efficacy of a CCTV system to monitor these discards.

In an onboard experiment holding tanks were available to retain live discards and monitor their survival rate. When the catch was pumped onboard, all individuals were sorted by a sorting machine, and target species were directed to the hold while a fraction of the discards were retained in the holding tanks. These discards were retained for 2–4 days to evaluate their survival rates. Fish selected for survival experiments were classified by their duration in the bunt of the purse seine prior to pumping onboard, and for many species the survival rates were higher than 80% (Table 9). Survival rates tended to decrease with duration of the time spent in the bunt. The use of this technique to separate discards from retained catch is considered a viable option given the high reported survival rates.

Table 9. Survival rates by species and crowding time in the bunt. Figures in parentheses represent number of tanks used.

Species	Crowding time				
	0-5 min.	5-10 min.	10-15 min.	15-20 min.	20-25 min.
Mackerel	>95% (3)	>87% (3)	< 35% (2)	(-)	(-)
Horse mackerel	>99% (3)	(-)	(-)	(-)	> 94% (2)
Anchovy	98% (1)	94%(1)	(-)	>83% (3)	54% (1)
Sardine	100% (2)	97% (1)	(-)	(-)	> 83% (2)
Chub mackerel	100% (2)	100% (2)	(-)	(-)	(-)

Reduction of the shrimp bycatch from tropical trawling on the Colombian Pacific (by Mario Rueda, Alexander Girón and Jorge Viaña)

In Colombia, shrimp trawling occurs in the shallow waters of the Caribbean Sea (10-60 m), the shallow water of the Pacific Ocean, and the deep water of the Pacific Ocean (60-250 m). In both regions (Pacific and Caribbean), low opening trawl nets measuring 18-24 m are used, constructed from 50.8 mm mesh netting and 44.5 mm mesh codends. All trawlers tow two nets side by side. Since 2003, the number of fishing trips has decreased by 74%, and Catch Per Unit of Effort (CPUE) has remained at historic low levels. In addition to these fleets, there is a significant artisanal fleet that is responsible for greater total shrimp landings than the trawl fleet. Similar to many other tropical shrimp fisheries, the Colombian shrimp fishery is characterized by high bycatch, including juvenile fish, and habitat degradations. Shrimp typically comprise around 5% of the catch by weight, incidental catch comprises 43%, and discards comprise the remainder.

As part of the FAO/UNEP/GEF REBYC I project changes to shrimp trawl design were developed and tested. This included replacing PA or PE trawl netting knotless Ultra Cross Spectra and Silver netting. Mesh size in the wings of the trawl was 76.2 mm, in the body it was 57.2, while the extension and codend mesh size was unchanged (Figure 21). A TED and a fisheye (FE) to reduce fish bycatch was also tested. On the same fishing grounds the performance of this trawl was compared against a traditional trawl over 240 paired hauls.

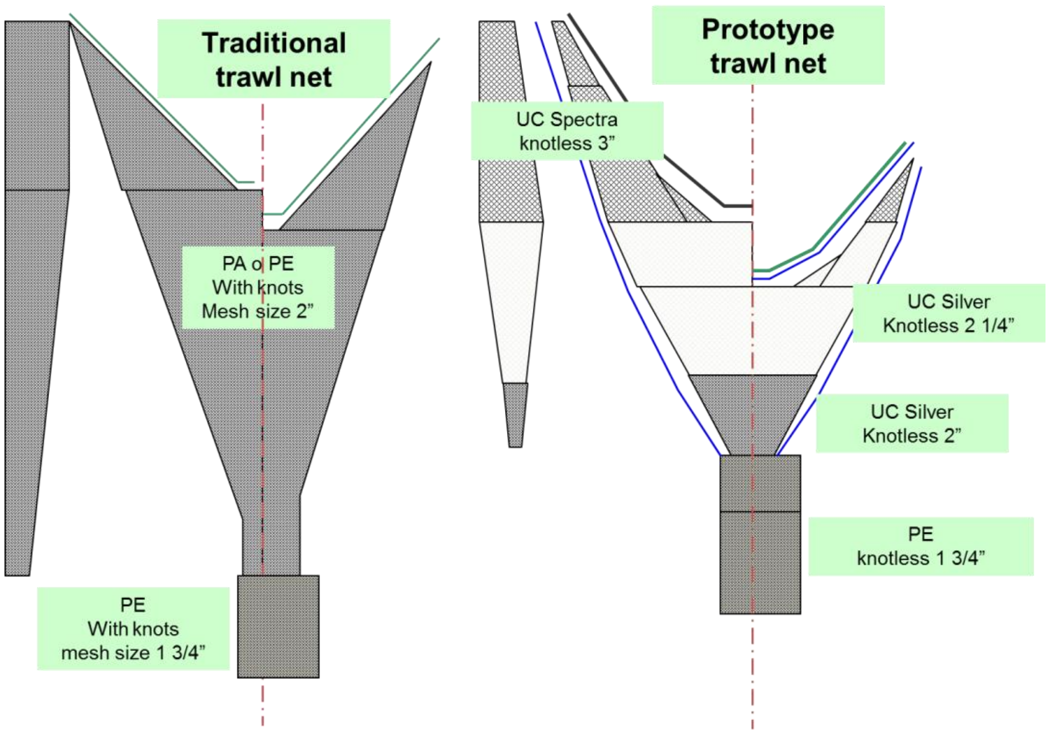


Figure 21. Traditional trawl (left) and the new prototype trawl.

The results indicated the FE reduced shrimp catch by 7% and the TED/FE combination by 12%. The FE and the TED/FE reduced the incidental (valuable) catch by 35% and 78% respectively, and the TED and TED/FE reduced discards by 22% and 59% respectively. A fuel savings of 25% was reported with the new trawl.

While these results are an encouraging start, they have not been implemented by the government. REBYC I project has also contributed significantly to capacity building of industry fishers, while REBYC II is anticipated to explore changes in fisheries management to support changes in fishing gear.

Illuminated area in front of a topless trawl in order to reduce bycatch in shrimp fisheries. (by Haraldur A. Einarsson, Hjalti Karlsson and Einar Hreinsson)

In the Icelandic inshore shrimp fishery, several problems with the existing shrimp grids exist, including: i) juvenile fish are not filtered by grids with bar spacing of 19 mm, ii) the grids sometimes clog with seaweed and shrimp loss occurs, and iii) the grids cannot cope with catch rates commonly around 100-200 kg per minute. In an attempt to overcome these issues a comparative experiment attempted to evaluate the performance of three trawls, a conventional trawl without grid, a conventional trawl with grid, and a conventional trawl modified to a topless design (without grid). Three fishing boats were used in this experiment fishing side by side. Each trawl had identical codends.

The median shrimp catch per hour was highest in the conventional trawl without a grid, although this was influenced by several very large shrimp catches. The median shrimp catch per hour was higher than the conventional trawl with grid, although it caught fewer shrimp across all length ranges. The conventional trawl with grid and the topless trawl retained fewer bycatch species (cod, haddock, pollock, and flatfish) by number compared to the conventional trawl without grid. The conventional trawl with grid tended to retain fewer bycatch species by length, followed by the topless trawl. When white lights were used on a topless trawl, fewer shrimps were retained, but also in most instances the capture of bycatch was reduced by number, compared to when the lights were turned off (Figure 22). This work suggests that use of lights has substantial potential in this fishery to reduce bycatch, and additional work is recommended.

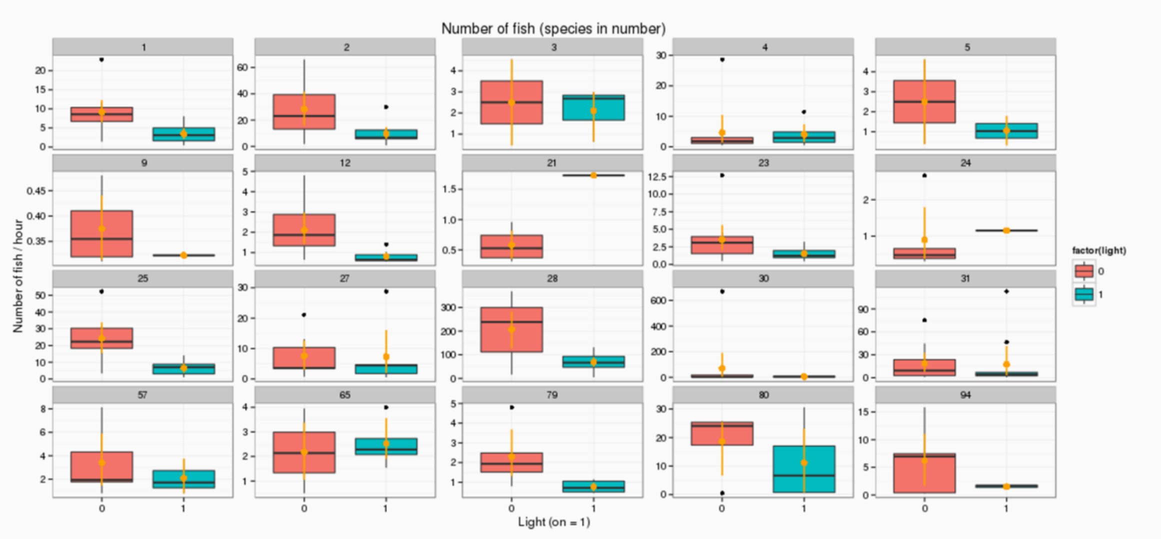


Figure 22. The influence of lights on fish bycatch by tow.

One step beyond: identification of 'improved selectivity' using selectivity experiments and population models for brown shrimp (Crangon crangon) beam trawl fishery in the North Sea (by Daniel Stepputtis, Sebastian Schultz, Claudia Günther, Juan Santos, Jörg Berkenhagen, Marc Hufnagl, Axel Temming, Bent Herrmann, Eckhard Bethke and Thomas Neudecker)

While codend selectivity experiments typically focus on the narrow goals of reducing undersized shrimp discards and reduction of other bycatch, there is a need to evaluate how codend selectivity influences population dynamics of shrimp and other species, and the economics of the fishery. A project known as CRANNET, comprising of staff from the Thunen Instititute of Sea Fisheries, Thunen Institute of Baltic Sea Fisheries, the University of Hamburg, and SINTEF, attempted to overcome this need in the North Sea brown shrimp fishery.

A fishing experiment was completed using a twin beam trawl system to evaluate the selectivity of multiple codend designs to reduce undersized shrimp and other bycatch, including T0, T45, and T90 netting orientation with mesh sizes ranging from 15-36 mm. A total of 270 hauls were completed, and over 541 000 shrimp were measured. Size selectivity was estimated for all codends.

The relationship between L50 and the selection range of each codend type was evaluated. A population model was then used to model the effect of each codend type on landings, discards, population mortality, and egg production. The model permits improvements in annual landings to be predicted based on codend type, growth, natural mortality, fishing effort, and survival after escape from the codend (Figure 23). Commercial trials were then conducted to validate the performance of multiple codend types. T0 26mm, T45 24 mm, and T90 26 mm codends all reduced discards by 17%, 19%, and 27% respectively. Flatfish discards were reduced by 67%, 34%, and 46% respectively.

Using these codends usually resulted in loss of commercial-sized shrimp. By delaying capture of small shrimp, greater landings of shrimp in subsequent months should be realized (Figure 24). The timing of the introduction of a new (selective) codend has substantial impact on total annual landings, as well as predicted payback times. In conclusion, the optimization of codends permits is possible and can realize greater catches, increased number of larger individuals, as well as substantial reduction in bycatch. The timing of the introduction of optimized codends is important and influences payback periods.

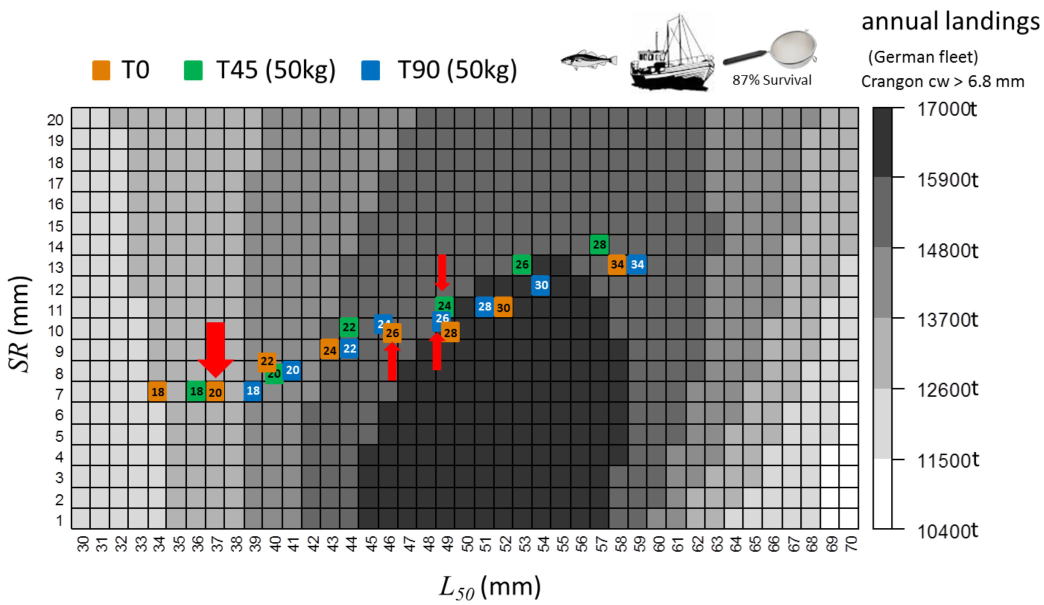


Figure 23. Relationship between selection range and L50 for a range of codends. Modelled annual landings suggest that larger-mesh codends will realize greater yields.

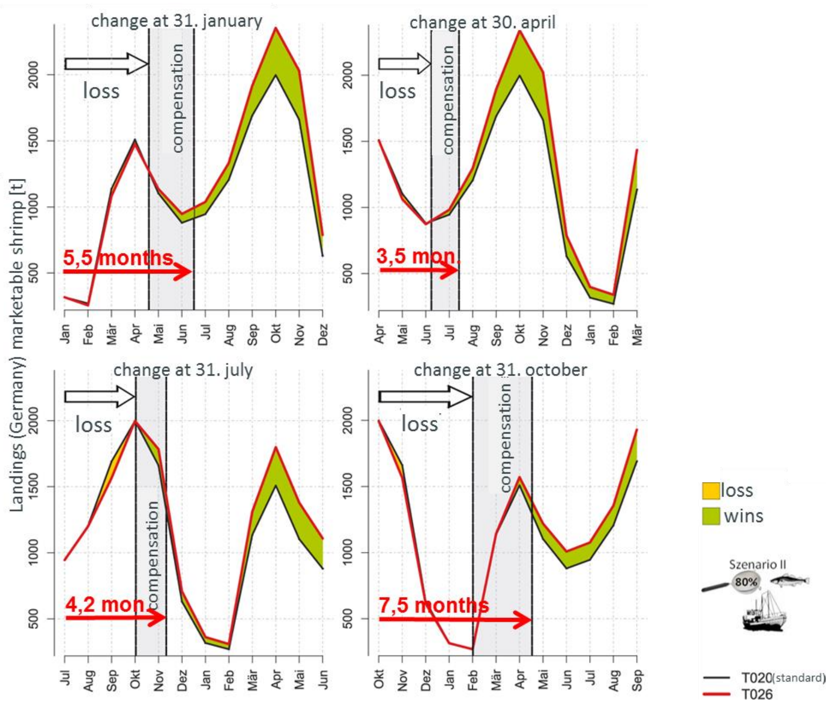


Figure 24. Impact of introducing larger mesh codends and importance of timing on payback periods.

Using fish behaviour to separate fish from Nephrops in a horizontally divided codend in the mixed trawl fishery (by Junita D. Karlsen, Ludvig Krag, Bent Herrmann and Henrik S. Lund)

Nephrops fisheries are challenged by large volumes of unwanted catch including fish species larger than nephrops. The use of large mesh solutions to reduce unwanted fish catches can result in large losses of nephrops and associated income. Subsequently, horizontal panels to divide the trawl or codend into two sections have a history of successful nephrops and fish separation. Nephrops tend to remain close to the seabed and enter the lower codend.

This study attempted to: i) quantify the separation efficiency of nephrops and fish in a horizontally divided codend, and ii) evaluate the potential for improving size selectivity. A nephrops trawl was used in this study, with the codend divided into two horizontal compartments. The upper compartment had a height of 60 cm and the lower a height of 30 cm. The mesh size of each codend was 40 mm square-mesh. The entrance to the lower compartment was fitted with rigid bars. Sea trials were performed from a commercial trawler on fishing grounds in Skagerrak.

Eights species were encountered in this study, Atlantic cod, haddock, hake, saithe, whiting, nephrops, plaice, and witch flounder. Most Atlantic cod, haddock, saithe, and whiting were retained in the upper compartment —54%, 82%, 78% and 63% respectively— while most hake, plaice, witch flounder, and nephrops were retained in the lower compartment —68%, 57%, 61%, and 91% respectively—.

Length-based separation efficiency was evaluated using catch comparison analysis (Figure 25). Large cod had preference for upper compartment, while small whiting had a strong preference for the lower compartment. Haddock and saithe had a preference for the upper compartment for almost all lengths, while plaice and witch flounder of all lengths had a strong preference for the lower compartment. This is the first step toward successful separation of fish from nephrops. Additional work is now required focusing on the lower compartment, including reduction of small fish, especially cod, and all lengths of hake and flatfish. Successful outcomes will help fishers optimize their utilization of quota by avoiding landing of undersized fish, as well as help improve fish quality through separation of fish from nephrops.

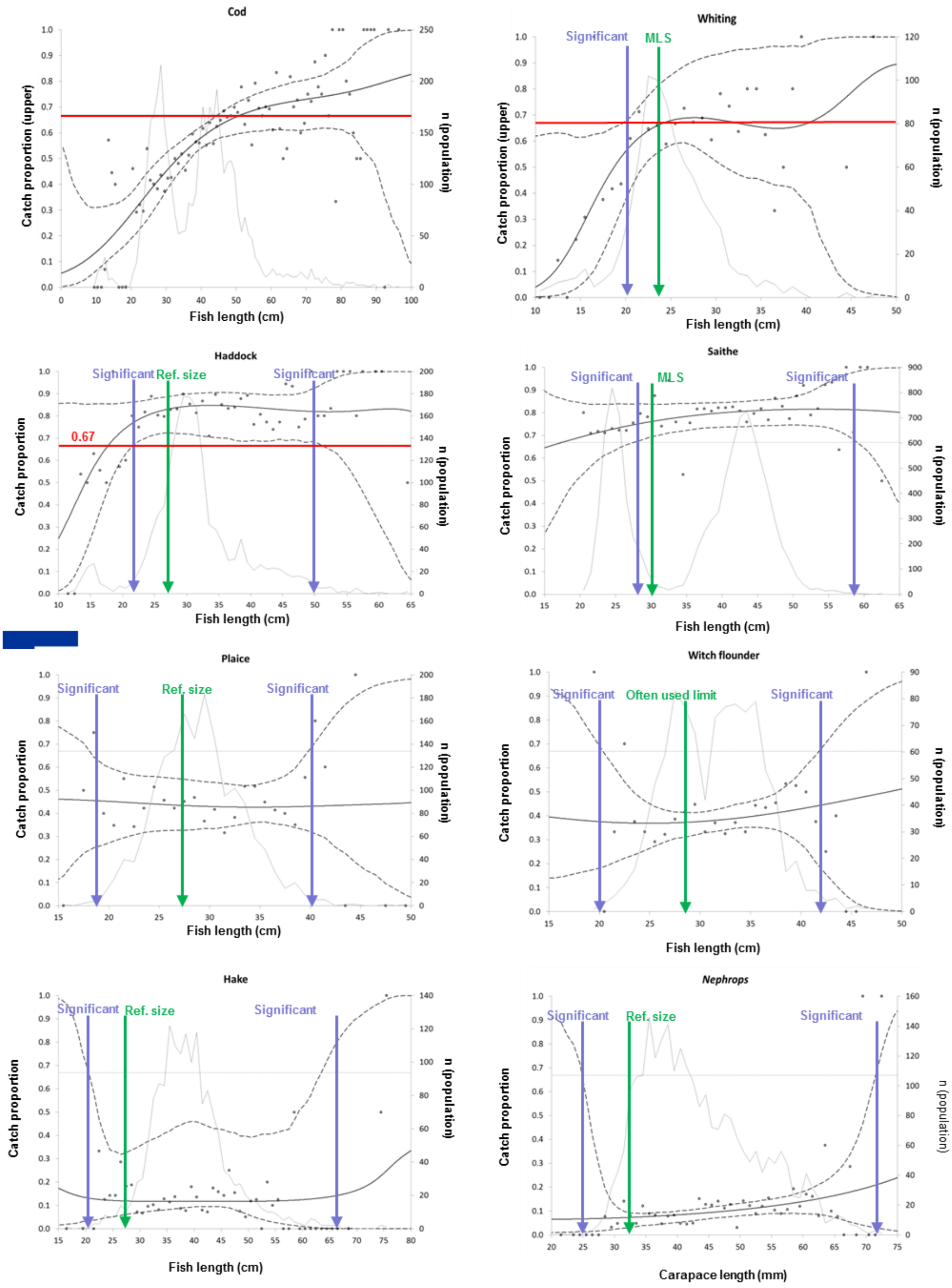


Figure 25. Catch comparison analysis by species.

A global analysis of cetacean bycatch and mitigation measures (by Aimee Leslie, Damon Gannon, Leigh Henry, Rab Nawaz and Heidrun Frisch)

The largest threat to marine mammals is their capture as bycatch in fishing gear (Figure 26). In 2003 it was estimated that 308 000 marine mammal deaths were caused by encounters with fishing gear. A decade later, this issue remains important with bycatch of vaquita, northern Atlantic right whales, and many other threatened species in certain fisheries. A common thread is that gillnet gear are a leading culprit in the mortality of these animals.

Figure 26. Fishing gear is the greatest threat to marine mammal populations.

From August 2016 onwards, seafood exports into the US will be required to satisfy a suite of requirements including marine mammal stock and bycatch assessment, prohibition on killing marine mammals, bycatch reporting and monitoring requirements, bycatch limit calculations, and regulatory programs to reduce bycatch below set limits. In the EU, three recommendations have been made by the Agreement on the Conservation of Small Cetaceans in the Baltic, NE Atlantic, Irish, and North Seas: i) an overarching legislation to protect cetaceans, ii) a management framework designed to reduced cetacean mortality, ultimately to zero, and iii) a risk based regional approach to the revision of Regulation 812/2004. The ICES WGBYC in 2014 concluded that: i) population estimates remain patchy, ii) pinger implementation and monitoring obligations are not being met by all states, iii) a bycatch risk-based approach should be used to classify fisheries in terms of risk to protected species, iv) information provided by many countries is insufficient to determine overall effectiveness of bycatch mitigation, and v) recommended the EC to establish a process of defining limits of acceptable interactions. In response, the EC indicated they did not intend to carry out a comprehensive revision of regulation 812/2004, and that it desires to move away from a central regulation and incorporate elements of the regulation into other regulatory frameworks.

Subsequently, it is felt the EU has a long way to go to provide effective protection for marine mammals. A review of bycatch mitigation methods was one important forward step. The review identified three main sources of cetacean bycatch: spatial and temporal overlap and encounter with fishing gear; scavenging from long lines and traps, and from depredating the catch. Strategies to reduce bycatch include reducing fishing effort, reduce bycatch of other species (that are prey for mammals), and reduce mortality of caught individuals.

Collaborative research between scientists and fishers is essential in all phases of bycatch mitigation research and includes: problem identification; agreement on general approach; proposal for funding; sampling design; testing protocols; sampling; data management; progress reports; analysis and interpretation of data, and; dissemination of results and conclusions. Challenging the bycatch mitigation research efforts are: concerns over target loss; lack of trust; involvement of too many individuals to manage; lack of knowledge; lack of understanding of regulatory framework; impracticality of the solution; lack of enforceability; unintended consequences; human cost; need for long-term commitments; and uncertainty.

Finally, a suite of recommendations was provided (Table 10), hopefully designed to encourage the EU countries and elsewhere to take steps similar to those taken in the US.

Table 10. Proposed recommendations to reduce marine mammal bycatch.

Recommendations	
• Act early, before the situation becomes drastic	• Follow a deliberate, transparent, concensus-based approach to develop a bycatch reduction strategy
• Determine level of urgency. Quantify the magnitude of the problem	• Estimate the efficacy of each proposed action; apply a combination of approaches
• Identify causes of mortality	• Take an adaptive management approach, developing information feedback mechanisms
• Set and agree with all stakeholders clear goals	• Don't allow pursuit of perfection to be the enemy of the good; build trust, and commit long-term

Development of a turtle releasing system (TRS) for set net fisheries (by Daisuke Shiode, Maika Shiozawa, Keiichi Uchida, Seiji Akiyama, Yoshinori Miyamoto, Fuxiang Hu, Tadashi Tokai and Yoshio Hirai).

Set net gear is a major and important coastal fishery in Japan. While many set nets can be classified as 'open' where the roof of the set net is open, others are 'closed'. The 'open' set nets allow sea turtles to breathe and fishermen can relatively easily facilitate their escape from the gear. A project was established to explore the potential of installing a sea turtle releasing device in a set net.

Initially consideration was given to installing a device similar to TEDs used in trawl fisheries. However, because this device relies upon sea turtles encountering the device to escape, in a large set net this was considered not a viable option due to low expected encounter probability.

Observations in a holding tank identified 'pushing up' behavior as sea turtles attempting to push past the netting in the set net and reach the surface (Figure 27). Subsequently, a sloping roof in the bag net (the section of set net that retains fish and is hauled onboard) was tested that exploits pushing up behavior and releases turtles through a Turtle Releasing Device (TRD). In a large aquarium, the behavior of loggerhead turtles was observed and recorded in response to a traditional box-shaped bag net (control), a bag net with a 10 degree sloping roof, and another with a 20 degree sloping roof.

This was followed by sea trials using the 20 degree sloping roof, which was deemed the most likely to permit escape of sea turtles. Observations of sea turtles indicated this modification was successful. To prevent fish escape the TRD was designed with a netting flap over the 2m x 2m escape opening. The flap was fitted with stainless steel rods around the perimeter to add weight to the flap and ensure a tight seal to prevent fish loss.

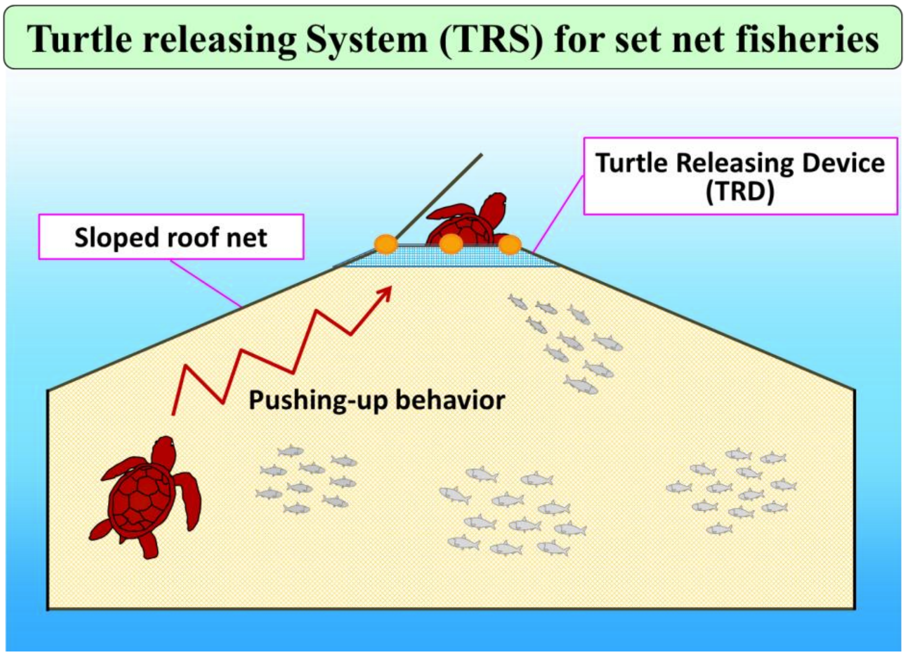


Figure 27. The sea turtle releasing system (TRS).

Avoidance of Atlantic cod with a topless trawl in the New England groundfish fishery (by Michael Pol and Steve Eayrs)

Atlantic cod stocks in New England have reached historic lows and cod quotas have been slashed in recent years. There is growing interest in the use of a topless trawl to reduce bycatch of cod, while targeting yellowtail founder and other flatfish (Figure 28). The premise is that the longer headrope allows cod an opportunity to rise over the approaching trawl while flatfish enter the trawl and are retained.

A research experiment in the Gulf of Maine attempted to evaluate the performance of a topless trawl against a traditional flatfish trawl (control). Both trawls were tested in an alternating hauls towed over the same location and in the same direction. A total of 30 haul pairs were completed over 10 days. The total catch was sampled.

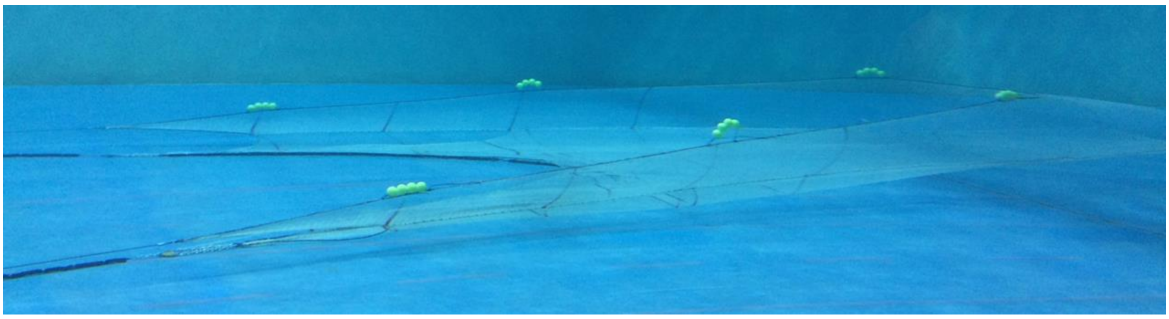


Figure 28. Scale model of the topless trawl in a flume tank.

The topless trawl reduced the cod catch by 51% and there was no significant difference between cod length in both trawls (Table 11). Equal catch plot analysis found only 7 haul pairs were the cod catch was greater in the topless trawl (Figure 29). No reduction was found in the catch rate of yellowtail flounder, and there was no significant difference in fish length in both trawls. Equal catch plot analysis indicated no bias in the yellowtail flounder catch by trawl type. There was a significant 25% reduction in American plaice in the topless trawl, although this was due to a reduction in catches of sublegal fish, and a non-significant 11% reduction in grey sole.

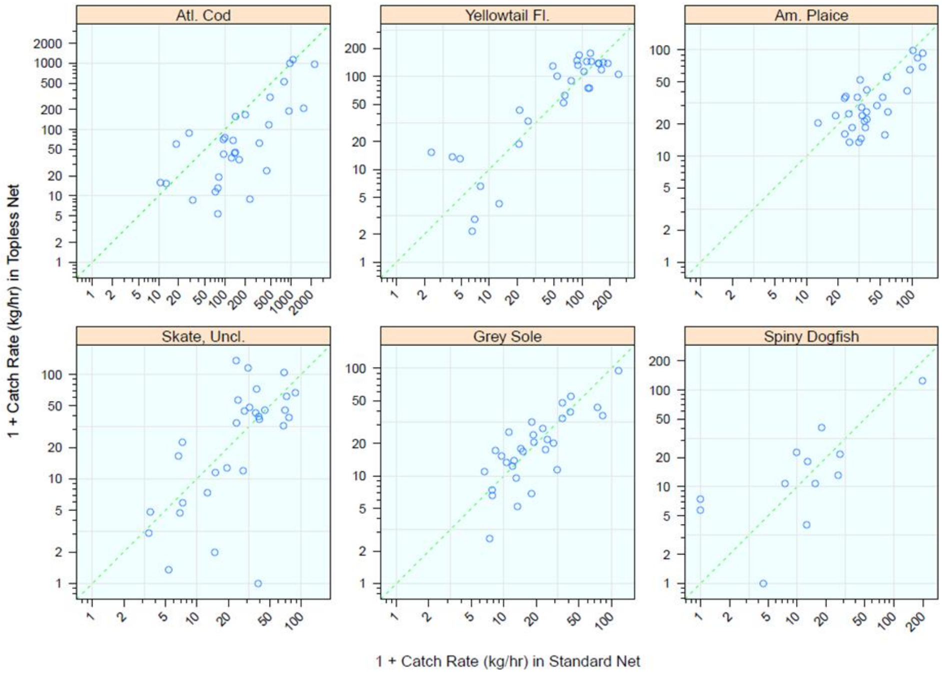


Figure 29. Equal catch plots of dominant species in the catch.

Table 11. Summary of catch results.

Species	**Average catch rate (kg/hr)**		**Statistic**					
	Std	**Topless**	**Diff. (%)**	**df**	**t-stat**	**p-value**	**var**	**Hypoth**
Atl. cod	374.4	182.1	51.4	29	3.0166	0.003	unequal	S>T
Yellowtail fl.	81.5	83.4	-2.3	29	-0.241	0.812	equal	S=T
Am. plaice	48.8	35.7	25.4	29	3.76	0.001	equal	S=T
Sp. Dog	26.7	22.3	19.9	11	0.6781	0.511	equal	S=T
Skates	31.5	36.3	-19.4	29	-0.848	0.4034	equal	S=T
Grey Sole	25.2	22.4	11.1	29	1.1337	0.2662	equal	S=T

It was posited that the success of this trawl was due to the headrope measuring 71% longer than the footrope. This is 20% longer than previous topless trawl studies in the fishery, all of which were unable to successfully exclude cod and retain flatfish. The layback distance between the headrope bosom and footrope bosom was 9.2 m, and at a towing speed of 2.8 kts, all but the smallest cod can generate the speed necessary to escape over the headrope. This use of additional flotation (28% more than previous studies), especially along the wings, is thought to have contributed to superior retention of flatfish.

Be Flexible; a simple and cheap flatfish BRD concept for roundfish trawl fisheries (by Juan Santos, Bernd Mieske and Daniel Stepputtis)

The EU landing obligation prevents the discard of fish at sea; however, trawl codends are often designed to exclude a small number of species, such as small cod, but are poorly selective for flatfish. A recent approach has been the development of FRESWIND, comprising a grid arrangement for fish to swim laterally from the trawl extension and a deflector anterior of the device to guide fish laterally towards the grids (Figure 30). Sea trials with this device have reported flounder and plaice reductions of 61% and 56 % respectively, 31% reduction in undersized cod, and a 9% reduction in marketable cod. While the results were promising, using the device came at substantial financial cost, took time to install, and was large and rigid.

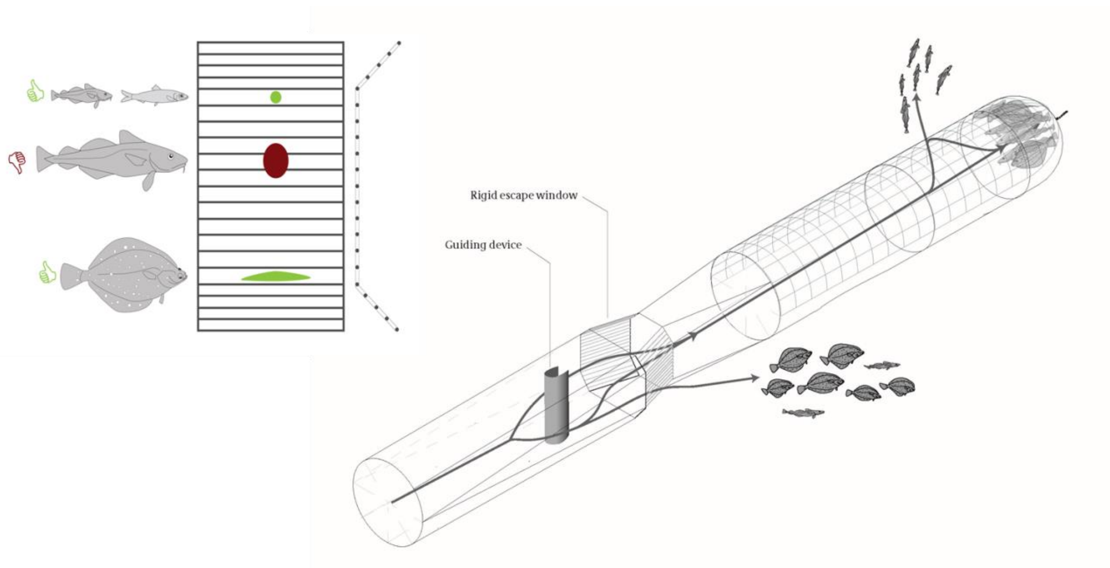


Figure 30. The FRESWIND flatfish excluder.

Another option was the FLEX, an escape opening in the bottom of the trawl extension for flatfish escape lined with rigid steel rods. Following further modification, including a panel (net shield) lined with small floats above and adjacent the escape opening, to help guide flatfish toward the escape opening (Figure 31), flounder and plaice reductions of 72% and 79% were recorded, plus a 14% reduction in undersized cod and a 6% reduction in marketable cod. To overcome cod losses, the FLEX escape opening was modified in shape and several horizontal tension threads inserted to physically prevent the escape of cod (Figure 32). The results were as follows:

- The rectangular frame with threads spaced 80 mm was superior in terms of flatfish reduction and loss of cod. It reduced plaice by 88%, flounder by 90%, and there was no significant reduction in cod.
- The rectangular frame with threads spaced 40 mm resulted in a 83% reduction in plaice, 73% reduction in flounder, but no significant reduction in cod.

- The curved frame with threads spaced 40 mm apart resulted in a 30% reduction in plaice, 45% reduction in flounder, but no significant reduction in cod.
- The curved frame with threads spaced 40 mm apart resulted in a 75% reduction in plaice, 85% reduction in flounder, but no significant reduction in cod.

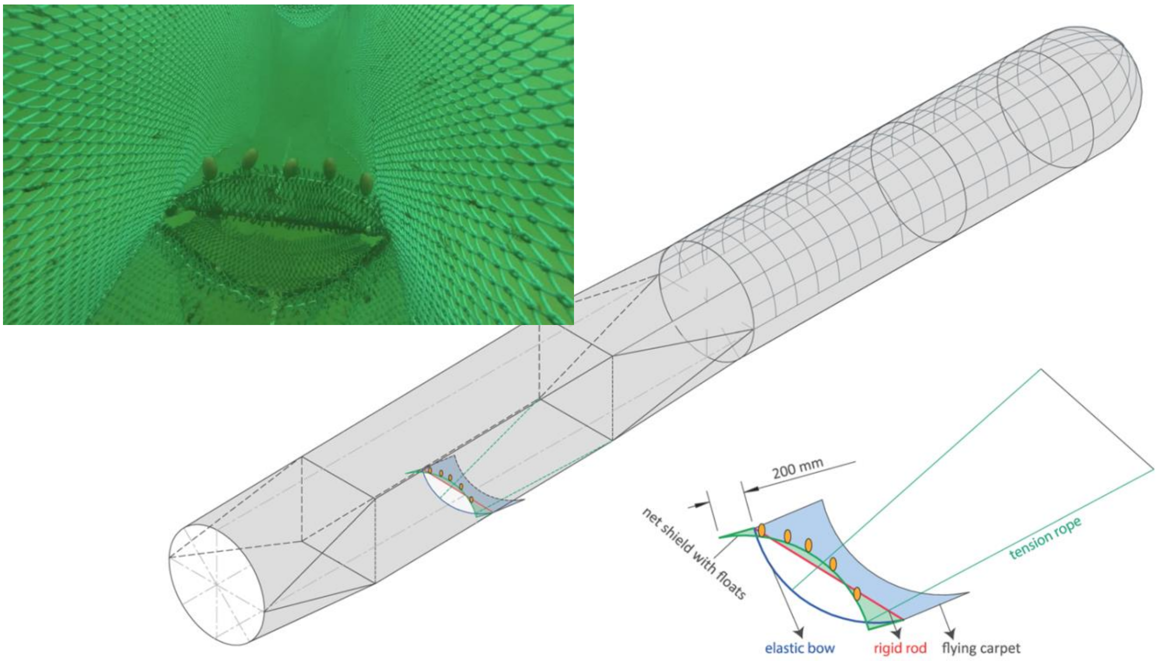


Figure 31. FLEX flatfish excluder.

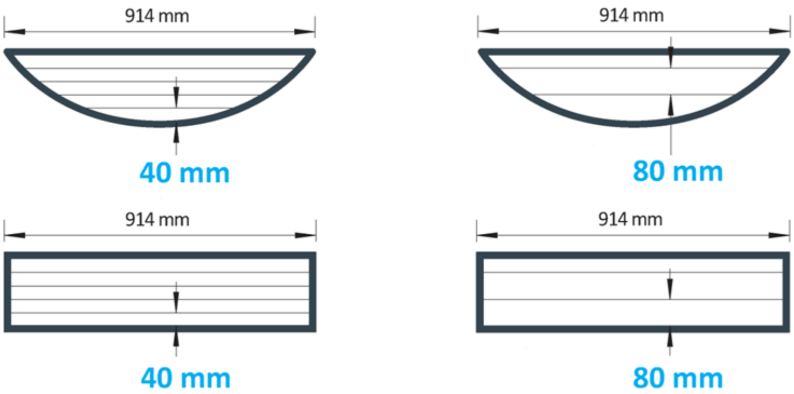


Figure 32. The four FLEX designs tested.

Trials and tribulations of halibut bycatch reduction in Alaska's Bering Sea trawl fleet (by Carwyn Hammond Flatfish survival assessment carried out in 2014–2015)

In the Bering Sea trawl fleet, bycatch of halibut, salmon, and crab are substantial issues, in part because they are targeted by other users using other gears, they are considered Prohibited Species Catch (PSC) and therefore must be returned to the sea immediately, and because bycatch is monitored and when it reaches a threshold trawlers must stop fishing. In recent years the bycatch allocation of halibut for the bottom and pelagic trawl sectors was reduced by 25%.

Halibut excluders have been tested with some success. One such excluder consisted of a grate of narrow horizontal slots fitted in the sides of the net to allow halibut to escape but not cod. This device reduced up to 86% of halibut and 11% of cod, most of which were small, unmarketable individuals. Additional tests involved constructing the grate from scrap coaxial cable, and halibut was reduced by 57% and 35% reduction in cod. To date, one manufacturer has built over 70 of these devices.

Rigid grates have also been tried for excluding halibut, but many small boats could not haul the grate around the net drum. Recently a new design of halibut excluder has been developed (Figure 33). It consists of a large square mesh tunnel (cylinder) of netting inside the extension/codend through which target species swim and are retained in the codend. Halibut, however, cannot pass through the selection tunnel and are guided to an escape opening. The mesh size of the tunnel ranges from 140 mm to 178 mm depending on target species. Many fishermen have adopted this device, which costs around USD 30 000 and measures around 27.5 m long. It is challenging to repair at sea, and some fishers claim a catch loss of up to 30%. Subsequent tests of this device in the pollock pelagic trawl fishery were unsuccessful due to high catch loss.

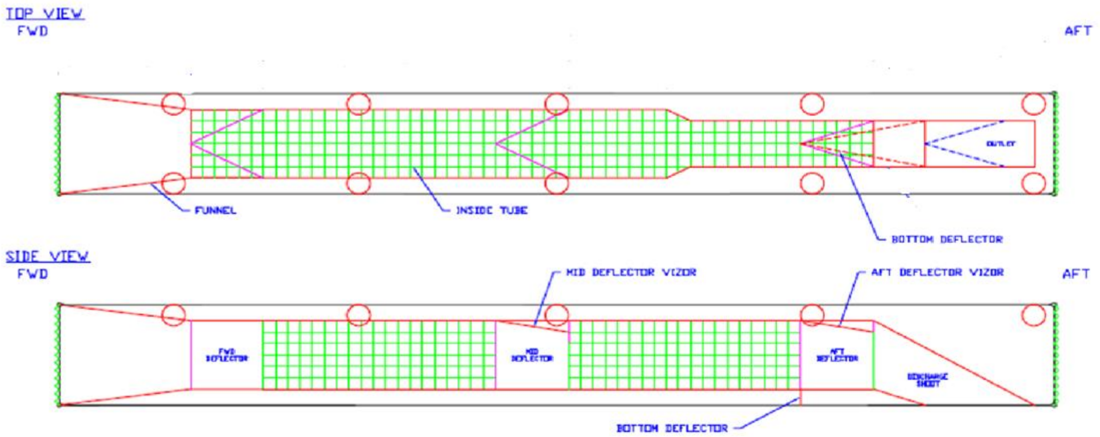


Figure 33. The Halibut excluder.

In 2015, new versions of the halibut excluder were tested. Several modifications were tested, including removal of deflector panels, adjustment of deflector panels, and lightening tunnel mesh. This work is ongoing and final results are not yet available. Additional consideration is now being given to focusing on halibut exclusion from fisheries that target flatfish. Still, cooperation and persistence is key to maintaining industry enthusiasm and ultimately reach a successful outcome.

Flatfish survival assessment carried out in 2014–2015 (by Pieke Molenaar)

In the Dutch trawl fishery large volumes of flatfish are discarded at sea. The EU discard landing obligation is coming into force stepwise, with retention of sole entering into force in 2016, plaice in 2018, and dab in 2019. Currently all discards for the purposes of stock assessment are assumed to suffer 100% mortality.

In 2004–2005 an attempt was made to estimate the survival of flatfish discards. This attempt suffered from poor experimental design, including lack of control fish, inadequate filtration (waste from one tank flowed into the next), and high mortality. Recently a new holding tank arrangement has been developed, consisting of multiple holding chambers each with an independent temperature controlled water supply (Figure 34). It is capable of relocation from vessel to lab via forklift and truck, with ongoing water circulation or adequate oxygen. It is also designed to minimize fish disturbance, and includes sound and light insulation. Overall this holding tank weights approximately 800 kg and measures 1520 mm long x 1570 mm high x 595 mm wide.

Figure 34. The new flatfish holding tank arrangement comprised of multiple holding chambers.

At sea, the codend is emptied into a hopper. Fish are guided to a conveyor belt and then on to a sorting belt where valuable fish are sorted from the discards. To evaluate survival fish were collected from the hopper, the beginning of the sorting belt, and 15 minutes after removal from the sorting belt. Individual fish from each stage of the processing line were placed in holding chambers in the holding tank. Control fish were also placed in holding chambers.

Species specific survival was then evaluated for fish caught using a pulse trawl and a twin trawl. Control fish had higher survival compared to landed fish, irrespective of collection location in the processing line, although for plaice the mortality rate of control fish increased after 5 days (Figure 35). For many species, mortality rates plateaued after 5–10 days, and was usually highest for fish collected at the end of the sorting belt. The survival rate of fish caught using the twin trawl was generally lower than that for fish caught using the pulse trawl, irrespective of collection location in the processing line (Table 12). This holding tank is a significant improvement over previous designs, however some questions remain, such as why control plaice suffered high mortality soon after transport to the laboratory.

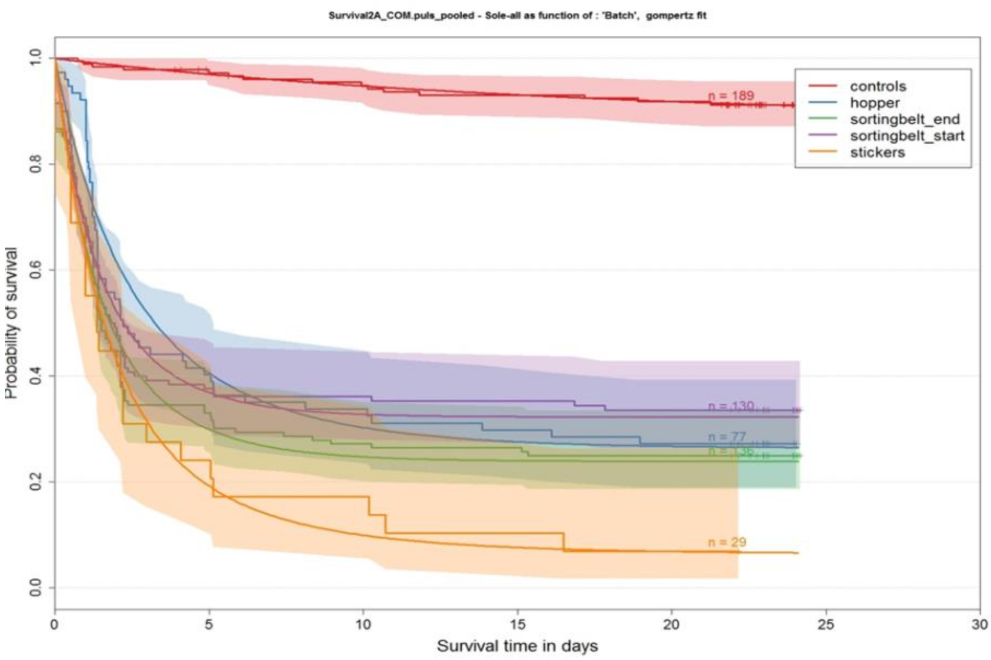


Figure 35. Survival of sole following capture in the pulse trawl. Shaded regions represent 95% confidence intervals.

Table 12. Summary results comparing survival of fish caught by pulse trawl and twin rig. Com – commercial haul.

Gear	Species	N-trips	Haul type	Survival		
				min %	**max %**	**mean %**
Pulse	SOL	6	com	8.3	48.1	**30.8**
		2	short	23.8	58.8	**41.3**
	PLE	7	com	3.7	28.0	**15.9**
		2	short	6.7	39.2	**22.9**
	DAB	1	com	-	-	**15.0**
Twin rig	PLE	2	com	4.6	15.8	**10.2**
	DAB	1	com	-	-	**8.0**

Effects of environmental variables on bycatch rates of Acanthocybium solandri in waters near Cook Islands (by Liming Song, Zhihui Zheng, Kai Xie and Hailong Zhao)

In pelagic longline fisheries in the South Pacific Ocean, wahoo bycatch can be a significant issue. There is limited evidence suggesting a relationship between the bycatch of wahoo and environmental variables. This study attempted to evaluate the relationship between Wahoo distribution and sea surface temperature, chlorophyll-*a*, and distribution of prey species. This information could then be used to propose appropriate mitigation measures.

Commercial fishing activity took place in the general vicinity of the Cook Islands. During September and November 2012 a total of 11 wahoo were caught. Additional data collection including deployment position and soaking time of the longline, depth of hook that caught the wahoo, number of hooks fished, and temperature, salinity and chlorophyll-*a* concentration.

To evaluate hook depth, temperature depth recorders were affixed a total of 303 hooks. A hook depth prediction model was then built:

$$\overline{D_x} = 1.374 D_x \times x^{-0.170} \times (\sin Q_w)^{0.124} \times (V_w)^{-0.116}, (n = 303, r = 0.59)$$

Where Dx = theoretical hook depth, x = hook number, Qw = angle between longline and wind direction, and Vw = wind velocity. The bycatch rate of wahoo was found to be greatest in shallow waters and high water temperatures (Figure 36). They also preferred a salinity range of 36.3–36.9 ppm and chlorophyll-*a* range of 0.07–0.24 µg/L.

The results of this study suggest pelagic longlines should be set at deeper depths to reduce wahoo bycatch, and at cooler water temperatures. Further work is necessary to evaluate the influence of ocean currents, thermocline depth, availability of plankton and food source on wahoo distribution.

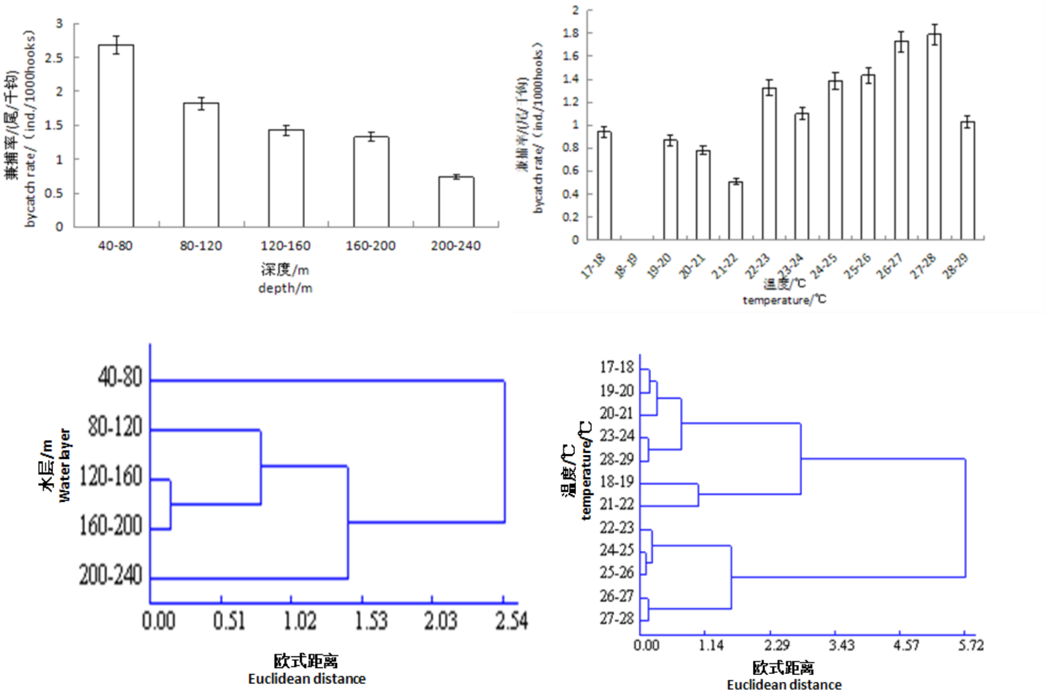


Figure 36. Wahoo catch rates by depth (upper left) and water temperature (upper right), and hierarchical cluster analysis of wahoo catch rates by depth (lower left) and water temperature (lower right).

Sustainable management of bycatch in Latin America and Caribbean trawl fisheries – transforming wasted resources into a sustainable future (by Petri Suuronen and Carlos Fuentevilla)

In the average tropical shrimp fishery the quantity of bycatch is between 3 and 15 times higher than the catch of target species (Figure 37). To address this issue, FAO has a global program that includes projects in Central and South America (REBYC-II LAC) and Southeast Asia (REBYC-II CTI). These projects built on the success of REBYC-I; Reduction of bycatch in tropical shrimp trawling, from 2002–2008. The success of this first project was uneven, so a more holistic approach was being adopted in the REBYC II projects, which included technology and governance and management of these fisheries, accounting for social-economic considerations, including food security, as well as potential for bycatch utilization.

Project countries include Brazil, Colombia, Costa Rica, Mexico, Suriname, and Trinidad and Tobago, and project partners include the private sector, regional fisheries organizations (i.e. the Western Central Atlantic Fishery Commission and the Caribbean Regional Fisheries Mechanism), NGOs, universities and research institutes. In additional to bycatch reduction, this project aims to improve employment opportunities and livelihoods, and contribute to regional food security, in part through improved stock productivity and reduced operational costs. Project challenges are poor/uneven management across the region, complex government environments, and limited understanding of the role of bycatch in terms of its impact on food security and ecosystem health.

Figure 37. Bycatch typically dominates the catch in tropical shrimp trawl fisheries. Source. S. Eayrs.

A core component of this project is motivating change and understanding critical barriers to responsible fishing including: understanding need-based incentives; ensuring effective engagement; introducing practical and cost-effective solutions; and effecting enhanced compliance.

The project is divided into multiple components. Component 1 is a review of normative frameworks to set the scene for co-management of stocks. This includes improved institutional and regulatory arrangements, review of legislative frameworks and gap identification, development of bycatch management plans and agreement of co-management frameworks. Component 2 focused on introduction of responsible fishing practices, and related activities include baseline bycatch data collection, introduction of measures designed to reduce bycatch, testing of incentives, evaluation of market-based measures, and capacity development. Component 4 is focused on livelihoods, food and nutrition security, and gender balance. Activities include evaluation of the role of bycatch in food security and livelihoods, evaluation of alternative income generating opportunities, and exploring opportunities to overcome gender imbalance. Component 4 aimed at sharing and outreach of project outcomes to fishers, communities, countries, and other regions. Collectively, it is hoped this project transforms current food losses and wasted into a sustainable future that provides for multiple long-term and wide-ranging regional benefits.

Underwater observations of fish behavior related to bottom trawl codend in the Mediterranean
(by Chryssi Mytilineou, Chris Smith, Caterina Stamouli and Persefoni Megalophonou)

The Mediterranean bottom trawl fishery can be characterized by the capture of up to 280 species of which only a small number (~20%) are target species, including hake, mullets, shrimp, nephrops, and squid. Recent research suggests that 42 fish stocks are overexploited; annual landings of one species of hake is 19 times greater than MSY. This fishery is managed by a suite of efforts controls (licence limitation, gross tonnage restrictions, and closed areas) as well as minimum landing sizes, and mesh size and configuration restrictions. However, an estimate 13–26% of the catch is discarded, and evidence suggests most discards do not survive.

The objective of this study was to identify the characteristics of fish behaviour that could lead to the optimization of trawl selectivity. The selectivity of three codend mesh sizes, 40 mm diamond, 40 mm square, and 50 mm diamond were evaluated using a covered codend method. GoPro cameras were used to observe fish behavior.

These observations were useful to identify that the codends and cover were performing as anticipated and to observe fish behavior. A total of 69 hauls were evaluated. Overall the catch comprised 60 taxa, dominated by teleost species; the total number of taxa in each codend ranged between 43 to 47 taxa (Table 13). Few elasmobranchs and crustaceans were recorded in the cover. The cameras were useful to help categorize fish behavior in the codend (Table 14).

Table 13. Fish catch by codend type**.**

	CODEND			COVER		
	40D	**40S**	**50D**	**40D**	**40S**	**50D**
Osteichthyes	**26**	**29**	**32**	**11**	**20**	**17**
Ammodytidae	x			x		
Argentina sp.		x				
Boops boops	x	x	x	x	x	x
Blennius ocellaris	x	x	x	x		x
Conger conger	x	x	x			x
Cepola macrophthalma	x	x	x	x	x	
Pleuronectiformes	x	x	x	x	x	x
Diplodus sargus			x			
Dentex sp.	x	x	x		x	x
Dentex dentex			x			
Dentex gibbosus		x	x			
Engraulis encrasicolus	x	x	x	x	x	x
Triglidae	x	x	x		x	
Echelus myrus	x	x	x		x	x
Gadiculus argenteus argenteus			x	x		x
Gobiidae			x			
Helicolenus dactylopterus		x	x			
Lophius budegassa	x	x	x		x	
Lepidopus caudatus	x	x				
Mullus barbatus	x	x	x	x	x	x
Mullus surmuletus	x	x	x		x	x
Merluccius merluccius	x	x	x		x	
Micromesistious poutassou	x		x		x	
Macroramphosus scolopax			x		x	x
Pagellus spp.	x	x	x		x	x
Pagrus sp.			x			
Serranus cabrilla	x	x	x		x	x
Serranus hepatus	x	x	x	x	x	x
Spicara spp.	x	x	x	x	x	x
Synodus saurus	x					
Scorpaena spp.	x	x	x			
Spondyliosoma cantharus			x			
S. pilchardus		x			x	x
Trachinus spp.	x	x	x		x	
Trachurus trachurus	x	x	x	x	x	x
Uranoscopus scaber	x	x	x			
Zeus faber	x	x	x			
Caranx rhonchus		x				
Muraena helena		x				

Table 14. Categorization of fish behavior in the codend.

ACTIVITY /AREA	Swimming vigorously forward	Moderate swimming forward	Moderate swimming around	Walking around	Motionless (occasionally in net's wrinkles)
Upper	Ammodytidae *E. encrasicolus* *S. pilchardus* *Argentina sp.*	*C. ronchus*	*C. macrophthalma*		
Middle	*B. boops* *Dentex sp.* *D. dentex* *D. gibbosus* *D. sargus* *Pagellus spp.* *S. cantharus* *P. pagrus* *Mullus spp.* *Spicara spp.* *Trachurus spp.* *Mustelus sp.* *S. blainville*	*G. arg.argenteus* *S. officinalis*			
Bottom	*S. canicula*	*Blennius sp.* *H. dactylopterus* *M. scolopax* *Scorpaena spp.* *S. cabrilla* *S. hepatus* *S. saurus* *Trachinus spp.*	Triglidae *C. conger* *E. myrus* *M. helena* *D. pastinaca* Rajiidae	Triglidae C. granulata *L. depurator*	Gobiidae Pleuronectiformes *Scorpaena spp.* *H. dactylopterus* *Trachinus spp.* *U. scaber* *S. canicula* *T. torpedo* *T. marmorata* *L. depurator* *S. cabrilla* *S. hepatus* *O. vulgaris* *Eledone spp.* *N. norvegicus*

General discussion of the session 4

A question was asked about the use of grids and the influence of rigging on water flow in the codend and how this might affect codend and grid selectivity. This is a complicated matter. Bar size is known to influence drag and water movement, which some fish catch utilize and it may facilitate escape of other species. Square or round cross section bars have an inconclusive impact on fishing performance.

A point was raised that most of the research by the Working Group is focused on fish bycatch, but does not include benthic invertebrate species. A call was made that the Working Group should expand research to include these species.

Another question raised related to the ban of pelagic trawls in Norway. An explanation was that this gear was responsible for large catches of juvenile fish, most of which were discarded at sea.

SESSION 5: Innovative Technologies for Observing Fish and Fishing Gear

A review of technologies for observing fish and fishing gear underwater (by Barry O'Neill)

Why do we observe fish and fishing gear underwater? The answer is we do it to understand how the fish capture process influences the biological, economic, and environmental sustainability of fisheries. To do this we need to understand catchability, selectivity, fish survival, fuel efficiency, and benthic impact. This means we need to understand fishing gear design and engineering performance.

To achieve this understanding a variety of instruments, testing facilities, equipment, and techniques are used (Figure 38).

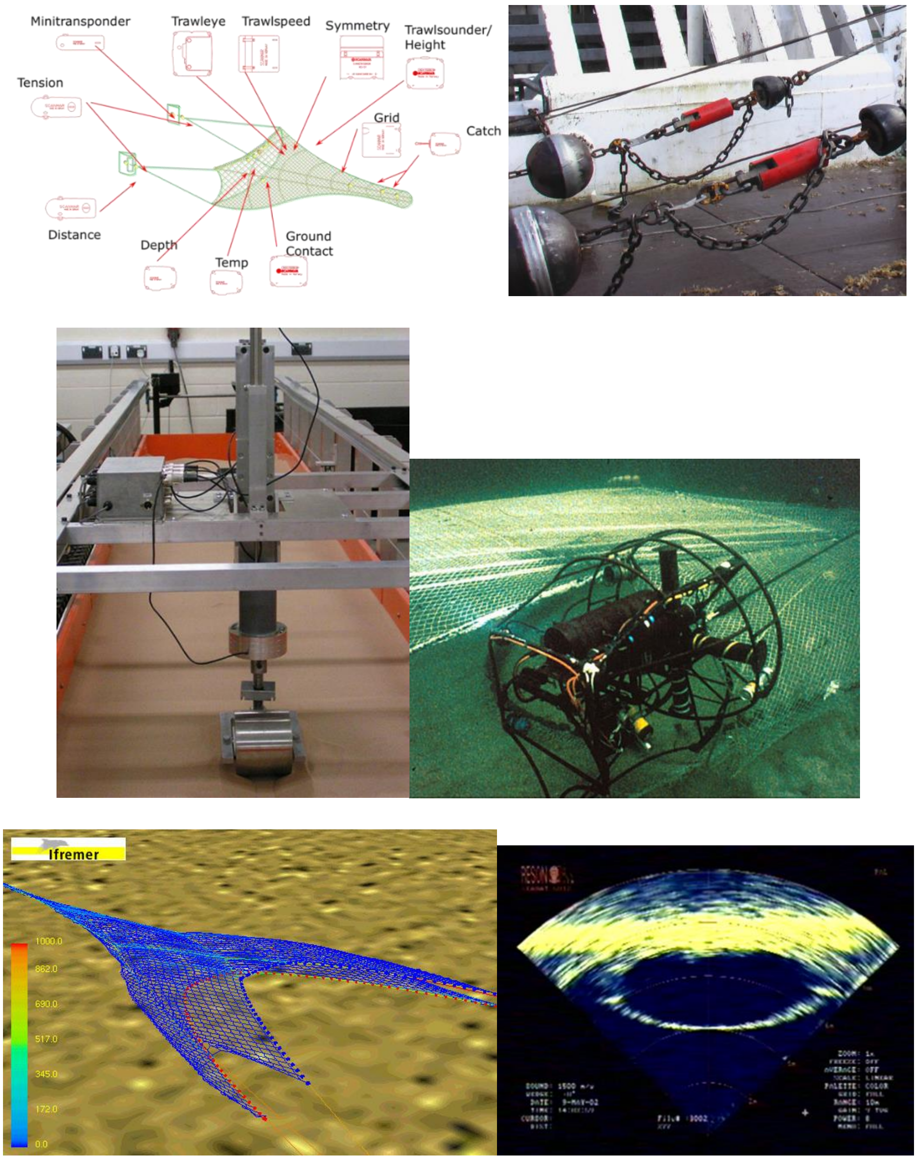


Figure 38. A plethora of instruments and techniques are available to evaluate fishing gear performance including (from top left to bottom right) trawl mensuration sensors, load cells, sand channels to measure resistance, towed manned vehicles, numerical modelling, and acoustic measurement.

We can test fishing gear performance in flume tanks, or towing tanks, or even sand channels. We can observer gear in situ using net mount camera, seabed mounted frames, remotely controlled vehicles, or towed vehicles, or we can use acoustic techniques to measure gear parameters, fish behaviour, and seabed impact. In the laboratory we can house fish in tanks to measure behaviour to gear components and swimming performance, or we investigate fish physiology including visual and acoustic acuity, and muscle contraction times. Increasingly we can use numerical modelling and simulations to evaluate gear performance, or comparative full-scale trials at sea. To analyze these data we have a variety of options and techniques available.

So, "to do everything we do" we have a plethora of options and techniques available to us. We also rely on the expertise of individuals with skills in a variety of disciplines, from netmakers to fishermen to gear technologists to mechanical engineers to statisticians. However, the real success of our work lies where each of these categories or discipline areas interact, and where they are combined to produce a successful outcome.

A case study of this interaction involves the application of light to further refine the performance of horizontal separators in trawls. While light has a long history of use with static gears its use in active gears is relatively rare. An evaluation of separator trawl performance confirms that as separator panel height increases, a higher proportion of cod are retained in the lower codend. Many other species, such as haddock, whiting, saithe, and plaice behave similar in response to increased panel height. Consideration was given to illuminating the leading edge of the separator panel using fibre optic cable. Results found that when lights were on more fish entered the lower codend, although the results were not that dramatic. Another experiment attempted to put lights on a grid to improve species separation (Figure 39). With lights on, a greater proportion of fish entered the lower codend. This work incorporated multiple categories and disciplines, such as instrumented trials, visual observations, comparative trials, and statistics.

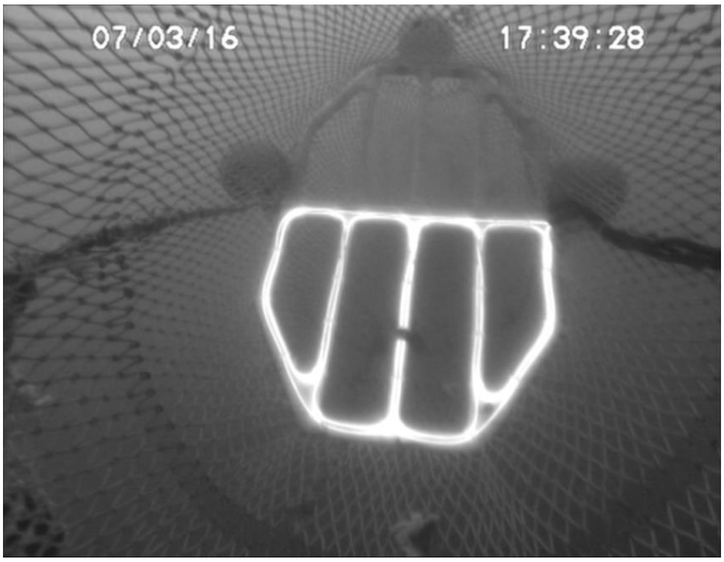


Figure 39. The use of lights to illuminate a grid.

Another case study was an effort to quantify the hydrodynamic and physical impact of towed gears on the seabed. Using specialized sleds fitted with short groundgear sections and instrumentation, the drag and turbulence of groundgear components could be evaluated. Full scale and model tests allow the physical impact of gear components on different types of sediments could be evaluated. Overall, this work incorporated instrumented trials, flume, towing, and sand channel tests, visual observations, numerical modelling, comparative trials, and statistics.

The effect of sea state on fishing gear can be evaluated using instrumented trials, both at sea or in the flume tank, which require visual observations, fishing trials, and statistics.

In conclusion, this presentation was in effect a comment on how we do the things we do. A wide range of technologies and expertise is required to do what we do, and their interaction and interplay is essential.

Automated images processing a tool for better understanding of fish escape behaviour (by Julien Simon, Benoît Vincent, Sonia Mehault, Dorothee Kopp, Pascal Larnaud, Mariane Robert, Fabien Morandeau and Jean Philippe Vacherot)

To reduce discards in trawl fisheries a common approach is to use underwater video cameras to observe fish behaviour and net geometry to understand the escape behaviour of fish. While substantial progress has been made in recent years in terms of image quality, frame rate, battery life, data storage, and miniaturization, the fact remains that many hours of video are produced that requires considerable processing time. This is also a tedious process that tends to produce qualitative data and little quantitative data. Therefore, a need exists to develop suitable post processing systems to overcome these limitations.

IFREMER have been working on a post processing system that effectively counts fish by comparing video images with fish and without fish to count their presence and trajectory. To test this system, a camera system filming at the rate of 50 frames per second along with 2 LED lights with a wavelength of 660 nm was used to film fish escape from a square-mesh panel. By collecting footage during a haul, the time when individual fish escaped from the panel can be recorded, as can their trajectory after escape (Figure 40). This approach has been found to improve the precision of fish counts compared to manual (human) counts, although it can be challenged with multiple fish are behind one another. Future work includes improving software detection of fish, the addition of another camera to facilitate fish measurement and 3D tracking, and to test the software counting fish ingress and behavior around pots.

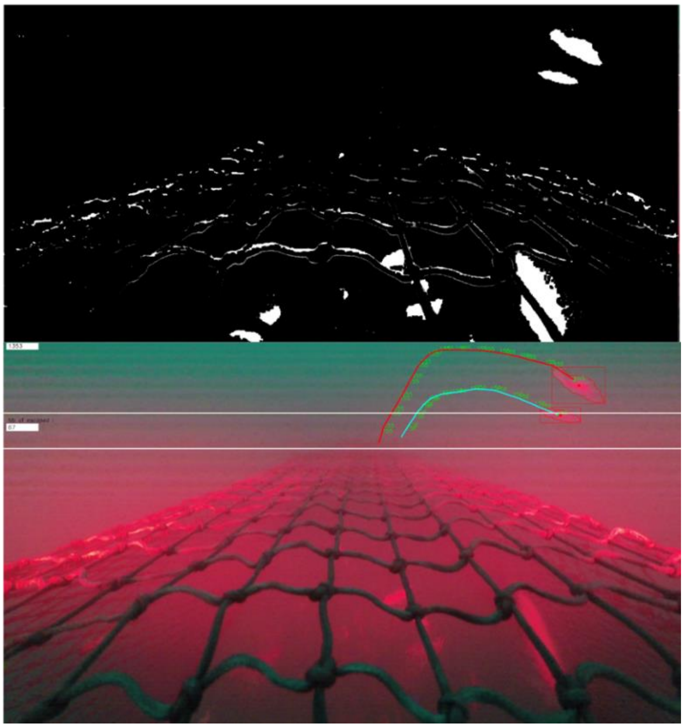


Figure 40. Underwater video of fish escaping a square-mesh panel (below), and the same video following post-processing (upper). Two escaped fish can clearly be seen.

Field measurement of sinking characteristics of tuna purse seine of different mesh sizes and its effect of catch performance (by Liuxiong Xu, Xuchang Ye, Guoqiang Xu, Hao Tang and Cheng Zhou)

The Chinese tuna purse seine fleet typically use nets measuring approximately 1700 m in length and over 300 m deep. The net is comprised of up to 30 panel sections and can weigh 50 tonnes including all netting, ropes, and weight. As a result of increasingly regulated and restrictive fishing around Fish Aggregating Devices (FADs), there is an increasing imperative to target free swimming schools of tuna. However, the number of abortive (failed) sets is increased due to the escape of tuna. This means it is important to reduce the number of purse seine sets around free schools.

To improve purse seine success, efforts were made to improve sinking performance. Sinking performance is linked to mesh size, twine thickness, weight, hanging ratio, and experience of fishing master. Consideration must also be given to the relationship between sinking speed and strength of netting, avoidance of gilled fish, and that altered mesh size does not result in use of weaker twines. Subsequently, efforts to improve sinking performance focused on reducing net resistance, rather than increasing weight. Importantly, these efforts needed to consider normal fishing practice and likelihood of acceptance by fishermen.

In the main body of the purse seine, netting panels are constructed from 260 mm mesh size constructed from PA braided twine. In the first experiment, five panels were replaced with 300 mm mesh with a twine diameter of 1.85 mm. In the second experiment an additional ten panels were replaced with the larger mesh panels (Figure 41). Computer simulation predicted these changes would substantially increase sinking speed of the purse seine, and permit optimal depth to be achieved in approximately 20% less time.

The prototype (control) purse seine and the two modifications were tested at sea in a controlled comparative experiment using a commercial purse seiner. Purse seine sinking depth was evaluated using 10 TDR-2050 temperature and depth probes located at strategic locations along the bottom of the net. A successful set was deemed to be if the catch was 5 t or more per haul. As only one net is taken to sea at a time, the experiment was spread over several months. A total of 79 sets were completed (18 for the control, 41 for the net with five large mesh panels, and 20 sets for the net with fifteen large mesh panels. The mean sinking speed of the control was 0.17 m/s; sinking speed for the net with 5 panels increased by almost 12% and for the net with 15 panels it increased by almost 24%. The proportion of abortive sets with the control was 52.6 %, but this was reduced by 15% using the net with 15 panels. The use of large mesh panels is considered a viable improvement to purse seine design and catching efficiency.

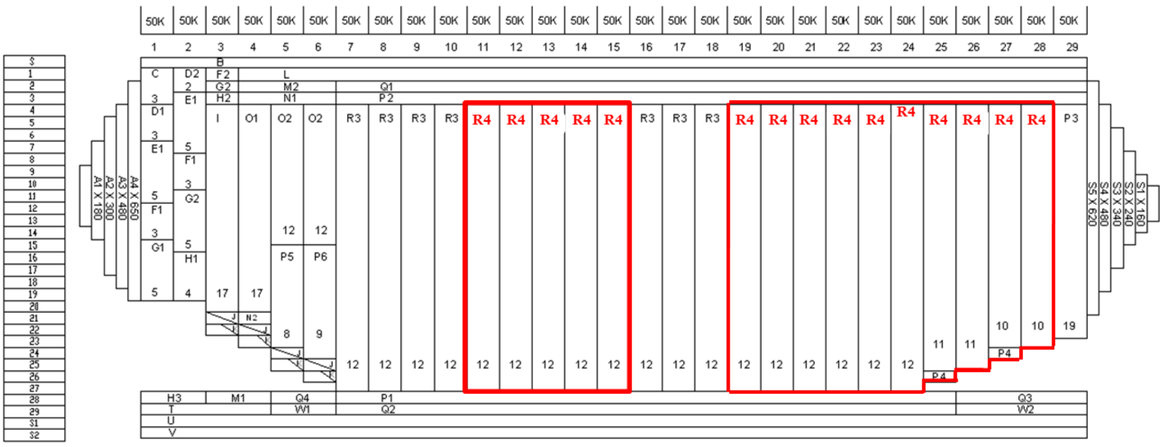
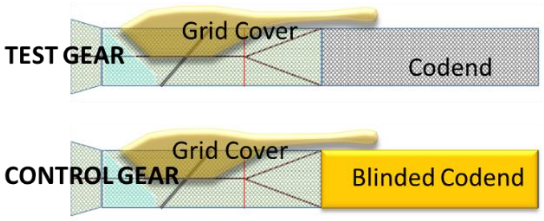


Figure 41. Purse seine with 5 panel large-mesh modification (center) and additional 10 panel large-mesh modification.

New method to identify the optimal bar spacing for grids in shrimp trawl fisheries: the case of the deep water shrimp (Pandalus borealis) in the North-East Atlantic (by Bent Herrmann, Manu Sistiaga and Roger B. Larsen)

In the deep water shrimp fishery in the NE Atlantic, trawl codends use small mesh (35 mm) to retain the target species. Unfortunately this also means a significant number of juvenile fish species are also retained. The Nordmøre grid has been successfully introduced to overcome this problem, and despite a bar spacing of 19 mm, many small fish still pass through the grid and are retained in the codend.

To evaluate the efficacy of the grid, a comparative experiment was performed that combined the covered codend method of evaluating selectivity with the alternate haul method. The control gear comprised of the traditional Nordmøre grid and codend, and a cover net was used to retain all shrimp and fish that passed through the escape opening while the codend was ‘blinded’ to retain all shrimp and fish that entered the codend (Figure 42). In this way the control gear was totally non-selective and the entire population of fish and shrimp that entered the trawl was sampled. The test gear comprised the same grid and codend although only the cover net was used.



$$\frac{nGT_l}{qGT} \qquad \frac{nCT_l}{qCT}$$

$$\left(\frac{nGC_l}{qGC} + \frac{nCC_l}{qCC}\right)$$

$$nO_l = \frac{nGT_l}{qGT} + \frac{nCT_l}{qCT} + \left(\frac{nGC_l}{qGC} + \frac{nCC_l}{qCC}\right)$$

Figure 42. Experimental design of test gear and control gear.

The results of this experiment confirmed that the grid performed as anticipated, with close to all shrimps passing through the grid. However, there was a high retention probability for fish species of a narrow length range. Improvement in grid selectivity is ongoing with fish fall-through experiments to evaluate the selectivity of fish of different size, by species. The observed data was modelled, and length dependent probability of retention in the cover net, codend, or blinded codend was evaluated (Figure 43). This enables grid passage probability and codend size selectivity curves to be produced, and ultimately, test gear size selection curves. The grid passage probability for shrimp was close to 100%, indicating almost all shrimp were retained; bar spacing is therefore close to optimum in terms of shrimp retention. The codend size selection curves indicates very low retention probability for small shrimp (<15mm); codend mesh size is also close to optimum. The size selection curve indicates that nearly all shrimp larger than 20 mm that enter the trawl and pass through the grid into the codend are retained. The grid passage probability was close to zero when redfish, American plaice, cod, and haddock individuals were respectively larger than 20 mm, 35 mm, 26 mm, and 30 mm. Estimated codend selectivity L50 and selection range statistics were respectively 9 mm and 4mm for redfish, 7 mm and 2 mm for American plaice, 14 mm and 3 mm for cod, and 12 mm and 2 mm haddock. However the overall selection curve for redfish and American plaice indicate the grid and codend combination are not ideal for the selection of these species. This work highlights a need to seek further gear refinement to reduce the capture of undersized fish species, including fish fall-though experiments using grids of different bar spacing.

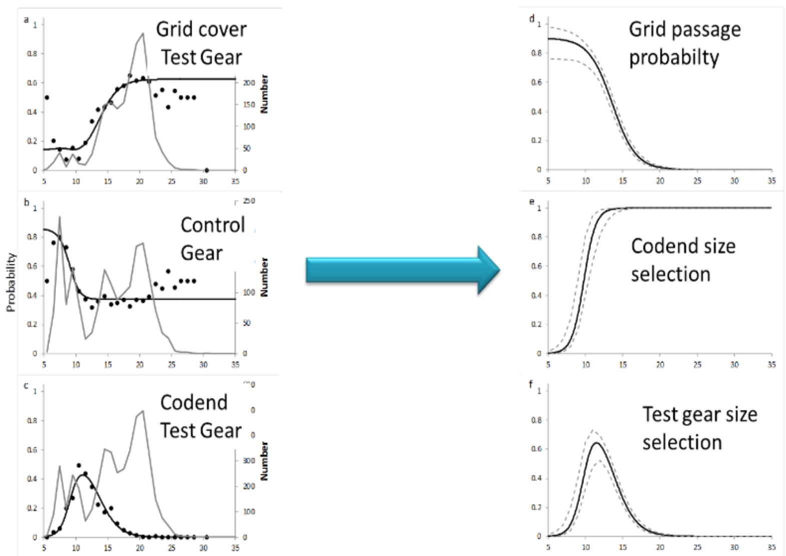


Figure 43. Estimating gear selectivity.

General discussion of the session 5.

A call was made for increasing the time allocation at future ICES-FAO WGFTFB meetings to research on escape behaviour of fish.

SESSION 6: Fishing Technology to Eliminate Vaquita Bycatch from Fisheries in the Upper Gulf of California (UGC)

Results of the experiments with alternative fishing gear in the Upper Gulf of California (by Daniel Aguilar)

A core issue influencing efforts to conserve the vaquita population is the impact of artisanal gillnet fishers. These fishermen use fine mesh gillnets to target blue shrimp, finfish, rays, and sharks that also incidentally catch vaquita. While federal regulations limit the length of these nets to 200 m, some fishers use lengths up to 2 500 m.

Previous efforts to address this issue include fishing trials for shrimp with pots, and then more recently with the suripera 'cast' net, and with trawl nets equipped with TEDs and bycatch reduction devices, including long droppers extending between the footrope and a groundchain (Figure 44). A total of 54 pangas used this gear, and after 2 528 tows, only 52% of trips from Baja California fishing grounds were profitable and only 2.6% of trips from Sonara grounds were profitable.

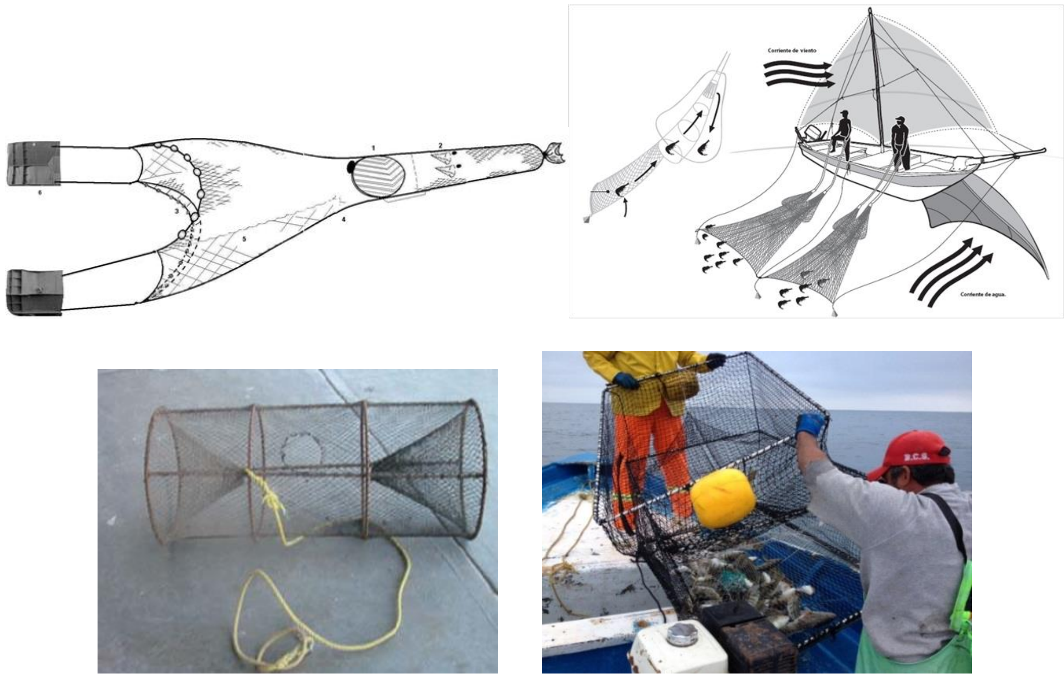


Figure 44. Options being considered to avoid vaquita bycatch without banning fishing activity include shrimp trawling with TED and BRD (upper left), Suriper cast net (upper right), shrimp pots, (lower left), and fish traps (lower right).

Explanation for the poor results from the Sonara grounds includes deliberate misreporting/sabotaging trials by fishers, low shrimp abundance (compared to previous seasons), high water temperature, and low catchability using trawl gear. Currently, with no immediate solution to vaquita bycatch available, there is a ban on all finfish and shrimp fisheries for two years, with an expectation that INAPESCA will develop alternative gears before the conclusion of the ban.

Given fears that catching commercial quantities of fish and shrimp may be a significant challenge, efforts are also being taken to explore options to improve catch value, explore if an auction system can drive up prices, improve produce traceability, or expand fishing grounds for fishers to use vaquita friendly alternative gears in other areas. For example, using TEDs shrimp trawl activity has not recorded a vaquita mortality, so access to closed areas may be a possibility. Additional work that is ongoing includes finfish traps, octopus traps, and finfish trawling.

Participation of Civil Society Organization for developing new gear to substitute gillnets from the Upper Gulf of California (by Enrique Sanjurjo)

WWF is presently supporting local communities to find solutions to vaquita bycatch, including the introduction of vaquita-friendly shrimp trawl gear, new gear for finfish, scientific monitoring, promotion of vaquita-safe seafood, and capacity building of local fishers. Government funds were made available to finance the purchase and use of vaquita-friendly gear, but a survey of fishers found that only 42% were using these alternative gears.

A trade-off analysis was completed that evaluated the influence of 4 types of closure (refuge, extended, 90%, all), four fisheries (shrimp, finfish, both, none), fisher buy-out (0%, 10%, 20%, 30%) and effectiveness of enforcement (40%, 60%, 80%, 100%). The analysis indicates that in order to save (or grow) the vaquita population, a reduction in fisher revenue is inevitable unless alternatives are identified and introduced.

Substantial efforts have been made testing a variety of alternative gears. Participation by NGOs facilitated the identification of proficient and enthusiastic fishers to work with, in assisting the government in fieldwork, making independent analysis of data, running small experiments to test specific hypotheses, and bringing together individuals to explore fresh ideas. Despite all this work, technical/gear solutions are still not ready, despite less than one year before the gillnet ban expires.

Experiences in the Baltic Sea for developing alternative fishing gear for gillnet fisheries in the Sea of Cortez (by Sara Königson, Peter Ljungberg and Sven-Gunnar Lunneryd)

In Sweden, substantial work has focused on pontoon nets, seine nets, multifunctional pots, and shrimp pots. Pontoon traps derived from an idea from a fisher (Figure 45). These traps are used to efficiently target white fish and salmon, but have also been used to target schooling species such as herring and vendace. Problems with this gear include handling of large catches, bycatch, and fouling by fish and seaweed. Seine nets are used to catch vendace, herring, and flatfish, which has less bottom impact, and a short fishing time that helps reduce seal catch.

A cod pot program has been established using fisher-designed pots. These pots are made available to fishers to loan for a one-month period. Additional work has been completed with multifunctional pots that can be easily modified to fish for cod and at other times, lobster. A variety of shrimp pots have also been tested in various configurations including top or side mounted entrances, multiple sizes and designs, and multiple funnel designs.

When new fishing gear is required to be developed, be it in Sweden or Mexico, innovative and sometimes high-risk projects need to be considered. These projects can be time-consuming, and they must provide comparable catches to existing gear, reduce environmental impact, and should be practical to use.

Figure 45. Pontoon trap. The holding frame/bag is lifted to the surface using compressed oxygen so fishers can access the catch.

A bottom-up social process to find fishing gears different from gillnets to reduce Vaquita bycatch (by Sergio Alejandro Perez Valencia and Peggy Turk Boyer)

Since 2004 INAPESCA and WWF have tested several fishing gears to find alternatives to gillents. However, many fishers are reluctant to change their gear. To encourage the search for new gear that avoids vaquita, a contest was established for fishers to propose new ideas (Figure 46). The best ideas were then tested informally, and if the results were encouraging, a larger scale, robust experiment with the gear followed. Cash awards were offered to fishers whose idea was considered to be most suitable for further evaluation. Proposals were evaluated by an expert committee, and the best proposals were tested at sea. Four proposals were selected for development, including a modified suripera with funnels, two modified trawl nets, and a chain (string) of traps. This bottom up approach was deemed to offer an incentive for fishers to consider replacement of gear types; moreover, it provided an opportunity for them to complete preliminary tests prior to implementing well-designed, but more costly experiments.

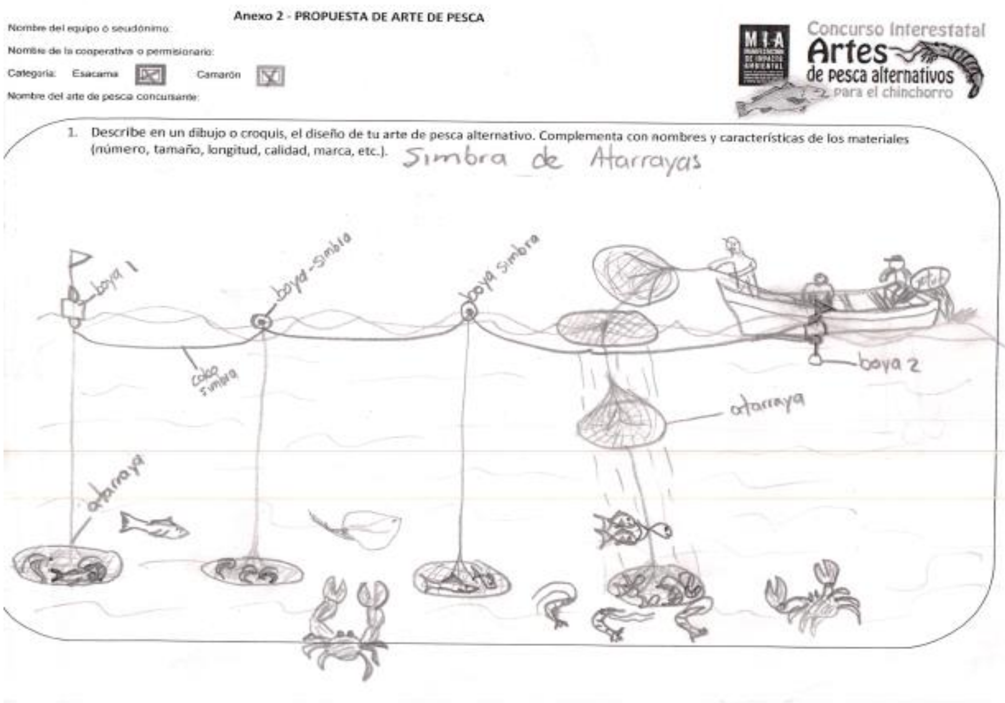


Figure 46. Ideas from fishers were sought to identify alternative, vaquita-friendly fishing gears.

Initiatives to protect porpoises in Denmark (by Lotte Kindt-Larsen and Finn Larsen)

There are endangered populations of porpoise in the North Sea, inner waters around Denmark, and the Baltic Sea. Council Directive 92/43/EEC sets the standard for nature conservation across of endangered, vulnerable, rare and/or endemic species in the EU, by seeking efforts to achieve favorable conservation status of listed species. Porpoise are listed in Annex II, which requires the designation of special areas of conservation. In addition, Council Regulation 812/2004 lays down measures designed to overcome the incidental capture of cetaceans in fisheries including minimizing the impact of fishing activity, use of acoustic deterrent devices, and bycatch monitoring.

Fishers are concerned that special areas of conservation will overlap with productive fishing grounds. A substantial effort includes bringing fishers, NGOs, scientists, and others together to openly discuss the issue of dolphins and seek solutions. Subsequently, many fishers are involved in efforts to monitor the impact of their fishing activity on porpoise using Electronic Monitoring (EM) equipment and self-reporting (Figure 47). Important haul data is also collected for the purpose of highlighting fisheries impact, including haul time, soak time, and location. Over time, this information is being used to identify areas of high risk at different times of the year. This information can be used to identify where and when fishing activity should be allowed. This information can also be used to guide ideas for gear modification. For example, modification to the height of gillnets is underway, as is work testing multiple pinger designs.

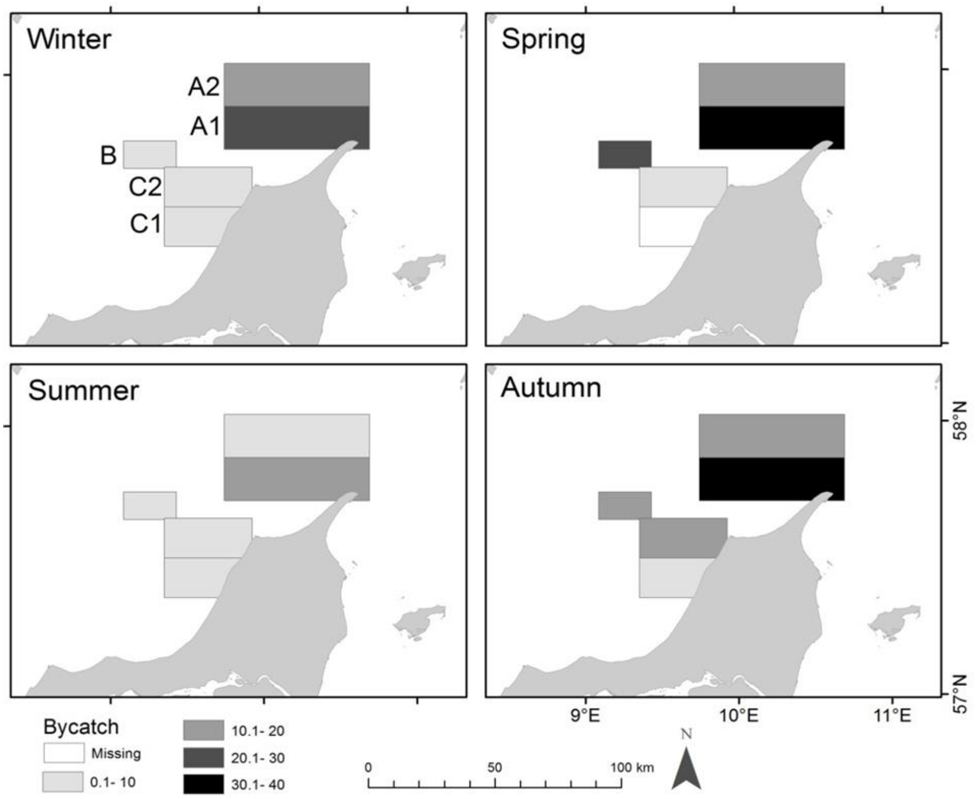


Figure 47. Porpoise bycatch mortality charts, by season.

General discussion of session 6.

In the discussion that followed the presentations in this session the use of pingers was proposed. It was noted that pingers have not been considered an option to reduce vaquita bycatch in the gillnet fishery due to concerns that the pingers would cause displacement of the vaquita from their normal habitat.

It was pointed out that the vaquita problem was highly complex. The gear ban ends in 2017 and it may not be extended. Many fishermen use gillnets much longer than permitted within the regulation, which appears to highlight a lack of commitment and/or enforcement capability, and financial penalties seem insufficient. The capture of totoaba and selling of their swim bladder is so lucrative (~USD 8 000/kg) and the penalties relatively so small that incentives to change behaviour are minimal.

There is very little time to act. A good fisher can catch over 100 totoaba a night. Moreover, drug cartels are involved in this trade. Therefore, the resources needed to find suitable gear solutions that also overcome the incentive to fish totoaba are huge. How can change be introduced and fishers motivated in this environment?

Fishermen may be i) willing to change, ii) some may consider change, and iii) there are those that will not change, perhaps because they are engaged in criminal activity. It needs to be discussed how to tackle the criminal element. The issue of changing the fishery is also technical and cultural, but now strong government action will be required to save the vaquita.

The limited communication on the vaquita population status and how to conserve the remaining stock is also an issue. The fisheries and environmental arms of the government have not communicated well in the past, nor have NGO's between themselves and others. Currently there is no mechanism (forum) established to improve communication between stakeholders. Particularly at the community level it is important to bring the problems and options to the table and to tackle the challenges in saving the vaquita at community level.

The 2016 annual meeting of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) was held from 25 to 29 April 2016 in Merida, Mexico. The meeting was hosted by FAO in close collaboration with the Universidad Marista de Mérida. More than 85 fishing technologists, scientists and other stakeholders, representing 23 countries from Europe, North America, Latin America and the Caribbean, and Asia, attended this meeting.

This report summarizes the three-day symposium, on "Technology Development and Sustainable Fisheries", which was organized as part of the 2016 annual meeting of the ICES-FAO WGFTFB. The symposium comprised six thematic sessions: (i) challenges and advantages in static fishing gears; (ii) encouraging technological change in capture fisheries; (iii) energy and greenhouse gas (GHG) reduction in capture fisheries; (iv) technology and practice for managing bycatch and reducing discards; (v) innovative technologies for observing fish and fishing gear; and (vi) fishing technology to eliminate vaquita bycatch from fisheries in the Upper Gulf of California (UGC).

The symposium provided an opportunity for fishing technologists and other experts from ICES member countries to exchange knowledge and ideas with contemporaries from around the world, especially from non-member countries in South America and Asia. A priority fishery research subject that emerged from this symposium was to further reduce bycatch without loss of target catch. It was also emphasized that greater efforts are required to understand fish behaviour. Awareness raising and capacity building on new fishing gears and technologies that reduce bycatch and lead to more efficient fishing operations was considered essential to increase uptake by fishers.

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