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Report of the

2019 SYMPOSIUM ON RESPONSIBLE FISHING TECHNOLOGY FOR HEALTHY ECOSYSTEMS AND A CLEAN ENVIRONMENT

Shanghai, China, 8–12 April 2019



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Cover photograph: Chinese Distant Water Fishing vessels.
Courtesy of Dr. Liming Song (2018)

PREPARATION OF THE DOCUMENT

This document is the final report of the 2019 Symposium on Responsible Fishing Technology for Healthy Ecosystems and a Clean Environment held from 8 to 12 April 2019 in Shanghai, China. The symposium was organized by the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) and hosted by FAO in collaboration with Shanghai Ocean University. The document was prepared by Dr Raymon van Anrooy (Fishing Operations and Technology Branch (FIAO) of the Food and Agricultural Organization of the United Nations) and Dr Pingguo He (School for Marine Science and Technology, University of Massachusetts Dartmouth, USA) on behalf of the ICES-FAO Secretariat to the Symposium. The document was formatted by Ms Estefanía Burgos (FAO).

The document has attempted to capture the issues raised by each presenter faithfully. The summaries of the presentations are attached as Appendix C of this report have been reproduced as submitted. The editors apologize for any misrepresentation that may have arisen in their summation. All photographs and figures in Appendix C were kindly provided by the authors of the respective abstract.

This Symposium was the third collaborative WGFTFB meeting hosted by FAO. The preparation, coordination, and planning for this Symposium was of very high quality, and the work of Professor Liming Song (Shanghai Ocean University, Shanghai, China) and his team contributed greatly to making the symposium a success. FAO would further also like to acknowledge the efforts of the WGFTFB co-Chairs, Dr Pingguo He and Dr Haraldur Einarsson, and Dr Liming Song for their contribution to the organization of the Symposium. Last but not least, the ICES-FAO 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 2019 annual meeting of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) was held from 8 to 12 April 2019 in Shanghai, China. The meeting was hosted by FAO in close collaboration with the Shanghai Ocean University. More than 120 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 four-day symposium, on “Responsible Fishing Technology for Healthy Ecosystems and a Clean Environment”, which was organized as part of the 2019 annual meeting of the ICES-FAO WGFTFB. The symposium comprised eight thematic sessions: (i) abandoned, lost and otherwise discarded fishing gear (ALDFG): assessment of quantity and measures to prevent ALDFG and its impact; (ii) interactions of protected species in capture fisheries; (iii) light, fish behaviour and fishing; (iv) technology and management to reduce bycatch and discards; (v) selectivity of fishing gear: means and methods; (vi) new technologies for fisheries research and education; (vii) energy, technology, analysis and simulation; and (viii) Chinese fisheries - status, challenges and future.

The symposium provided an opportunity for fishing technologists and other experts from ICES and FAO member countries to exchange knowledge and ideas from around the world, especially from non-ICES member countries in Asia and Latin America. Many new research findings and examples from field tests of gears were presented, including ways to systematically collect and recycle used fishing gear, options to reduce bycatch in trawl fisheries through modifications to the gears, fuel efficiency gains in fisheries through lighter gears, technologies to monitor fish behaviour with underwater cameras on fishing gear, and many other innovations.

The symposium acknowledged that many of the technological innovations in recent years would make the fisheries sector more economically healthy and environmentally sustainable. However, the uptake of technological innovations by the private sector fishers is often slow. The symposium discussed ways to speed up the transfer of suitable technologies to developing countries’ fisheries sector, through joint projects, collaboration between research institutions and the private sector, demonstrations and pilots, as well as working together with early adapters, and through translation of manuals and guidelines in local languages.

Hosting the ICES-FAO Working Group meeting in China was an important step in strengthening the collaboration between fishing technologists from China and those from western world, in order to jointly develop, introduce and disseminate responsible fishing technologies that contribute to healthier ecosystems and a cleaner marine environment.

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INTRODUCTION

1. The Food and Agriculture Organization of the United Nations (FAO) organized the 2019 annual meeting of the International Council for the Exploration of the Sea (ICES)–FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) in Shanghai, China between 8 and 12 April 2019. The meeting was hosted by FAO in collaboration with Shanghai Ocean University. More than 120 fishing technologists, scientists and other stakeholders, representing 23 countries from Europe, North America, Latin America and Asia attended this meeting. The fisheries technologists and scientists shared findings of studies and field testing of many fishing gears and technologies. The topics discussed at the meeting included, amongst others, abandoned, lost or otherwise discarded fishing gear (ALDFG) and how to assess and reduce these, interactions with protected species in fisheries, the use of light in fisheries and its effects on fish behaviour, technologies to reduce bycatch and discards in fisheries, methods to improve use of fishing gears, the latest technologies used in fisheries research and education, and developments of energy-saving technologies in fisheries. A special session was dedicated to Chinese fisheries, its status, challenges and opportunities.
2. The ICES–FAO WGFTFB was established in 2002. Prior to this time, the working group was comprised primarily of individuals from the member countries of the ICES in Europe and North America. 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 arrangement was held in Bangkok, Thailand, from 6 to 10 May 2013, and the second meeting was held in Merida, Mexico, in the period 25-29 April 2016¹.
4. The objectives of the 2019 annual meeting of WGFTFB remained similar to those of recent years:
 - 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 a four-day symposium on “Responsible Fishing Technology for Healthy Ecosystems and Clean Environment”. The symposium was further divided into eight sessions, with presentations related to the following:

¹ The reports of the 1st and 2nd meetings are available at: www.fao.org/3/a-i4384e.pdf and www.fao.org/3/ca4015en/ca4015en.pdf

- a) Abandoned, lost or otherwise discarded fishing gear (ALDFG): Assessment of quantity and measures to prevent ALDFG and its impact
- b) Interactions of protected species in capture fisheries
- c) Light, fish behaviour and fishing
- d) Technology and management to reduce bycatch and discards
- e) Selectivity of fishing gear: Means and methods
- f) New technologies for fisheries research and education
- g) Energy, technology, analysis and simulation
- h) Chinese fisheries – Status, challenges and future

6. The meeting agenda is attached as Appendix A. The list of participants with their affiliations is provided in Appendix B.

7. A summary of presentations from the symposium are provided in Appendix C, while details of the ICES topic groups, country reports and a general business session can be found in the 2019 ICES Report of the WGFTFB².

I. OPENING OF THE MEETING

8. The participants to the Meeting and Symposium were welcomed by representatives from Shanghai Ocean University, ICES and FAO. Vice President Jiale Li of Shanghai Ocean University welcomed the participants and introduced the speakers. President Yudong Cheng of Shanghai Ocean University started by informing the audience of the long, 107-year, history of the university and its development over the years. He referred to the start of the fisheries related studies and the efforts of the university to become a leading global institution for fisheries education. His welcome address emphasized the importance of developing fishing technologies that contribute to more responsible and sustainable fisheries. Recognizing the many students that attended the meeting, he added that the current fisheries students, the young generation, would in the near future support fisheries science and management and would have key roles to play in making fisheries more sustainable.

9. Dr Raymon van Anrooy, Senior Fishery Officer of FAO, acknowledged the importance of collaboration between ICES and FAO, and shared some key information from the 2018 FAO State of Fisheries and Aquaculture (SOFIA)³. He emphasized that the work of fishing gear technologists is essential to continue developing not just more efficient fishing gears, but gears that contribute to selectivity in fishing, responsible harvesting and safer working environments in fishing.

10. Dr Haraldur Einarsson, ICES WGFTFB Co-Chair, noted the importance of sharing experiences with experts in China, given that China's capture fisheries sector contributes nearly 20 % to the world's capture fisheries production. He said that improvements that could be made to increase selectivity and reduce bycatch in China's fisheries will benefit everyone.

11. Dr Pingguo He, Symposium Chair and FAO WGFTFB Co-Chair, thanked the Shanghai Ocean University and FAO for their support to the meeting, and stressed that sustainable fisheries require sustainable ecosystems. He stressed that "we need to work hard to reduce impact of fishing operation on the environment for a cleaner ocean and healthy ecosystems".

12. Dr Liming Song, Shanghai Ocean University, introduced the scientific session by introducing the keynote speaker, Dr Pingguo He, who made a presentation on "Responsible fishing operations for clean oceans, healthy ecosystems and sustainable fisheries".

² The 2019 annual ICES-FAO WGFTFB report is available at: <http://www.ices.dk/community/groups/Pages/WGFTFB.aspx>

³ FAO. 2018. The State of World Fisheries and Aquaculture. www.fao.org/3/I9540EN/i9540en.pdf

13. Another keynote speech was made at the start of the second day by Dr Åsmund Bjordal (Institute of Marine Research, Norway). His speech was titled “The becoming, being and return of a fish behaviour and fishing technology scientist” and was introduced by Dr Pingguo He.

II. SUMMARY OF THE SYMPOSIUM

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

14. The primary focus of this session was to explore and share the latest information on the ALDFG, international and national efforts and practical tools to reduce ALDFG. This session was moderated by Dr Raymon van Anrooy (FAO).

15. The session comprised five presentations of which two had a global perspective and three were focused on national level interventions in Iceland, USA and Germany. The presentations included preliminary information from an assessment of global fishing gear losses, and information on international measures such as the “Voluntary Guidelines on the Marking of Fishing Gear”, which were adopted by the FAO Committee on Fisheries at its 33rd session in 2018. Practical examples of how marine litter is being reduced in Iceland, how lost lobster pots can be detected using side-scan sonar in the USA, and options to reduce the marine pollution caused by dolly ropes in beam trawl fishing operations in the Baltic sea, were presented as well.

16. The plenary discussion following the various presentations included questions on how the metadata analysis was being conducted on fishing gear losses. It was noted that governments generally do not collect gear loss data and that partial losses of gears are not included in most research efforts on this subject. The costs of fishing gear marking were discussed. It was suggested that fishers should be rewarded for good behaviour instead of punished for bad behaviour in relation to fishing gear disposal and supporting recycling of gear materials. Given that fishers depend on a clean ocean, they are likely to collaborate with responsible port-based low-cost gear disposal and recycling schemes. Questions about the practical implementation of the fishing gear collection and gear recycling programme in Iceland were made and about how the costs were covered (i.e. through taxes by weight on fishing gear sold in Iceland). Sonar techniques to locate pots were discussed as well as the scope of the problem of ghost fishing by lost pots.

Session 2: Interactions of protected species in capture fisheries

17. This session focused primarily on ways to reduce bycatch of protected marine mammals and other non-target species in fishing operations. It was moderated by Dr Pingguo He (FAO/UMass Dartmouth).

18. The session comprised five presentations from four countries. The presentations provided an overview of mitigation strategies for reducing bycatch in gillnet fishing in the USA, tools to mitigate bycatch of porpoises in Denmark, an introduction to legislative provisions to reduce marine mammal bycatch in the USA, innovations in turtle excluder devices from Japan, and marine mammal selectivity of various mesh sizes of different types of bottom-gillnets in Iceland compared to driftnet in Nigeria.

19. The general discussion following the presentations in this session was brief. It was mentioned that the bycatch mitigation tools require uptake in developing countries in order to have a significant impact. Practical tools tested seem to reduce marine mammal bycatch effectively. It was further noted that the US Marine Mammal Protection Act does not include targeted marine mammal fishing, as is the case in some countries.

Session 3: Light, fish behaviour and fishing

20. The focus of this session, which included one presentation from Norway, on the responses to artificial light by mesopelagic fish. The session was moderated by Dr Noëlle Yochum (NOAA, USA).

21. The presentation informed the participants about investigations into the response of mesopelagic fish to different light colours at various water depths. Follow-up research was recommended in view of the large mesopelagic fisheries worldwide. The discussion focused on the importance of biomass of

mesopelagic fish in the oceans, the opportunities for targeting fish lower in the food chain and the various types of light fishing that are being used in various fisheries worldwide.

Session 4: Technology and management to reduce bycatch and discards

22. This session explored recent efforts to reduce bycatch and discards in capture fisheries. It was moderated by Dr Noëlle Yochum (NOAA, USA) and Dr Daniel Stepputtis (Thuenen Institute of Baltic Fisheries, Germany).

23. The session comprised 12 presentations from 7 countries. Presentations in this session covered a variety of fishing gears, including demersal fish trawls, shrimp trawls and purse seines. A variety of research into techniques to reduce bycatch were presented including analysis of shrimp distribution inside a trawl, grid developments, square mesh panels, bycatch reduction devices (BRDs), benthos release panels, innovative net and BRD technologies with different materials and codend mesh sizes and orientation. The session was highly oriented towards trawl fisheries.

24. The discussions that succeeded the presentations were highly diverse and included questions on the thickness of grid bars, materials used, the research setup applied, the outcomes of the REBYC II LAC, Gearing-up and DiscardLess projects, the need for training of fisheries inspectors on species identification and why certain technologies led to changes in bycatch species, and the difference between bycatch rate and bycatch volume.

25. Significant discussion took place on the use of electric-pulse trawl fishing for flatfish and its potentially use in shrimp trawling. It was noted that the current debate in the European Union is more of an emotional than a rational nature, and that facts presented by fishing technologists are insufficiently used in the debate. The pulse trawl research conducted so far showed significant reductions in fuel/energy consumption of the trawlers, important reduction of bycatch species and an increased catch of target species.

Session 5: Selectivity of fishing gear: Means and methods

26. This session provided an opportunity for presenters to discuss specific codend selectivity research findings from trawl fisheries in Europe, North and Central America, and China. It was moderated by Dr Michael Pol (Massachusetts Division of Marine Fisheries, USA).

27. The session comprised six presentations from five countries. The presentations focused on trawl gears and specifically codends. Mesh sizes and shapes and selectivity research findings were discussed.

28. The general discussion included questions on mesh size regulations and participation of fisherfolk in decision making processes on trawl gears.

Session 6: New technologies for fisheries research and education

29. The focus of this session was to explore new techniques and methods for fisheries research, capacity building and education. The session was moderated by Dr Liming Song (Shanghai Ocean University, China).

30. The session comprised five presentations from four countries. The presentations in this session were diverse and covered acoustic catch monitoring methods in purse seine fisheries, software models for gear selectivity, infrared light use for fish observation, capacity building applications for fishing technology and measurement boards for fish measurements.

31. During the general discussion following the presentations several observations were made regarding the use of underwater drones to monitor the trawl operations and the costs of electronic fish measurement boards.

Session 7: Energy, technology, analysis and simulation

32. This session incorporated a variety of subjects. The session was moderated by Dr Haraldur Einarsson (Marine and Freshwater Research Institute, Iceland).

33. The session comprised of seven presentations from six countries. Innovations in energy use, fishing technology, trap fisheries, trawl fisheries, rope materials and flow simulations, were presented in this session.

34. The discussion which followed the presentations included questions about the slow uptake by fishers of energy efficient technologies, the need for a global fuel saving study for fisheries, the appropriateness of using catch per unit of fuel consumption instead of catch per unit of effort (CPUE), the marking and electronic tracking of passive gears, the use of the DeepVision camera in other fish surveys, buoyancy of rope materials and floats, and about the extreme seal population growth in the Baltic sea.

Session 8: Chinese fisheries – Status, challenges and future

35. This session was dedicated to Chinese fisheries and was moderated by Professor Liuxiong Xu (Shanghai Ocean University, China). The session comprised of six presentations, all from China.

36. The presentations focused on the situation in Chinese fisheries and included findings from fishing gear selectivity research, monitoring of the coastal fishing fleet, the challenges of China's distant water fishing fleet, IUU fishing issues and Chinese policies and practices to combat IUU fishing, as well as the development of fishery improvement projects in China.

37. The plenary discussion following the presentations included questions on the application of the Ecosystem Approach to Fisheries (EAF) in China, Turtle excluder Devices (TEDs) and dehooking devices for turtles, China's international responsibilities as flag state, coastal state and port state in global fisheries, the use of catch documentation schemes in China, Vessel Monitoring Systems (VMS) and seabirds bycatch in longline fisheries in the Pacific Ocean.

38. A symposium poster presentation session was also organized where participants discussed with the authors of the posters. The abstracts of posters can be found in Appendix D.

III. CLOSURE OF THE MEETING

39. Before closure of the symposium representatives of FAO and ICES thanked the host institution, Shanghai Ocean University, the meeting secretariat and FAO rapporteurs, and also all participants for their contributions to the symposium. The chairs also expressed desire to see many of the ICES-FAO WGFTFB members again in the next meeting of the working group, scheduled to be held in Bergen, Norway in April 2020.

40. The symposium was formally closed by Dr Pingguo He, co-chair of the WGFTFB on Thursday 11 April at 11:30 AM.

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AGENDA AND TIMETABLE

Monday April 8

- 7:30 Registration
- 8:30 Opening and Welcome – Introduced by Jiale Li, Vice President of Shanghai Ocean University
 Yudong Cheng (President, Shanghai Ocean University)
 Raymon van Anrooy (Senior Fishery Officer, FAO)
 Haraldur Einarsson (WGFTFB Chair, ICES)
 Pingguo He (Symposium Chair and WGFTFB Chair, FAO)
- 10:00 Tea/Coffee break
- 10:20 Scientific programs
 Logistics and remarks
- 10:30 Keynote presentation
Pingguo He (FAO, Italy and UMass Dartmouth, USA)
 Responsible fishing operations for clean oceans, healthy ecosystems and sustainable fisheries
 Introduced by: Liming Song (Shanghai Ocean University, China)
- 11:00 **Session 1: Abandoned, lost or otherwise discarded fishing gear (ALDFG): Assessment of quantity and measures to prevent ALDFG and its impact**
 Moderator: Raymon van Anrooy (FAO, Italy)
- 11:00 Kelsey Richardson, Britta Denise Hardesty and Chris Wilcox (Commonwealth Scientific and Industrial Research Organisation, Australia)
 Assessing and estimating global fishing gear losses
- 11:20 Joanna Toole, Raymon van Anrooy and Pingguo He (FAO, Italy)
 International actions on reducing sea-based marine litter, especially abandoned, lost or otherwise discarded fishing gear and its impact on fisheries resource and marine environment
- 11:40 Georg Haney and Haraldur Einarsson (Marine and Freshwater Research Institute, Iceland)
 Reducing marine litter – a practical example of the Icelandic fisheries
- 12:00 Mike Pol, David Chosid, Kathryn Ford and Steve Voss (MA Division of Marine Fisheries, USA)
 Using side scan sonar to detect lobster pots in simple and complex habitats
- 12:20 **Lunch Break and Poster Viewing**
- 13:40 Uwe Lichtenstein, Bernd Mieske, Thomas Noack and Daniel Stepputtis (Thuenen Institute of Baltic Sea Fisheries, Germany)
 Stripping the beam trawl – get rid of abrasion protection
- 14:00 **Session 2: Interactions of protected species in capture fisheries**
 Moderator: Pingguo He (FAO, Italy and UMass Dartmouth, USA)
- 14:00 Tim Werner (New England Aquarium, USA)
 An overview of mitigation strategies for non-target species bycatch in gillnets
- 14:20 Lotte Kindt-Larsen and Finn Larsen (DTU Aqua, Denmark)
 Porpoise bycatch mitigation and management tools used in Denmark
- 14:40 Lauren Fields and Nina Young (NOAA Fisheries, USA)
 Update on the U.S. Marine Mammal Protection Act import provisions: Implementation process and analysis of marine mammal bycatch in commercial fisheries

- 15:00 Daisuke Shiode, Maika Shiozawa, Fuxiang Hu, Tadashi Tokai and Yoshio Hirai (Tokyo Univ. of Marine Science and Technology, Japan)
A newly developed soft-type turtle releasing device (Soft-TRD) for set net fisheries
- 15:20 Haraldur A. Einarsson, Guðjón Már Sigurðsson, Georg Haney and Justina Adaugo Obienu (Marine and Freshwater Research Institute, Iceland)
Length based selectivity of different mesh sizes in gillnets for cetaceans from two different fisheries
- 15:40 Tea/Coffee break
- 16:00 **Session 3: Light, fish behaviour and fishing**
Moderator: Noëlle Yochum (NOAA Fisheries, USA)
- 16:00 Åsmund Bjordal, Melanie Underwood, Anne Christine Utne Palm and Jan Tore Øvredal (Institute of Marine Research, Norway)
Mesopelagic fish: responses to artificial light
- 16:20 **Session 4: Technology and management to reduce bycatch and discards (1)**
Moderator: Noëlle Yochum (NOAA Fisheries, USA)
- 16:20 Daniel Stepputtis, Juan Santos, Bernd Mieske, Jimmy van Rijn, Karsten Breddermann (Thuenen Institute of Baltic Sea Fisheries, Germany) –10 min only.
Vertical distribution of North Sea brown shrimp inside the trawl
- 16:30 Juan Santos, Daniel Stepputtis, Bernd Mieske, Jimmy van Rijn and Karsten Breddermann (Thuenen Institute of Baltic Sea Fisheries, Germany)
Investigating grid technologies for improved exploitation patterns in the North Sea Brown shrimp fishery
- 16:50 Mattias van Opstal and Maarten Soetaert (ILVO, Belgium)
Gear innovations to reduce the catch of undersized whiting in fly shooting fisheries
- 17:10 Discussion
- 17:30 Poster session
- 18:00 Conference dinner – Haitian Lou

Tuesday April 9

- 8:00 Opening/announcement
- 8:05 Keynote presentation
Åsmund Bjordal (Institute of Marine Research, Norway)
The becoming, being and return of a fish behaviour and fishing technology scientist
Introduced by Pingguo He (UMass Dartmouth, USA)
- 8:35 **Session 4: Technology and management to reduce bycatch and discards (2)**
Moderator: Daniel Stepputtis (Thuenen Institute of Baltic Sea Fisheries, Germany)
- 8:35 Thomas Catchpole (CEFAS, UK)
Applying new technologies and approaches at different phases of commercial fishing operations to minimize unwanted catches
- 9:00 Amparo Pérez Roda and Eric Gilman (Hawaii Pacific Univ., USA)
Discards in global marine capture fisheries: The most recent update
- 9:20 Raymon van Anrooy, Carlos Fuentesvilla, Mario Rueda, Daniel Aguilar, Tomas Willems, Nerissa Lucky, Cecilia Quiroga, Fabian Escobar, Nicholas Hopkins (FAO, Italy)
Progresses, challenges and preliminary results of REBYC-II LAC - The Sustainable Management of Bycatch in Latin America and Caribbean Trawl Fisheries

- 9:40 Juan Santos, Bent Herrmann, Bernd Mieske, Daniel Stepputtis (Thuenen Institute of Baltic Sea Fisheries, Germany)
Do you really want to leave? The attractiveness of square mesh panels as exit devices for cod
- 10:00 Tea/Coffee break
- 10:20 Ole Ritzau Eigaard, Ludvig Krag, Bent Herrmann, Jordan Feekings and Claus Sparrevohn (DTU Aqua, Denmark)
Test of a netting-based alternative to rigid sorting grids in the industrial Norway pout (*Trisopterus esmarkii*) trawl fishery
- 10:40 Valentina Melli, bent Herrmann, Junita Karlsen, Jordan Feekings and Ludvig Krag (DTU Aqua, Denmark)
Is two better than one? Predicting the performance of a combination of bycatch reduction devices in a Nephrops-directed fishery
- 11:00 Soetaert Maarten, Klaas Sys and Heleen Lenoir (ILVO, Belgium)
The use of (electrified) benthos release panels in beam trawl fisheries targeting sole
- 11:20 Eric Gilman, Milani Chaloupka, Laurent Dagorn, Martin Hall, Alistair Hobday, Michael Musyl, Tony Pitcher, Francois Poisson, Victor Restrepo and Petri Suuronen (Hawaii Pacific Univ., USA)
Robbing Peter to pay Paul: Replacing unintended cross-taxa conflicts with intentional trade-offs by moving from piecemeal to integrated fisheries bycatch management
- 11:40 Dérien Lucie Verneti Duarte, Bianca Bentes, Carlos Fuentesvilla, Luiz Felipe Cestari Dumont, Rodrigo Medeiros, Vanildo S. Oliveira and Fabio Hissa Vieira Hazin (CEPSUL/ICMBio, Brazil)
Bycatch reduction actions in scope of REBYC-LAC II/FAO in Brazil
- 12:00 Discussion
- 12:20 **Lunch Break and Poster Viewing**
- 13:40 **Session 5: Selectivity of fishing gear: Means and methods**
Moderator: Michael Pol (Massachusetts Division of Marine Fisheries, USA)
- 13:40 Zhaohai Cheng, Haraldur Einarsson, Shannon Bayse, Bent Herrmann and Paul Winger (Memorial Univ. of Newfoundland, Canada)
Comparing the size selectivity of three different codend mesh orientations in the Icelandic Northern Shrimp (*Pandalus borealis*) trawl fishery
- 14:00 Daniel Aguilar Ramírez, José Alejandro Rodríguez Valencia and Luis Vicente González Ania (National Institute for Fisheries and Aquaculture, Mexico)
Development and performance of selective trawl net prototypes for pink shrimp from Campeche, Mexico
- 14:20 Liuyi Huang, Yuyan Li, Huiliang Gao, Qingchang Xu and Yanli Tang (Ocean Univ. China, China)
Study on the selectivity of stow net in the Haizhou Bay
- 14:40 Matthew McHugh, Daragh Browne, Martin Oliver, Cólín Minto and Ronán Cosgrove (BIM, Ireland)
Benefits of 120 mm diamond and 100 mm T90 codends in mixed demersal fisheries
- 15:00 Hongliang Huang, Xuefeng Song, Taichun Qu (East China Sea Fish. Res. Inst., China)
Selectivity of diamond and square-mesh codends in the East China Sea trawl fishery for *Parimichthys polyactis*
- 15:20 Pieke Molenaar and Chun Chen (Wageningen Marine research, The Netherlands)

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

15:40	Tea/Coffee break
16:00	Session 6: New technologies for fisheries research and education Moderator: Liming Song (Shanghai Ocean Univ., China)
16:00	<u>Maria Tenningen</u> , Jan Tore Øvredal and Gavin Macaulay (Institute of Marine Research, Norway) Development of acoustic catch monitoring methods for purse seine fisheries
16:20	<u>Mollie Brooks</u> , Tiago Veiga-Malta, Ludvig Krag and Jordan Feekings (DTU Aqua, Denmark) Open source software for statistical models of gear selectivity
16:40	Andreas Hermann, <u>Daniel Stepputtis</u> , Marcellus Rödiger and Joachim Hensel (Thuenen Institute of Baltic Sea Fisheries, Germany) Open Scientific Measurement Board (OpenSMB)
16:50	Andreas Hermann, <u>Daniel Stepputtis</u> and Jerome Chladek (Thuenen Institute of Baltic Sea Fisheries, Germany) Infrared Fish Observation iFO
17:00	<u>Stephen Eayrs</u> (Smart Fishing Consulting, Australia) The SeSAFE learning management system: Application and potential to provide training and build capacity in fishing technology
17:20	End of scientific program
17:30	Campus visit (Flume tank/Safety Training Centre etc.) – Liming Song
19:30	Social activity: Performances by Student Art Troupe

Wednesday April 10

8:00	Opening/announcement
8:05	Session 7: Energy, technology, analysis and simulation Moderator: Haraldur Einarsson (Marine and Freshwater Research Institute, Iceland)
8:10	<u>Antonello Sala</u> and Emilio Notti (CNR-ISMAR, Italy) Energy use in fisheries and development of eco-driven fishing techniques
8:40	<u>Aud Vold</u> (Institute of Marine Research, Norway) CRISP - Eight years of innovation in fisheries technology
9:00	<u>Peter Ljungberg</u> (Univ. of Agricultural Sciences, Sweden) Large scale pontoon trap in cod fisheries, a retrospect
9:20	<u>Isara Chanrachkij</u> , Tanut Srikum, Nakaret Yasook, Santipong Putsa, and Arong Ruangsivakul (SEAFDEC, Thailand) Some relationship of the characteristics of trawl net, otter board and trawlers in Thailand
9:40	<u>Wenhua Chu</u> and Xuchang Ye (Shanghai Ocean Univ., China) Numerical simulation on the mechanical properties of marine float
10:00	Tea/Coffee break
10:20	<u>Stephan Schacht</u> and Mathias Paschen (Univ. Rostock, Germany) Numerical and experimental investigations on twisted ropes with regard to their hydrodynamic behaviour
10:40	<u>Karsten Breddermann</u> and Mathias Paschen (Univ. Rostock, Germany) Flow simulation in and around a North Sea brown shrimp beamtrawl

11:00 Discussion
 11:10 Field trip
 Eve. Conference dinner

Thursday April 11

8:00 Opening/announcement
 8:15 **Session 8: Chinese fisheries – Status, challenges and future**
 Moderator: Liuxiong Xu (Shanghai Ocean Univ., China)
 8:15 Liuxiong Xu, Jian Zhang and Zhongqiu Wang (Shanghai Ocean Univ., China)
 Research on fishing gear selectivity and its application in China
 8:40 Yiping Ren, Binduo Xu, Chongliang Zhang and Ying Xue (Ocean Univ. of China, China)
 Monitoring and assessment of China's coastal fisheries
 9:05 Liming Song and Di Wang (Shanghai Ocean Univ., China)
 China's distant water fisheries –status, management and challenges
 9:30 Huihui Shen and Shuolin Huang (Shanghai Ocean Univ., China)
 China's policies and practice on combatting IUU in distant water fisheries
 9:50 Ying Dai and Naizhong Liu (Dalian Univ. Foreign Languages, China)
 IUU-related International Law Issues and China's facing challenges and Countermeasures
 10:10 Tea/Coffee break
 10:30 Eric Gilman (Hawaii pacific Univ., USA)
 Experiences of Liancheng Overseas Fishery (Shenzhen) Co. Ltd transitioning from Fishery
 Improvement Projects to Marine Stewardship Council Certification
 10:50 Discussion
 End of Symposium

INDIVIDUAL PRESENTATION SUMMARIES

KEYNOTE PRESENTATION

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

Pingguo He^{1,2}

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

This presentation outlined the status and trends of global marine capture fisheries and how fisheries may have affected our oceans and their ecosystems, which may jeopardize sustainable fisheries and global food security. Marine capture fisheries are recognized as primary causes of overfishing with number of overfished stocks still in the upward trend. Bycatch and discards in capture fisheries threaten biodiversity and protected species, cause extirpation of species, and represent a waste of food (Figure 1). Fisheries-related marine litter in the form of abandoned, lost or otherwise discarded fish gear (ALDFG) pollute marine environment, threatens marine lives and reduces commercial fisheries resources. Fishing operations on or near the seabed causes modification to physical, chemical and biological structure of the seabed, which may influence productivity, subsequently harvestable resources.

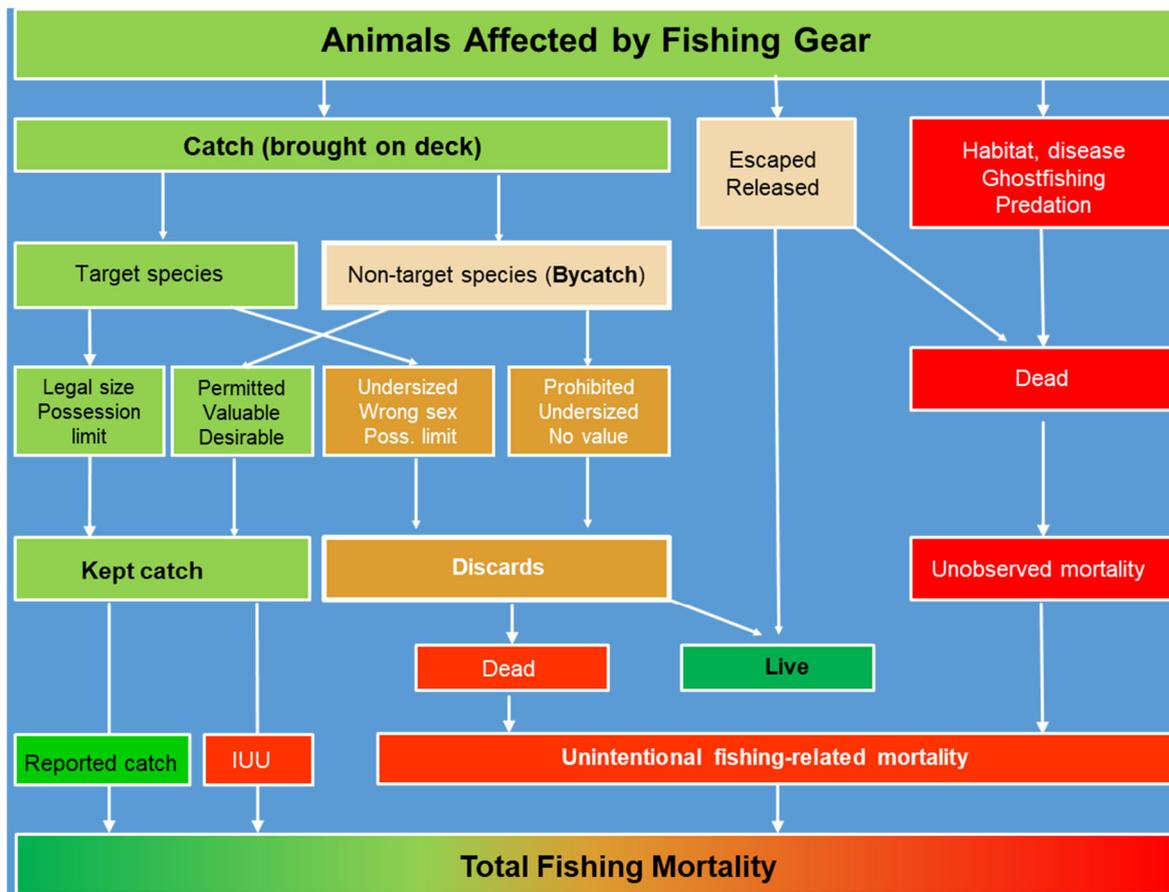


Figure 1. Description of how fishing gears affect fishing mortality.

The Food and Agriculture Organization of the United Nations (FAO) has spearheaded these issues as they affect ecosystem sustainability and long-term production of fisheries. From the cornerstone of the Code of Conduct for responsible Fisheries, many guidelines, agreements, and action plans have been developed and agreed. Together with other UN agencies and other international organizations and member states, FAO has pushed for the passage of instruments on bycatch management and reduction of discard, plans for the protection of seabird, turtles, marine mammals, sharks and other sensitive and protected species, agreements on measures to combat illegal, unreported and unregulated (IUU) fishing, and measures to combat ALDFG, including the Voluntary guidelines on the marking of fishing gear. FAO's work on these areas contributes to UN's Sustainable Development Goals, especially on SDG target 14 – Life below water.

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

Assessing and Estimating Global Fishing Gear Losses

Kelsey Richardson*, Britta Denise Hardesty and Chris Wilcox

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Abandoned, lost or otherwise discarded fishing gear (ALDFG) represents a significant, yet ultimately unknown, amount of global marine debris, with a diversity of socioeconomic and environmental impacts. Fisheries impacts include damage to and loss of fishing gear, loss of catch, the potential to diminish fish stocks and hazards to navigation and safety at sea. ALDFG can also injure and/or kill marine wild life and damage marine ecosystems and benthic habitats. Recovery and clean-up of gear is expensive, complicated, time intensive and can be dangerous. While studies have been conducted since the 1970s on the amounts of fishing gear lost by gear types, fisheries and geographic areas around the world, no statistically rigorous estimates exist to date that quantify global fishing gear losses (Figure 2).

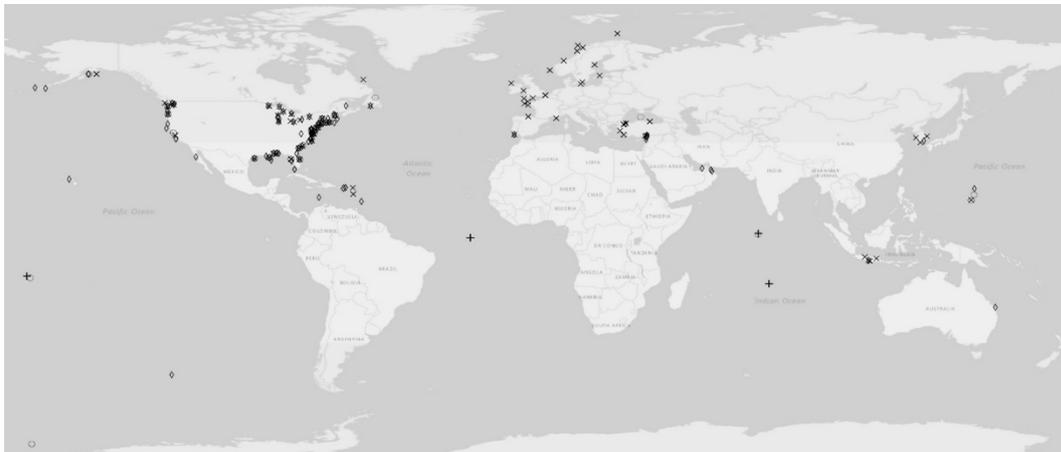


Figure 2. Maps showing the distribution of 68 gear loss studies conducted in the period 1975-2017 and included in the literature review. Legend: Nets: X; Traps: ◇, Lines: ○, Fish Aggregating Devices (FADs): +.

This lack of global estimates for fishing gear losses acts as a barrier to implementing solutions designed to prevent and/or decrease amounts of ALDFG as a key and distinct source of marine debris, as well as an obstacle in monitoring the effectiveness of these interventions on a global scale. This presentation reported on the research project “Assessing and Estimating Global Fishing Gear Losses”. The project aims to provide statistically rigorous global baseline estimates of the total amounts of commercial fishing gear losses annually across key gear types, geographic areas and fisheries, focusing on losses from a variety of net, trap and line fisheries. The project is achieving these goals through: 1) a global literature review and meta-analysis of fishing gear losses; and 2) surveys with fishers from different countries around the world about why, when and how they lose gear. The presentation summarised key findings and progress from this project including sharing our estimates of global gear loss by fisheries around the world from the global literature review and meta-analysis. Initial finding from the surveys with fishers around the world were presented as well.

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

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Abandoned, lost or otherwise discarded fishing gear (ALDFG) constitutes a significant part of marine plastic pollution, threatens marine life, wastes fisheries resources, and fouls sensitive marine habitats. ALDFG also poses problems to navigation and safety at sea. There is also a link between ALDFG and illegal, unreported and unregulated (IUU) fishing, because fishers may dump their gear to try to evade detection by authorities, or there may be conflict between gears due to poor regulation of fishing effort in a particular area. Marking of fishing gear is widely regarded as one of the most effective tools that can prevent and reduce ALDFG, by facilitating identification (of the owners of the gears) and the recovery of gears. This presentation provided background on the global processes that led to the recent-adoption of the Food and Agriculture Organization of the United Nations (FAO) “Voluntary Guidelines on the Marking of Fishing Gear” by the Committee on Fisheries at its 33rd session, held in July 2018. The presentation highlighted key items in the guidelines (Figure 3), and stresses how its implementation may benefit the marine environment and sustainable fisheries.

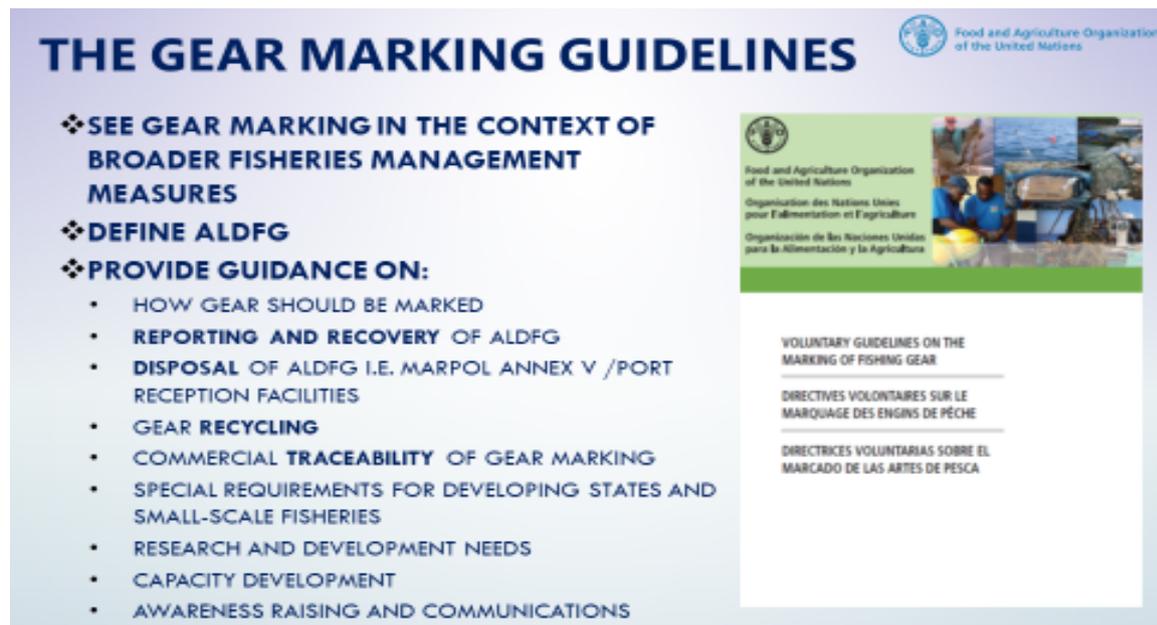


Figure 3. The FAO Voluntary guidelines on the Marking of Fishing Gear.

A review was provided of technologies for the marking of fishing gear and technology limitations were identified. Barriers to implementation of the Guidelines by in developing States and small-scale fisheries were discussed and some solutions were proposed. Finally, some information was provided on the FAO umbrella programme on “Responsible practices for sustainable fisheries and reduction of impacts of fishing operations”, which aims to support the implementation of the Guidelines.

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Reducing marine litter – a practical example of the Icelandic fisheries

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

Recent data shows that up to 90% of all Icelandic fishing gear that has reached its end of life has been sent to be recycled. Several factors contribute to achieving this remarkable number. Laws prohibit the discard of gear at sea. They further implement that vessel operators are liable and responsible for gear recovery and have a duty to report it. In 2005 the organization of companies of the marine sector of Iceland (SFS) signed a contract with the fund to provide gear collection facilities in all major harbours.



Figure 4. Gear collection facility at a fishing harbour in Iceland.

These facilities take old fishing gear from the Icelandic fleet without additional fees. Large companies and net makers take responsibility to sort disused gear by material and send it to facilities in Denmark and Lithuania. Foreign vessels can use the facilities as well but must pay for recycling. This voluntary commitment by the Icelandic fishing industry paired with the existence of a fund mandated by law led to nearly 1200 tons of fishing gear being sent to recycling facilities in 2016 alone (SFS, 2017).

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

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

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

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

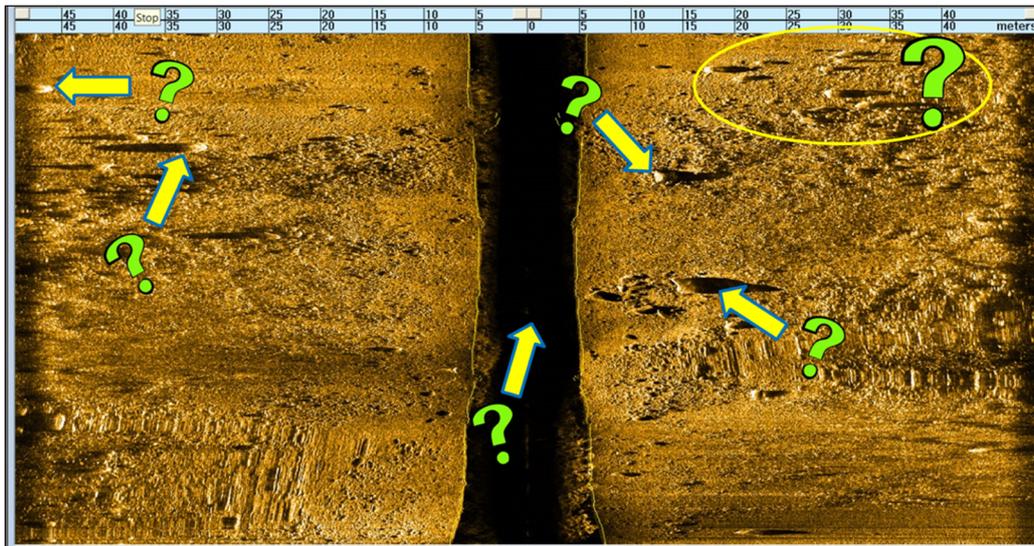


Figure 5. Finding ghost gear (lost lobster pots) with a side scan sonar provides challenges.

However, resulting detection rates for both habitats were low and not sufficient for pot abundance estimation in a larger survey area. These findings demonstrate that using side scan sonar surveys to quantify ALDFG lobster pots may be highly prone to error and that detection rates should be determined prior to estimating quantities of derelict gear.

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Stripping the beam trawl – get rid of abrasion protection

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In the European beam trawl fishery, strands of polyethene woven in to the lower panel of the trawl are widely used as abrasion protection. These - so called - 'dolly ropes' fray away very easily and consequently need to be replaced frequently (Figure 6). The torn off parts end up in the sea and contribute to the vast amount of marine litter. In addition to the general litter problem, dolly ropes

pose a direct danger to marine wild life, because sea birds use these strands as nesting material and therefore risk to get entangled in them. Last but not least, the fishery itself suffers, as the twines wrap around the ships propellers and the trawl gear, resulting in danger, damage and difficult removal procedures.

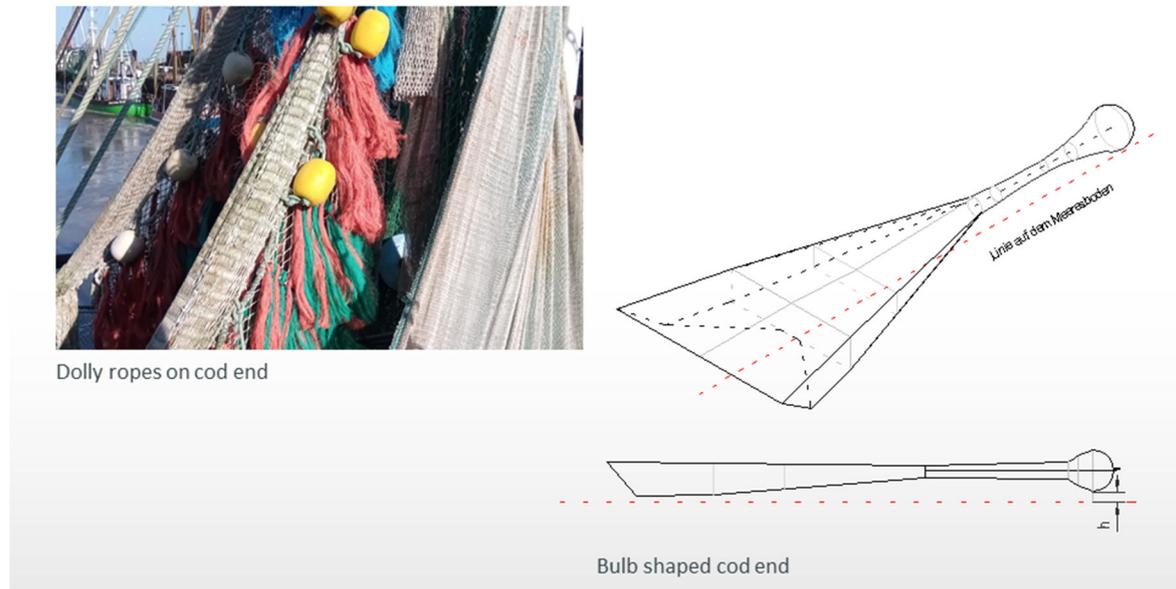


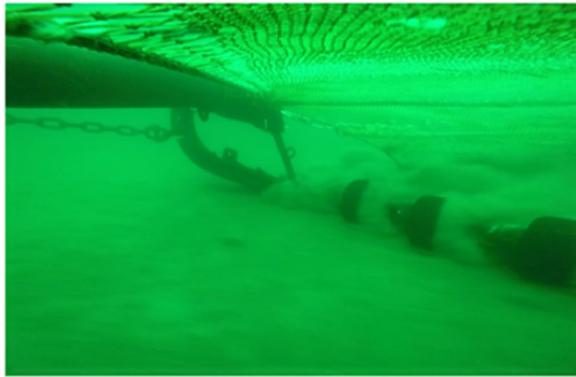
Figure 6. Dolly ropes use on cod ends.

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

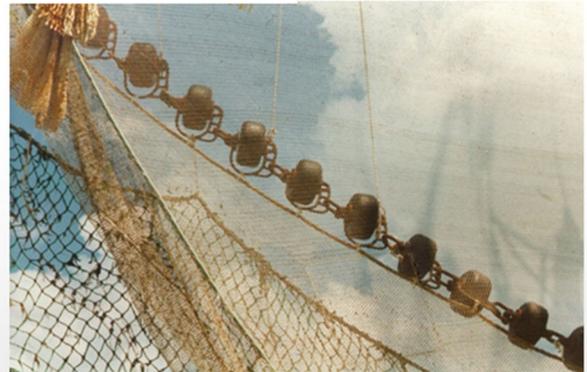
To identify reasons for ground contact of beam trawl nets and to develop and test potential solutions for avoiding such bottom contact, our project "Dolly Rope Suspension, DRopS" focuses on the North Sea beam-trawl fishery, targeting brown shrimp (*Crangon crangon*).

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

- a) use of passive (e.g. floats) and active (e.g. kites) buoyancy at the rear part of the net,
- b) reshaping the actual trawl design by using a special net cutting that results in an ascending trawl or using round straps to avoid ballooning of the codend,
- c) reduction of the amount of sediment that is swirled up by the ground gear using alternative groundgear designs (Figure 7),
- d) reduction of the amount of sediment in the trawl by releasing sediment, e.g. using benthos release panels or larger mesh sizes in the front sections of the lower panel.



Sediment swirled up behind ground gear



Tilted mounted ground gear bobbins

Figure 7. Use of bobbins to reduce swirling up of sediment.

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

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Session 2: Interactions of protected species in capture fisheries

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

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

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

Research undertaken at the New England Aquarium as well as by other groups worldwide was used to illustrate some of these measures and the lessons learned (Figure 8), especially drawing from experience with marine mammals.

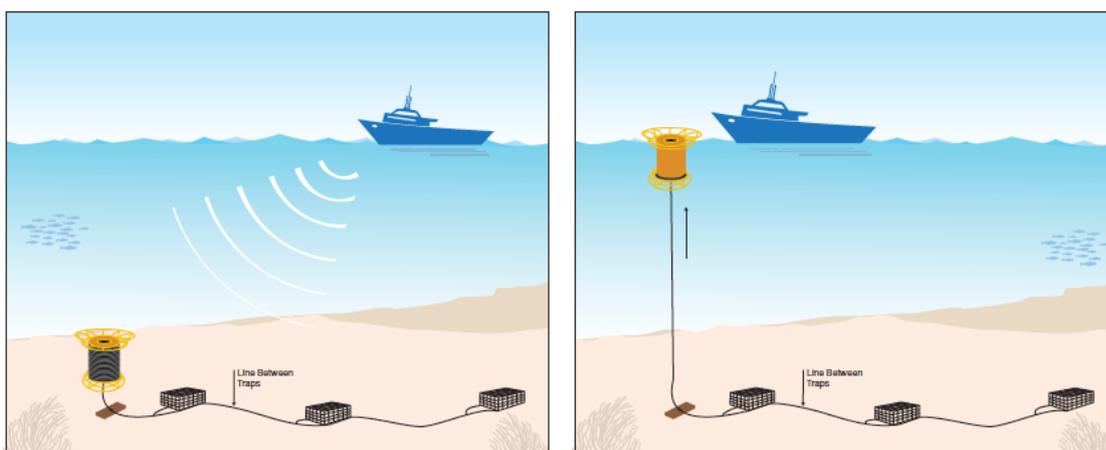


Figure 8. Testing of pop-up buoys/"rope-less fishing" to reduce marine mammal bycatch in pot fishing.

I also introduced some recent policy initiatives to address bycatch at the international scale, including the recent FAO endorsement the outcomes of a marine mammal-gillnet bycatch workshop, and the launch of the *Global Bycatch Exchange* to help serve as a clearinghouse of information on bycatch mitigation techniques, facilitate cooperation among stakeholders from government, industry, academic, and NGO sectors, and providing assistance to fisheries in identifying how to address bycatch obstacles in becoming certified or recertified under Marine Stewardship Council Standards.

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Porpoise bycatch mitigation and management tools used in Denmark

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The bycatch of harbour porpoise *Phocoena phocoena* is an issue of major concern for fisheries management and for porpoise conservation. Several solutions are available to prevent bycatch incidents here among acoustic deterrent devices (pingers), modification of fishing practices, gear change, reduction in fishing effort and area closures. In Denmark, the main tool to reduce bycatches used is pingers and currently new trials are conducted to collect knowledge on pinger effects with respect to increased pinger spacing. However, even though pingers have shown to have a positive effect on bycatch rates they can potentially keep porpoises away from e.g. important feeding grounds and maybe cause an even higher negative impact on the population than the incidental bycatch (Figure 9).



Figure 9. Pingers tests and their effects in terms of reducing bycatch.

Thus, if pingers are to be implemented it is important that it is only in areas where the risk of bycatch is substantial. To identify areas with potentially higher and lower risk of porpoise bycatch high-resolution spatial and temporal data on porpoise abundance and fishing effort has been used. Commercial gillnet vessels have been equipped with remote electronic monitoring (REM) systems. The REM system recorded time, GPS position and closed-circuit television (CCTV) footage of all gillnet hauls. REM data were used to identify fishing grounds, quantify fishing effort and document harbour porpoise bycatch. Movement data from porpoises equipped with satellite transmitters were used to model population density. A simple model was constructed to investigate the relationship between the response (number of individuals caught) and porpoise density and fishing effort described by net soak time, net string length and target species. The result showed that a simple

model including both porpoise density and fishing effort data could predict harbour porpoise bycatch. This type of model can thus be used as a tool to identify areas of bycatch risk and help managers to select the most appropriate solution for protection of the harbour porpoise.

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

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The United States' Marine Mammal Protection Act (MMPA) states that the United States shall ban the importation of foreign commercial fish or fish products, which have been caught with commercial fishing technology, which results in the incidental kill or incidental serious injury of marine mammals in excess of United States standards or of any fish or fish product that was produced in a fishery that intentionally kills marine mammals in the course of those fishery operations. Previously, NOAA Fisheries, in consultation with foreign trading partners assembled a List of Foreign Fisheries (LOFF). This LOFF contains global fisheries information for fisheries that export seafood products to the United States, including the target catch, gear type used, number of vessels or participants, area of operation of the fishery, and data regarding incidents of marine mammal interaction in the course of fishing operations. Fishery and marine mammal interaction information was provided by nations and cross-checked with published information from regional fishery management organizations and Food and Agricultural Organization's national reports, scientific publications, and grey literature. NOAA Fisheries is in year three of the five-year implementation period and here we provide updates on the implementation of this regulation, including the introduction of a new web-based portal for accessing fishery information and completing the 2019 Progress Report. The Progress Report asks fisheries managers to provide information regarding their nation's regulations relating to marine mammal bycatch and fisheries management with the goal of tracking the reduction of marine mammal interaction in commercial fisheries. We previously analysed fishing areas and gear types with the highest marine mammal incidental mortality. Passive gears, particularly gillnets, disproportionately entangle and kill more marine mammals than active gear types (Figure 10).

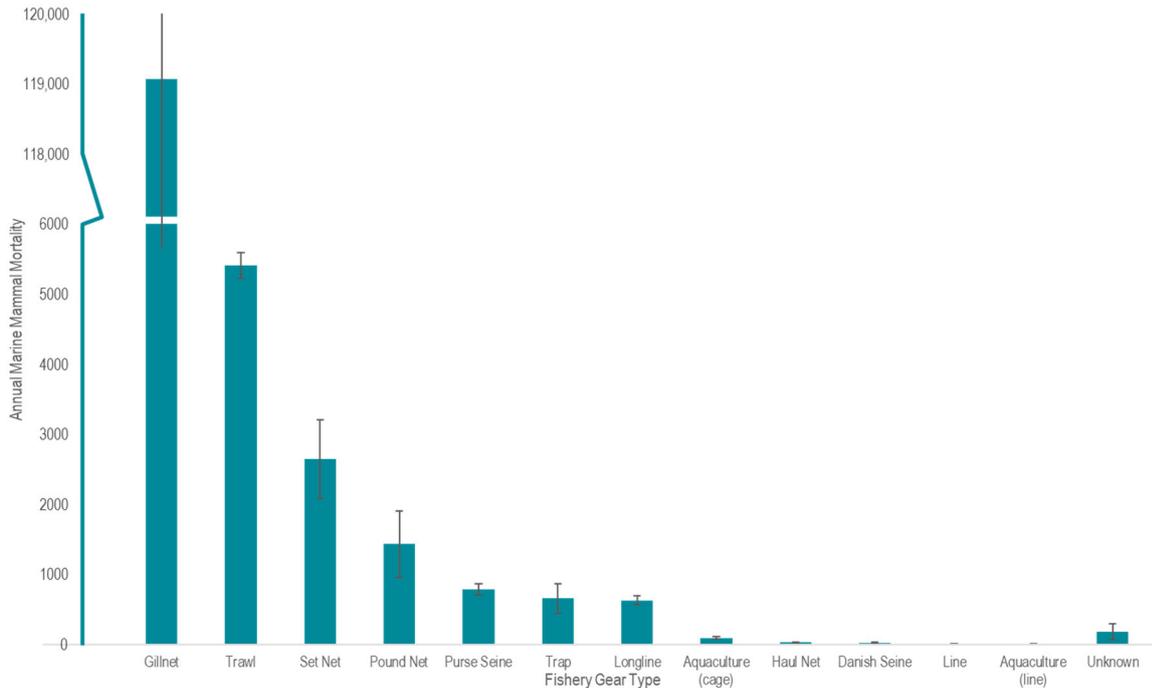


Figure 10. Bycatch of marine mammals by gear type in 2018 in the USA. Source NOAA.

A tried and true mitigation method to reduce harbour porpoise mortality is the use of net pingers, which act as a warning for porpoises in areas of submerged nets. However, for fisheries impacting multiple marine mammal species, no one method has been proven effective in reducing all interactions with nets.

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

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This study presents a newly developed soft-type turtle releasing device (Soft-TRD) for set nets. Setnets are one of the coastal passive fishing gears and consist of a lead net, pound nets, funnel nets, and fish chambers (bag nets) (figure 11).

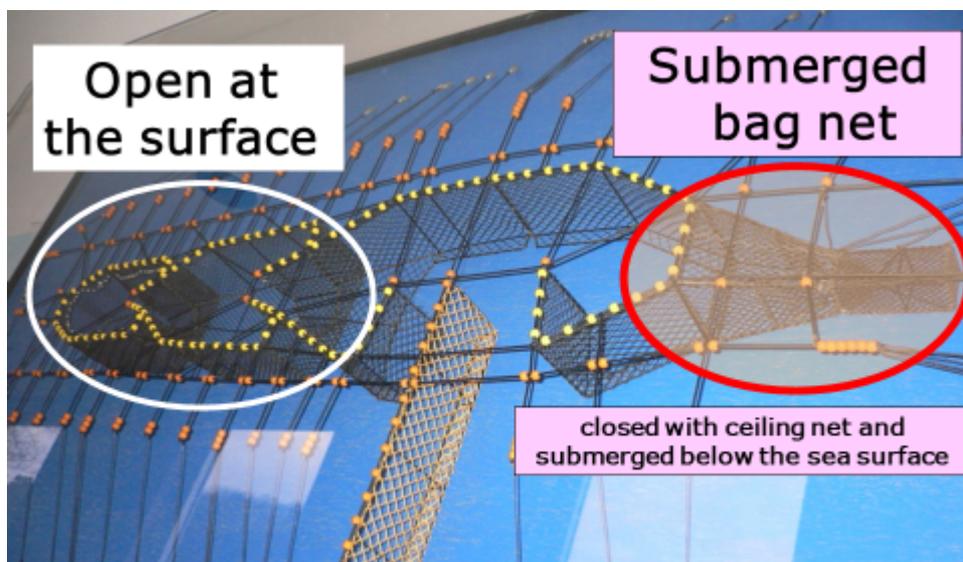


Figure 11. Set net fishing gears used in Japan; one bagnet is open at the surface.

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

In this study, a new type of TRD (Soft-TRD) without any solid frame was developed. The Soft-TRD has a slit as an escape component in the centre of a 2 m square net. By overlaying the net of both edges of this slit each other and attaching a float at each end, the escape part is closed to prevent fishes from getting out. When a sea turtle pushes the escape component upwards, the escape slit opens and allows the turtle to escape out from the bag net. A turtle releasing trial was conducted in an outdoor water tank, using an experimental bag net of which the Soft-TRD was mounted at the centre part of the ceiling. Four loggerhead turtles (SCL: 67.1-72.8cm) and five green turtles (SCL: 42.4-63.4cm) were deployed for the experiment. A single turtle was separately put into the experimental bag net, and its escaping behaviour was observed. In the model that has an escape slit of 1.5 m long, the width of overlaying 10 cm, and with a float of 4 kg in buoyancy at each end, all turtles successfully escaped out (Figure 12).



Figure 12. Optimum design of a soft TRD, tested in a basin.

The escape component was immediately closed after the turtles escaped. Sea trials were also performed in a submerged bag net (30m x 10m x 10m) with application of this system. About 90% of loggerhead turtles entrapped successfully escaped out through the Soft-TRD in 2-months of fishing operations. The operational activities of the respective fishermen were not interrupted by the introduction of the device. Our result revealed that the use of the Soft-TRD would be helpful in releasing sea turtles from the passive fishing gears such as the set nets, and contribute to the efforts of conserving sea turtles.

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

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Gillnets are well known for strong size selectivity of target species relative to mesh size. At the same time gillnets are responsible for a large part of the worldwide unwanted bycatch of marine mammals, turtles and birds. How gillnets select against bycatch like marine mammals is rarely discussed as data collections on unwanted bycatch are usually too poor. In this presentation, we attempt to compare data from Iceland and Nigeria. The gillnet fisheries of the two countries have distinct differences but both have bycatch of small whale and dolphin species. Harbour porpoise (*Phocoena phocoena*) and some dolphins species are common in the Icelandic bottom gillnets fishery targeting cod (*Gadus morhua*) while Nigeria is dealing with bycatch of various dolphin species in driftnet fishery targeting mainly various shark species (Figure 13). In Iceland, during the annual gillnet surveys the length of Harbour porpoise bycatch has been registered for each of 4 mesh sizes used (152,178, 203 and 229 mm) which represent commonly used mesh sizes in the fishery. The length distribution of the Harbour porpoise is very narrow. While no clear selectivity by length was observed there was a significant difference in the number of bycatches per mesh size. The data from the Nigerian fishery was collected by observers of 8 fishing boats of over a two-year period (2017 and 2018). 5 mesh sizes (102, 127, 152, 178 and 191mm) are in use to catch diverse species. The different mesh sizes show clear size selectivity for dolphins.

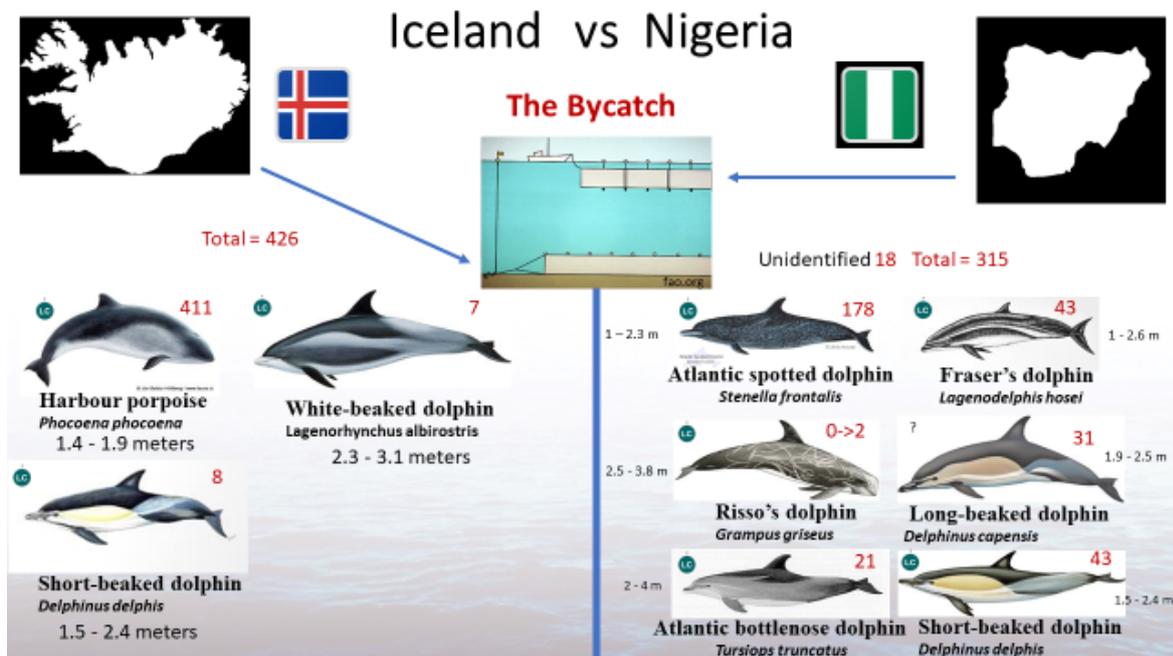


Figure 13. Bycatch of dolphins in Icelandic and Nigerian gillnet fisheries

Two datasets were compared and discussed. They both showed possible approaches how management of gillnet fisheries around the world can avoid or reduce the bycatch of small cetaceans.

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Session 3: Light, fish behaviour and fishing

Mesopelagic fish: responses to artificial light

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

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

The observations were done from the research vessel “Hans Brattstrøm” (25m) using a rig equipped with wide band acoustic transceivers (WBAT) (Figure 14), GoPro camera and different light sources. Lights used were diving torches with infrared, red, blue, green and white light – and stronger, white lights. Acoustic data were also recorded by the vessel’s echo sounder (Simrad EK60) and environmental data were collected by CTD and ADCP. A few biological samples were taken from the two upper mesopelagic layers, using a MIC-sampler.



Figure 14. WBAT rig with lights and camera.

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

- No/little response to the rig without lights and with infrared and red lights.
- No attraction to light was observed.
- Horizontal avoidance was observed to green, blue and white light.

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

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

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Session 4: Technology and management to reduce bycatch and discards

Vertical distribution of North Sea brown shrimp inside the trawl

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

The vertical distribution of shrimp influences where the shrimp hit the grid and hence how the contact probability and contact duration of shrimp and grid. To further understand and improve the efficiency of grids, it is important to take into account the vertical distribution of shrimp inside the trawl and its dependency on selection devices (i.e. sieve nets) and/or guiding panels. In this study, we experimentally investigated the vertical distribution of brown shrimp, using a device which split the aft of the trawl into four vertical compartments (Figure 15).

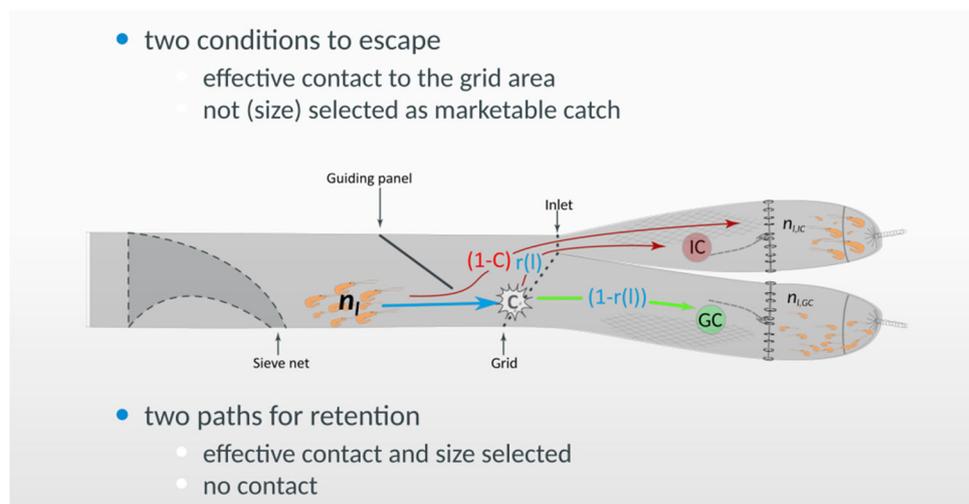


Figure 15. Experimental design for brown shrimp selectivity grid.

In particular, the standard codend was replaced by an extension piece mounting a quad-split frame, used to establish four vertically-arranged compartments. Small-mesh covers were connected to each frame compartments to collect the shrimps at different heights of the water column. Further, three different gear designs (D) were tested to assess the effect of sieve nets (D2, the most used Bycatch Reduction Device in the fishery) and guiding panels (D3) on the brown shrimp vertical distribution, relative to the baseline trawl design (D1).

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

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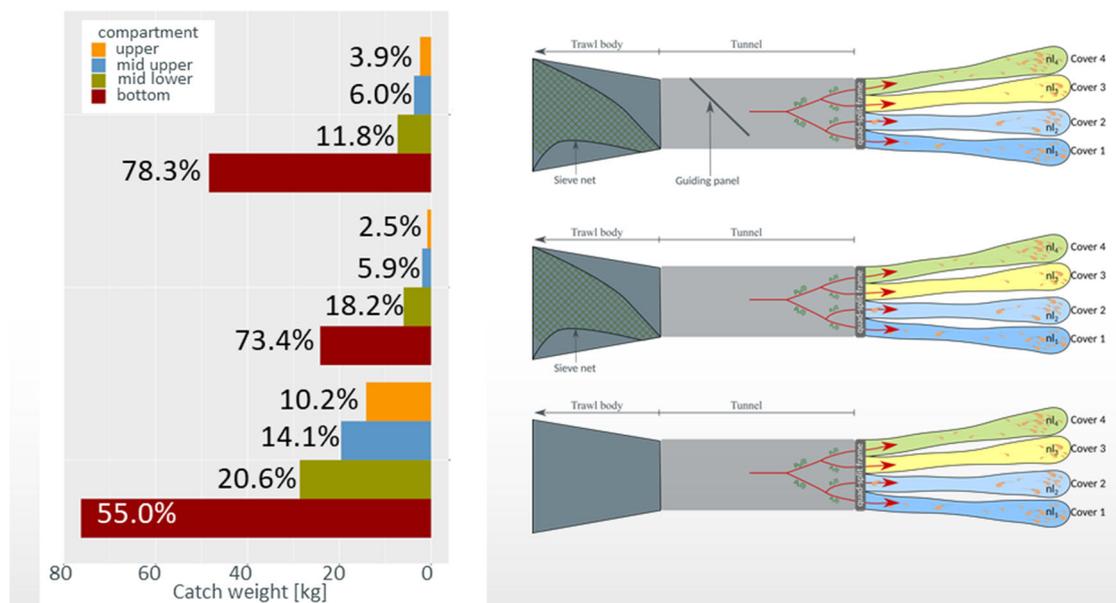


Figure 16. Vertical distribution of brown shrimp using sieve nets and a grid panel.

Contact probabilities ranged from 55% to 69% indicating further investigations are required in order to make the observed grid selectivity available for larger percentages of shrimps entering the gear.

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

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

The goal of this research was to reduce the bycatch of undersized whiting with an acceptable loss of other marketable fish. Scientific literature on flyshoot fishing is very limited, therefore the first phase of the project focused on acquiring video recordings of the behaviour of the caught fish. The fishing gear of a commercial flyshooting vessel (SCH-135) was equipped with go pro cameras to observe the behaviour of fish during the different catch phases, in relation to a square-meshed panel in the back of the net (mesh opening of 87.8 ± 2.3 mm) and to additional stimuli such as LED-lights and coloured ropes close to the panel. The recordings showed that a significant amount of whiting escaped through the panel (Figure 17). The LED-lights showed to have an effect on the behaviour of whiting, while the effect of other visual stimuli was negligible. A second phase of the project aimed at quantifying the escape rates through the panel without the use of additional stimuli. This was done by using a 2nd cod-end (mesh opening of 55.2 ± 1.0 mm) to collect all fish going through the panel. The results confirmed that 90% of the fish going through the panel was whiting, 48% of the total amount of undersized whiting (<27 cm) escaped.

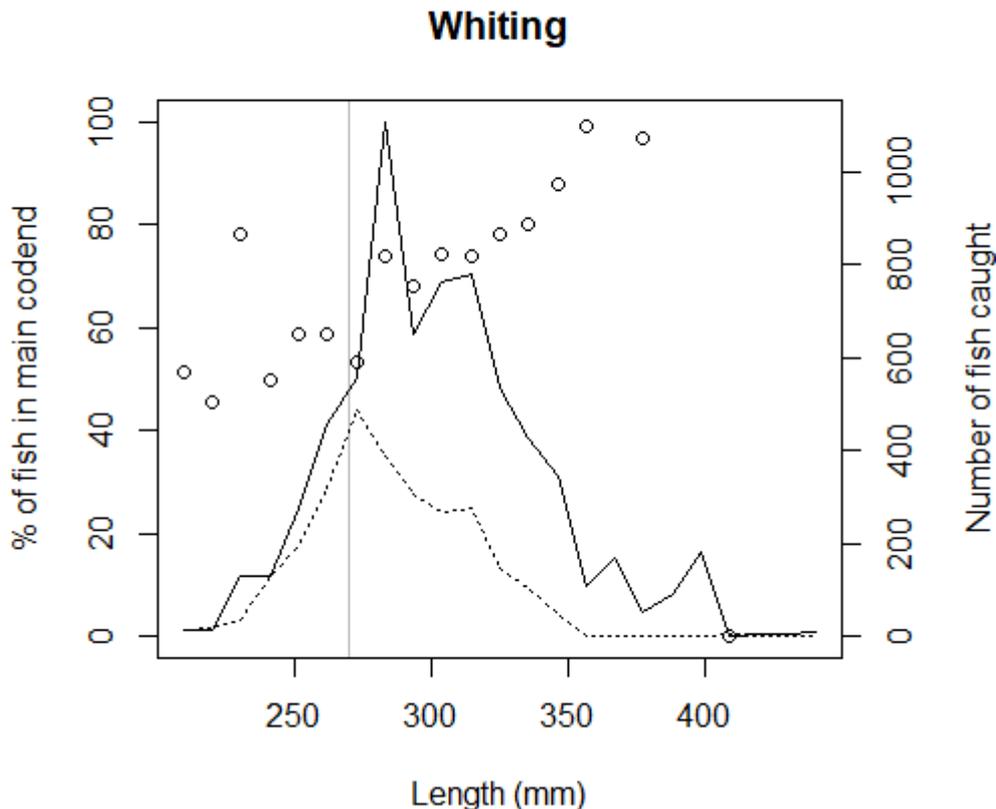


Figure 17. Effect of gear innovations on the catch of undersized whiting. Legend: Dotted line = Escape through panel; Solid line = Catch in main cod end

The only marketable species that was lost in a significant amount was red mullet smaller than 18 cm (20%), no squid or flatfish escaped. Our experiments show that the implementation of the panel can

help to reduce the bycatch of undersized whiting under the landing obligation, with only a very limited effect on the loss of marketable species.

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Keynote presentation

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

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

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

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

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

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



Figure 18. Phases of fishing operation and technology options to improve selectivity and avoid bycatch.

Examples were presented of the recently trialled and developing approaches and technologies from Europe and beyond, that could enhance selectivity at different phases of the fishing operation: 1) Deploying the fishing gear, 2) Monitoring the fishing operation, 3) Sorting the catch, 4) Reporting and landing the catch, and 5) Deciding to fish (Figure 18).

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Discards in global marine capture fisheries: the most recent update

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The Food and Agriculture Organization of the United Nations (FAO) considers bycatch and discards detrimental to the sustainability of ecosystem, fisheries and food security. Since the first report in 1994, two major updates were done with more and higher quality data and improved methodology. This presentation will provide methodology and key findings of the most recent update – A third update of global marine fisheries discards. This estimate adopted the ‘fishery-by-fishery’ approach employed in the second discards assessment published in 2005. The update included publicly available discard data in the last 20 years to establish a baseline of a time series of global marine fisheries discards (Figure 19). This is essential for monitoring the status and trends of discard management, which is the first step of the ecosystem approach to fisheries management cycle. The current study estimated that the annual discards from global marine capture fisheries between 2010 and 2014 was 9.1 million tonnes (95% CI: 6.7 – 16.1 million tonnes).

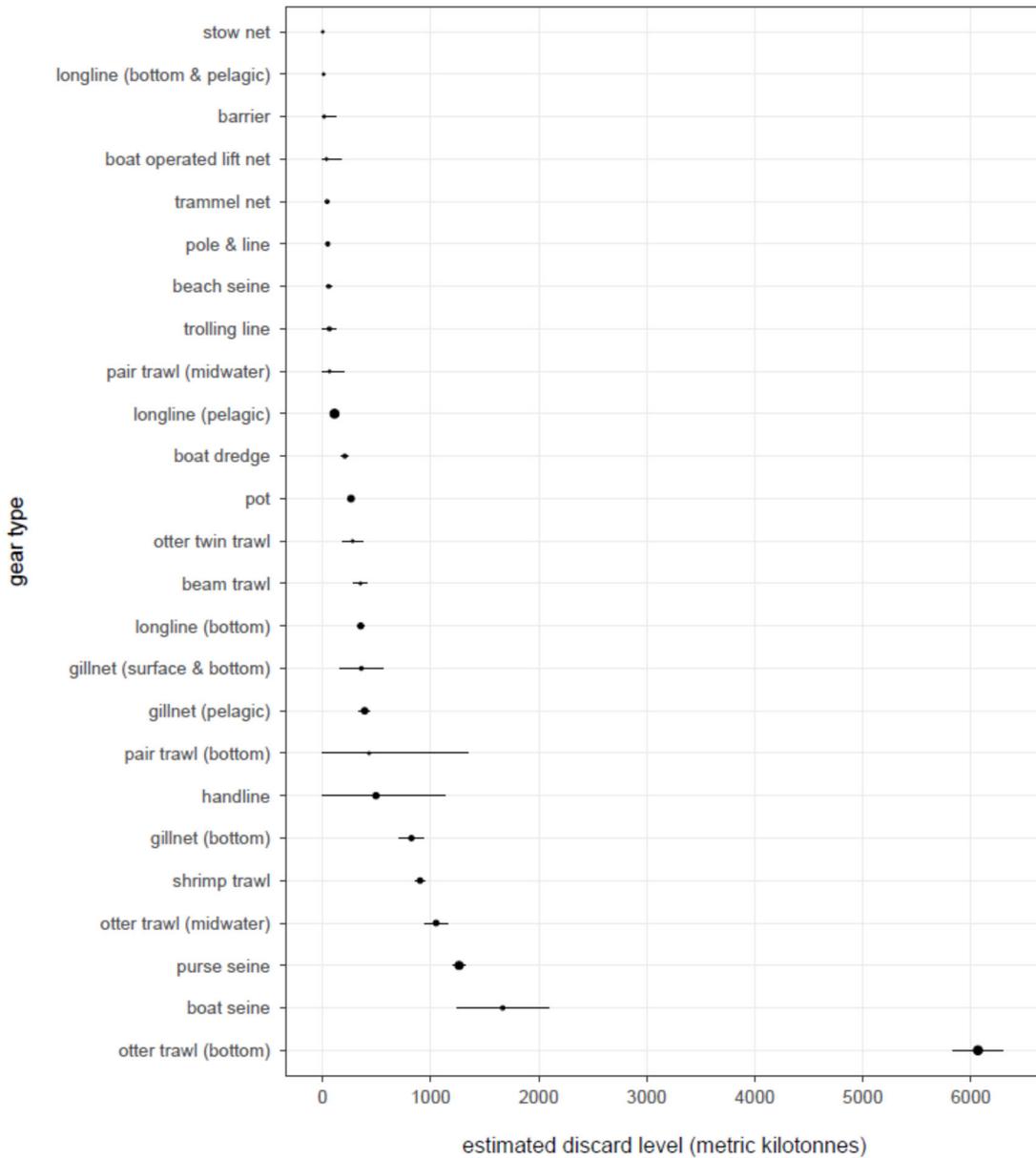


Figure 19. Mean discard levels (thousand tonnes) and 95% confidence intervals by gear type. The solid dots represent mean discard levels for different gear types, and their sizes are proportional to their sample sizes.

About 46% (4.2 million tonnes) of total annual discards were from bottom trawls. The study included a synthesis of estimates of bycatch and discards of endangered, threatened and protected (ETP) species. The report also included a review of previous research on discard practices, related regulations and management measures, and methods for accounting and mitigating against pre-catch, post-capture and ghost fishing mortalities to understanding of the relative importance of factors affecting indirect fishing mortality estimating total fishing-induced mortality and for designing and implementing mitigation measures.

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

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The GEF/FAO project on the Sustainable Management of Bycatch in Latin America and Caribbean Bottom Trawl Fisheries (REBYC-II LAC) seeks to improve the sustainability of these fisheries in Brazil, Colombia, Costa Rica, Trinidad & Tobago and Suriname. These are tropical multi-species fisheries with significant biodiversity and a disproportionate impact on local livelihoods and food security, requiring simple and practical approaches. A core output of the project rests on the introduction of bycatch reduction devices and improved fishing practices. The presentation discussed preliminary results of the introduction of various fishing gear improvements. In Suriname, tests of a flexible-TED for demersal fish trawl fisheries showed a 68-75% reduction in discards (mostly elasmobranchs). Fishers are not yet comfortable with the retention rate for marketable species, thus preventing voluntary uptake of the device. In the Colombian deep-water shrimp fishery, a prototype net showed a slight increase in target species catches, a 46% reduction in discarded bycatch and 24% reduction in fuel consumption (Figure 20).

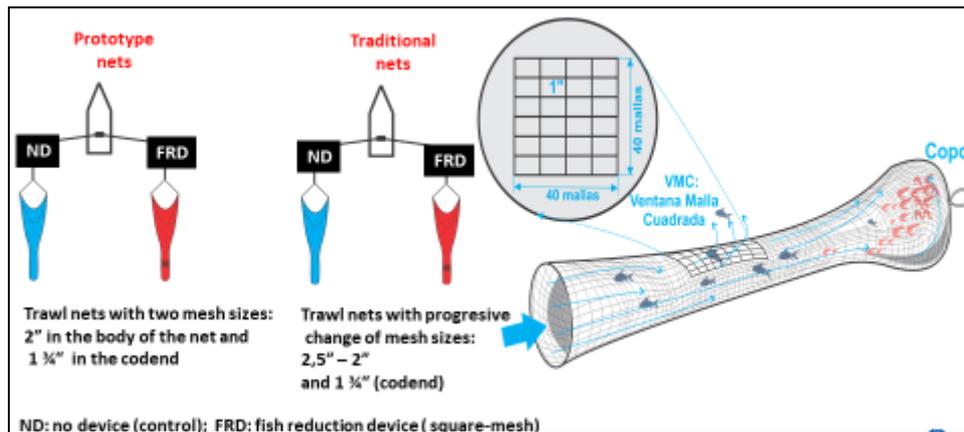


Figure 20. Test set-up of bycatch reduction devices in Colombian deep-water shrimp fishery.

Results are preliminary and require replication across different seasons, but the fishing industry is already switching to the new nets. In Mexico, results of three research cruises remain inconclusive given the variety of nets and trawling systems evaluated. In Trinidad and Tobago, a square mesh added to the cod end showed a significant 24.5% reduction of discarded species. None of the nets and devices tested are innovative, but overexploited, under regulated and over-capitalized fisheries require simple gear solutions if fishers are to adopt new practices. The Latin America and Caribbean region continues to suffer from inadequate capacity to develop and properly evaluate alternative fishing gear and bycatch reduction devices. International funding and technology/knowledge transfer are urgently required. Alongside its partners, the REBYC-II LAC has fostered an enabling environment in project countries, which includes policy and normative changes as well as increased stakeholder participation in the decision-making process. Dialogue and participation have strengthened trust between policy makers and fishers, leading to desired management processes. Change will require expertise, time and patience. FAO is committed to expanding its support for bycatch management in trawl fisheries and is looking for partners for new initiatives in the Near East and Africa and partners for follow-up activities in Southeast Asia and Latin America and the Caribbean.

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

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Square mesh panels (SMPs) are often applied as supplementary selectivity devices in the upper part of the trawl gears (e.g. extension or codend). To work efficiently, SMPs need to be attractive enough to induce fish attempts to contact with them. As for any other event taking place during the catch process, attractiveness to the SMP can involve complex behavioural mechanisms. However, this is often not properly assessed and can lead to wrong assumptions, e.g. fish contact is length-independent. Therefore, evaluating the primary attractiveness of the device is essential to develop more efficient selection devices. Based on catch comparison data collected with twin trawls, we assessed the attractiveness of top SMP on Baltic cod. Both trawls used non-selective codends, therefore the only escaping zone was an SMP inserted in the extension piece of one of the trawls. The SMP was made of thin, single twine and very large mesh size (200 mm) netting to avoid mechanical size selection, and to establish a zone with high sensorial contrast relative to the net tunnel to enhance attractiveness (Figure 21).

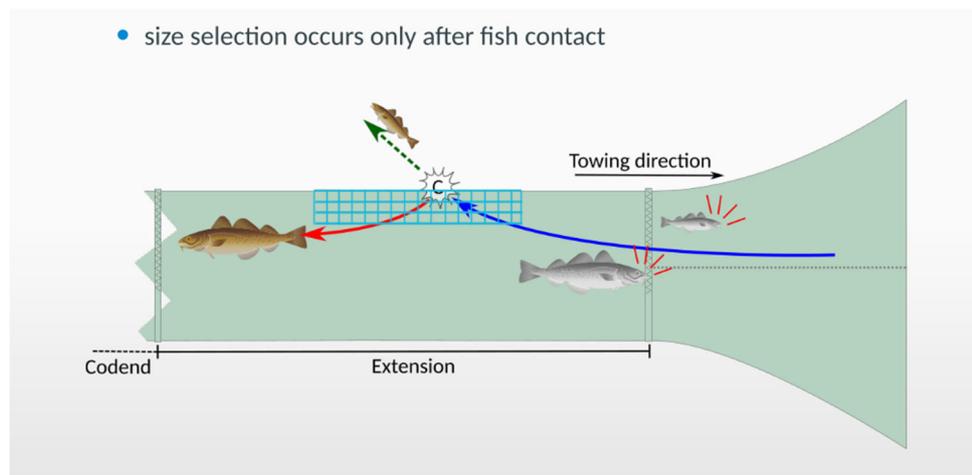


Figure 21. Assumed selective process of an SMP in a codend extension.

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

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

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A new bycatch reduction device (BRD), termed “Excluder”, is presented as an alternative to the traditional rigid sorting grids, which are mandatory in the industrial Norway Pout fishery in the North Sea (Figure 22). This fishery is a high-volume fishery with large demersal trawls and catches up to 200 tons per haul. The Excluder is a 24-meter long selective netting section with no rigid structures, developed to reduce bycatch and improving on-board gear handling. The Excluder (78 mm full mesh) was tested against a 1.6 x 3.6 m standard grid (35 mm bar spacing) in a twin-trawl experiment on-board the commercial 70 m trawler “S364 Rockall” on the Fladen Ground in the North Sea in November 2018. The resulting 11 twin-trawl hauls formed the data basis of length-dependent catch comparison and catch ratio analyses of target and bycatch species. For the target species, Norway Pout, there was an estimated increase in the average catch efficiency of 32 % (3 – 95 %).

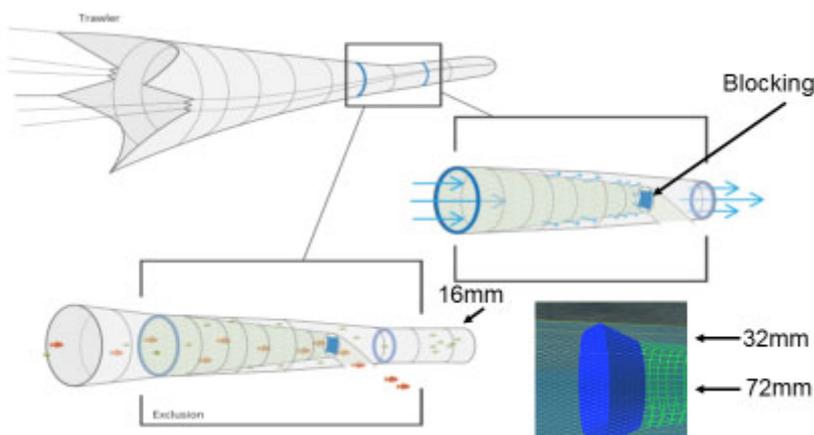


Figure 22. Excluder design principal by DTU Aqua

However, when considering the confidence limits, this increase could be as low as 3 %. For all 6 bycatch species considered, we estimated that the Excluder substantially reduced catches, either length-based or on average. The catches, averaged over all length classes, by the Excluder were: herring (21 %; CI: 11-49 %), mackerel (5 %; CI: 2-14 %), whiting (6 %; CI: 4-11 %), American plaice (70 %; CI: 27-142 %), witch (15 %; CI: 0-27 %), and lesser silver smelt (71 %; CI: 54-95 %) when compared to the grid. Therefore, if the size distributions encountered during the experimental fishing are typical of the commercial fishery, the use of the Excluder would lead to a substantial reduction in bycatches. Potentially, bycatch reduction could be improved further in the Norway pout fishery through modifying the mesh size of the Excluder. We also highlight that the Excluder has a large potential for improving selectivity in a number of other trawl fisheries with bycatch issues.

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

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Global efforts to reduce unwanted catches have led to the development of a vast array of bycatch reduction devices (BRDs), in particular for mixed demersal trawl fisheries. An example is the *Nephrops* (*Nephrops norvegicus*) directed mixed trawl fishery in the Northeast Atlantic, where modifications to most components of the gear have been tested and documented in literature. Since achieving the desired reduction of bycatch in these fisheries is rarely obtained via one single modification, some of these BRDs could be combined to further optimize selectivity. However, testing all possible combinations of documented BRDs would be prohibitive in terms of time and resources. So how do we identify potentially beneficial combinations? We can combine the species-specific, size-selectivity of each individually tested BRD and predict their combined selectivity and performance under different catch scenarios (Figure 23).

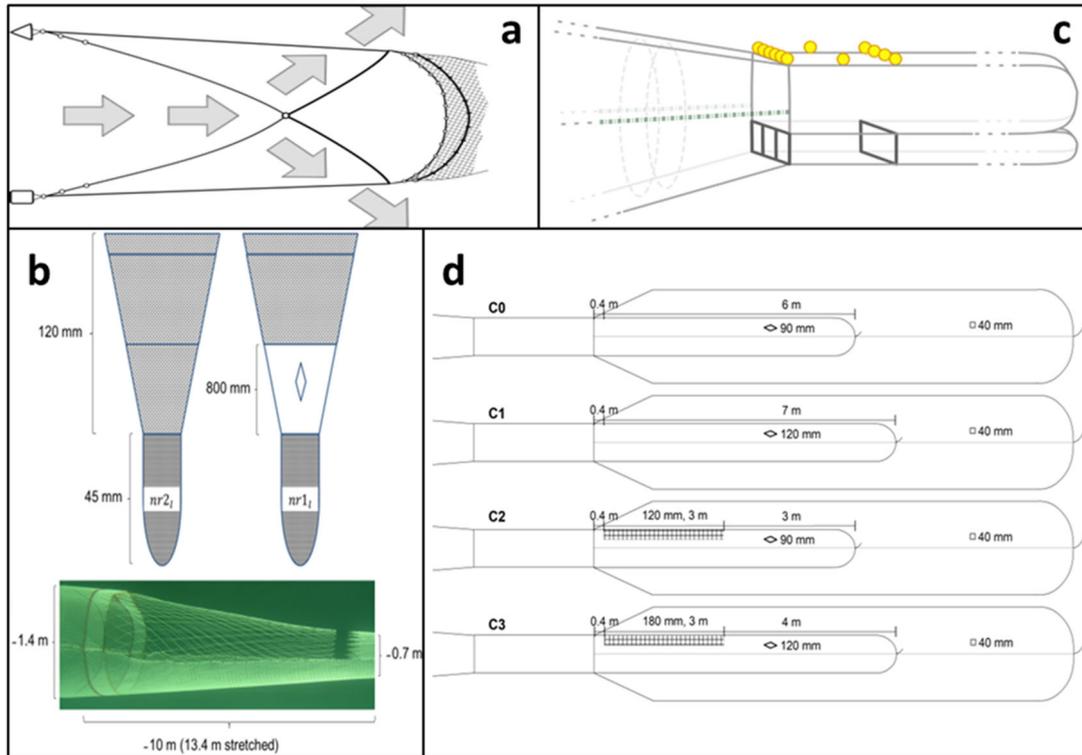


Figure 23. BRD options considered include FLEXSElect in the herding area, a large mesh size in the upper netting of the body section, the vertical separation and codend modifications.

For the *Nephrops*-directed fishery we considered a counter-herding device (FLEXSELECT), a modification of the netting in the trawl body, a horizontal separation and multiple codend configurations. From the pool of 100 possible combinations, we identified 15 promising BRD combinations that warrant experimental investigation. Moreover, the results highlighted that an anterior modification such as FLEXSELECT, that can be applied or removed at the haul-by-haul level, creates quickly interchangeable combinations that could lead to a more flexible and dynamic trawl selectivity.

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

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Benthos release panels (BRPs) were studied in the early 2000's as a tool to decrease the bycatch of benthos and debris, with authors such as Revill & Jennings (2005) and Fontyne & Polet (2002) reporting reductions over 80% for invertebrates and non-commercial fish and over 50% for debris such as stones and litter. Unfortunately, this square meshed panels in the belly of the net also allowed over 20% of the commercial sole (*Solea solea* L.) to escape, which was an unacceptable loss for fishermen so the BRP was never implemented.

However, the importance of fish quality and discard survival, which may improve as a result of the smaller and cleaner catches, has increased a lot in recent years. Therefore, several experiments have been done on the R.V. Belgica over the past 5 years to prevent the loss of commercial sole, testing and successfully optimizing (electrified) benthos release panels with two different approaches. The first focused on removing the slack previously observed in the panel. By implementing a stretched BRP in a net with rectangular footrope/square net, the BRP showed no more 'bagformation', eliminating horizontal escape possibilities for sole to zero in case of a 150 mm BRP (Figure 24).

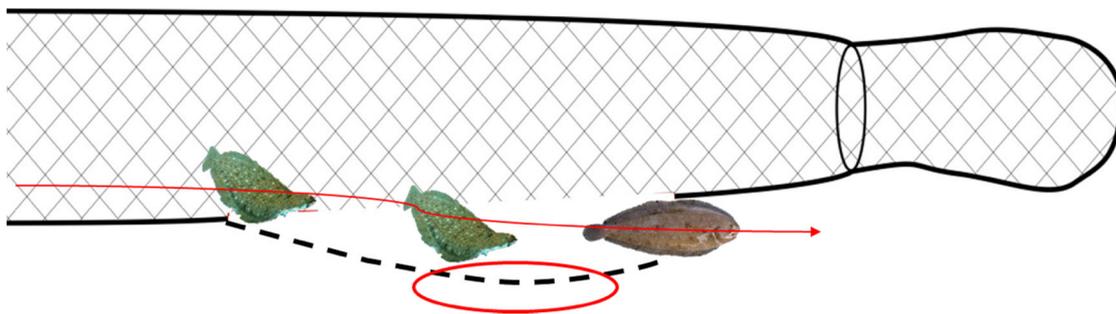


Figure 24. Elimination of bag formation is important reduce accumulation of material which facilitates escapement of sole and increases contact with the seafloor and potential damage.

The second configuration used an electrified cramp stimulus of 40 Hz on top of the panel to immobilize sole and prevent active escapement. As a result, this so called electrified BRPs (eBRP) can use larger mesh openings to 200 mm, further increasing the loss of benthos and debris, without losing commercial fish.

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

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Bycatch in fisheries can have profound effects on the abundance of species with relatively low resilience to increased mortality, can alter the evolutionary characteristics and concomitant fitness of affected populations through heritable trait-based selective removals, and can alter ecosystem functions, structure and services through food web trophic links. We challenge current piecemeal bycatch management paradigms, which reduce the mortality of one taxon of conservation concern at the unintended expense of others. Bycatch mitigation measures may also reduce intraspecific

genetic diversity. We drew examples of broadly prescribed ‘best practice’ methods to mitigate bycatch that result in unintended cross-taxa conflicts from pelagic longline, tuna purse seine, gillnet and trawl fisheries. We identified priority improvements in data quality and in understanding ecological effects of bycatch fishing mortality to support holistic ecological risk assessments of the effects of bycatch removals conducted through semi-quantitative and model-based approaches. A transition to integrated bycatch assessment and management that comprehensively consider biodiversity across its hierarchical manifestations is needed, where relative risks and conflicts from alternative bycatch management measures are evaluated and accounted for in fisheries decision-making processes. This could be accomplished, for example, by adapting the current piecemeal International Plans of Action of the Food and Agriculture Organization of the United Nations into international guidance for integrated assessments and management of fisheries bycatch. This would enable managers to select measures with intentional and acceptable trade-offs to best meet objectives, when conflicts are unavoidable.

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

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Shrimp trawling is one of the most important economic activities worldwide. The low selectivity of these gears results in a high bycatch ratio, and the lack of basic information on bycatch amount and composition in shrimp trawl fisheries hinders the management and conservation strategies. In these contexts, the project on Sustainable Management of Bycatch in Latin American and Caribbean Trawl Fisheries (REBYC II – LAC) has, among its goals, to establish baseline information on the impacts of shrimp trawling on bycatch species in Brazil, to develop and test bycatch reduction devices and use these technologies as part of management process. The project is active in three regions of Brazil, namely: North (Bélem, Pará State), Northeast (Barra de Sirinhaém, Pernambuco State), Southern (Santa Catarina and Rio Grande do Sul States). The first goal of the project was to assess the bycatch composition and abundance for different shrimp fisheries, as well as investigating the temporal and spatial variation. For instance, interannual bycatch of legal (fyke net) and illegal (trawling) fisheries were assessed in order to understand the main factors influencing the bycatch composition. Results indicated that the bycatch from trawling is composed of a higher number of species (61), some endangered. The second goal was to improve the selectivity of shrimp trawl gears by using bycatch reduction devices. In Barra de Sirinhaém, South of Pernambuco, a series of 108 tests were develop using fisheye, square-mesh and Nordmøre grids. The tests showed positive results, and the BRDs were able to significantly reduce bycatch with very low shrimp loss (Figure 25). It is also important to highlight that the fishermen were involved in the process and their needs were taken into consideration in the development of these devices.

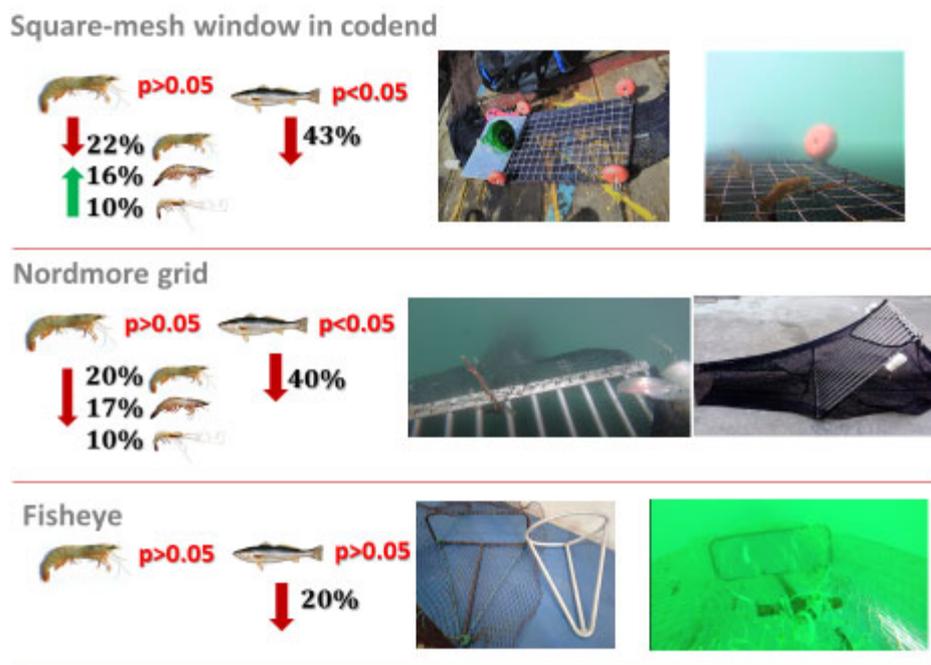


Figure 25. Some findings from BRD testing in shrimp trawl fisheries in Barra de Sirinhaém, Northeast Brazil.

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

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Session 5: Selectivity of fishing gear: Means and methods

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

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The size selectivity of a traditional T0 mesh codend was compared to experimental T45 and T90 mesh codends in the inshore Northern shrimp (*Pandalus borealis*) fishery of Iceland (Figure 26). Results showed that there was no significant difference in size selectivity of Northern shrimp between the T0 and T45 codends at lengths greater than 13 mm (Minimum references size; MRS); size selectivity for Northern shrimp less than the MRS was undetermined due to small catches at those sizes. Size selectivity was significantly different between T0 and T90 codends and T45 and T90 codends. The T90 codend retained less Northern shrimp between 9 and 19 mm than the T0 codend, and retained less between 15 and 19 mm than the T45 codend.

T0 – traditional diamond

T45 – square

T90



Figure 26. Mesh sizes of codends tested in the inshore Northern shrimp fishery of Iceland.

In conclusion, the T90 codend had better size selectivity than the other codends, decreasing the catch of undersized Northern shrimp at 9-12 cm when compared to the traditional T0, however capture of commercial sizes 13-19 cm are also captured less.

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

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The Campeche industrial shrimp fleet is the most important fishery in the Gulf of México. It fishes on endemic pink shrimp (*Farfantapenaeus duorarum*), producing in average 4 000 tonnes/season over this decade with reduced nominal effort (248 trawlers in 2008 and 102 in 2017; average yield: <3.5 tonnes/vessel/season). The fleet profitability is low, since old vessels continuously require repairs, fuel represents >85% of the total operative costs and local markets prefer juvenile shrimp.

A prototype of a lighter and selective shrimp net was tested in that fleet during 2018, framed by the FAO-GEF project “Sustainable Management of Bycatch in Latin America and Caribbean Trawl Fisheries” (REBYC-II LAC). The net has a four panels design; 50’ of head rope, buoy less, made with knotless Spectra™ webbing panel (4 ply); there is a mesh size gradient from 60 mm to 44.45 mm, connected to cod ends of P.E. 44.45 mm or 38.1 mm. It includes a turtle excluder device (Super shooter, downward exit), a fish excluding device (fish eye, 3.4 m forward from drawstring), and a second footrope as a drag train without tickle chain. The net performance was assessed using traditional wood trawl doors (8’x 40”, 180 Kg/each.) and steel hydrodynamic doors (Polar™ Neptune of 1.3m², 230Kg/each.) in quad-rigs arrangement (2 nets by board). The use of Acoustic Notus™ sensors and tension meters in three 15-day experimental cruises undertaken at different moments of the shrimp season (April, August and December) allowed the characterization of the net behaviour and its catches (Figure 27). The prototype net showed good performance and efficiency for fishing larger shrimp, while reducing by 40 % the bycatch of benthic species and offering lower resistance to the vessel advance.



Figure 27. Inspection of the nets during research trawls.

Vessels operating prototype nets operated at lower revolutions per minute (RPMs), implying reduced fuel consume. Steel trawl doors were difficult to operate in the third cruise and modifications in the drag train of prototypes during that cruise affected the catch and selectivity as well. A fourth cruise will be undertaken in the summer of 2019 for achieving 30 trials with strict statistical robustness. The local fleet has agreed on continuing testing the prototype net and fleets from other regions of Mexico are also requesting tests on board their vessels. This represents an opportunity for modernizing and improving Mexican shrimp trawling fishing and producing sustainable seafood.

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Study on the selectivity of stow net in the Haizhou Bay

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The Haizhou Bay is one of China's famous traditional fishing grounds, and also marine spawning grounds, feeding grounds and migration field. Stow nets are the main fishing gears used in Haizhou Bay, and mainly catch shrimp and small fish with a bycatch of crab and other shrimps. It is of great significance to study the selectivity of stow net for the admittance of stow net and the protection of marine fishery resources in this area (Figure 28). In this study, the selective tests of three mesh sizes of codends for the main economic varieties (*P. polyactis*, *T. curvirostris* and *O. oratoria de Haan*

were carried out by the cover-net method. The research showed that when the mesh sizes were 30mm, 35mm, and 40mm, the 50% selection lengths L_{50} of *P. polyactis* were 7.920cm, 9.503cm and 11.229cm, while the selection ranges (SR) were 1.975cm, 2.306cm, 3.775cm, respectively; the 50% selection lengths L_{50} of *T. curvirostris* were 5.400cm, 5.901cm, 7.404cm, while the selection ranges (SR) were 1.283cm, 1.376cm, 1.709cm respectively; the 50% selection lengths (L_{50}) of *O. oratoria de Haan* were 7.844cm, 8.324cm, 9.602cm, while the selection ranges (SR) were 2.680cm, 2.719 cm, 2.973cm respectively.

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		PE 42tex		
79	7.50	4*3	95	1800
85	5.95		70	1800
99	5.95	3*3	60	1800
113	5.10		45	1500
198	5.95		30	1100
255	5.10		20	750
425	4.25	3*2	10	600
88	1.5		17	
	41.3			

Figure 28. The main dimensions of the stow net (Tanzi net) used in this research are 53.9m×41.3m with a mesh size in the cod end of 17mm.

The selective tests of four mesh sizes of square mesh escape windows for *Pseudosciaena polyactis* and *Trachypenaeus curvirostris* were carried out. The research showed that when the mesh sizes were 35mm, 40mm, 45mm and 50mm, the 50% selection lengths L_{50} of *P. polyactis* were 9.27cm, 12.54cm, 13.46cm and 15.94cm, while the 50% selection lengths L_{50} of *T. curvirostris* were 6.01cm, 6.15cm, 7.73cm and 8.66cm. The results can be used as reference to determine the minimum mesh sizes and design selective stow nets for use in Haizhou Bay.

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

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The European Union landing obligation discard plans specify technical measures to increase gear selectivity and reduce unwanted catches. Scope exists to add more gears where equivalent selectivity for key species can be demonstrated. Ireland's commercially important Celtic Sea seine-net fishery is impacted by the technical measures. Seiners traditionally use a 100 mm diamond mesh codend

with 120 mm square mesh panel (SMP), but also a 120 mm diamond mesh codend (T0 120) without a SMP which helps prevent fish meshing in the SMP when hauling the seine. The T0 120 is not included in the technical measures. This study aimed to compare selectivity between T0 120 and a gear which is included in the Celtic Sea technical measures, a 100 mm T90 mesh codend (T90 100).

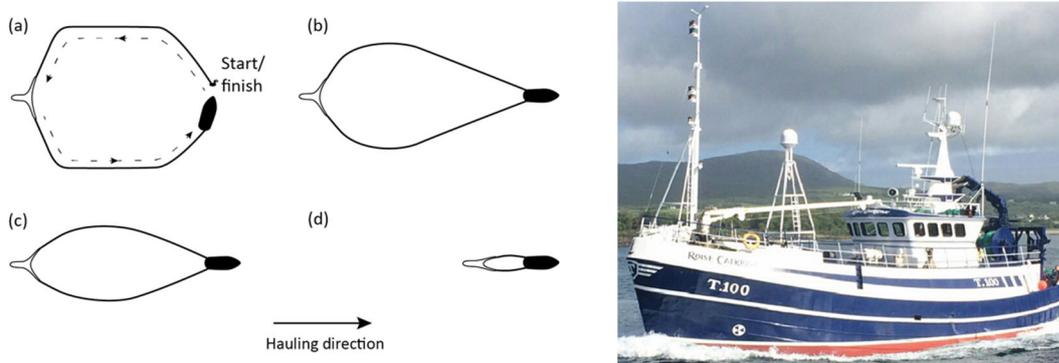


Figure 29. Seining operation description (a-d) and the vessel Róise Catriona (T100) used in this research.

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

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

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A new mesh configuration trawl was conducted in the East China Sea. Traditional diamond mesh and square mesh codends with 40mm, 50mm, 60mm, 65mm, mesh size were tested using the cover net method. The catch data using different sets of net configurations, different mesh sizes were analysed. Selective parameters were estimated by using a logistic equation with the maximum likelihood method and significant differences of two mesh configurations were analyzed with SPSS software. The results show that: 1) when the codend mesh size is 40mm, *P. polyactis* cannot escape from the codend, neither is selective. The other three mesh sizes display that square mesh escape rates are slightly higher than diamond shaped mesh sizes, but escape rate differences were insignificant ($P > 0.05$); 2) when the mesh sizes were 60 and 65mm, square mesh configuration capsule 50% retention length ($L_{0.5}$) then the corresponding diamond mesh bag, the square mesh has a better selectivity on *P. polyactis*; 3) For the *P. polyactis* with a 50% retention body length ($L_{0.5}$),

and using the current catch standard and capture fishery production, the appropriate trawl has a diamond shaped mesh size of 60mm or square mesh size of 55cm, both of two have the same selectivity and practical application effect.

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

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Electrified pulse trawls have replaced traditional tickler chain beam trawls in the North Sea fisheries for sole (Figure 30). This study investigates the mesh selection in pulse trawling of conventional cod-ends (80 mm cod-end mesh) used in the current pulse trawl fishery, and the effects of increasing the cod-end mesh size to 90 mm on catches of sole (*Solea solea*) and undersized plaice (*Pleuronectes platessa*). Cod-end selectivity was estimated for 79-80 mm and 87-88 mm codends during two experiments on a commercial pulse trawler using a cover cod-end.



Figure 30. Electric pulse trawl operation at the 40 meters pulse trawl vessel TX 94

The results show that with a mesh size of 79-80 mm the length where 50% of the individuals are retained (L50) for sole is 19 cm with a selection range (SR) of 4.9 cm. Given the observed length distribution of sole on the fishing ground this results in a 10% loss of marketable sole catches in the 24-27 cm length range. Increasing the mesh size in experiment one to 87 mm resulted in a L50 for sole of 22 cm with SR = 4.9 cm and in experiment 2 to a L50 of 26 cm and SR = 4.9 cm was found for 88 mm cod-end, resulting in a loss of marketable sole of 24% and 38% in experiment 1 and 2, respectively. These losses were detected in the 24-33 cm length range. Compared to sole, plaice showed steeper selection curve with a L50 of 14.4 cm (SR 2.5) and 14.1 cm (SR 2.1) for the 79-80 mm cod-ends in experiment 1 and 2, respectively. In the 87 mm cod-ends, this L50 shifted to 15.6

cm (SR 2.5) for experiment 1 and 18.7 cm (SR 2.1) for the second experiment. The ratio of plaice discards per kg marketable sole caught was 0.4 in experiment one for 80 mm cod-ends, and increased to 0.5 in an 87 mm cod-end. In the second experiment this was 2.3 for 79 mm and 2.5 for 87 mm. Increasing the minimum cod-end mesh to 90 mm thus increases the discard quantities of undersized plaice when the sole total allowable catch (TAC) is fully exploited.

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Session 6: New technologies for fisheries research and education

Development of acoustic catch monitoring methods for purse seine fisheries

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Control over catch size, composition and behaviour in relation to fishing gear is important for sustainable and economic fisheries. In purse seine fisheries targeted fish schools are acoustically evaluated before the seine is set. Despite this, unwanted fish may be caught by the net. It is then important to obtain school information before the fish densities inside the seine reach detrimental levels and it is still legal to release the catch. Currently, no suitable monitoring systems exist, mainly because of difficult observational conditions during fishing. The aim of the present work is to obtain a better understanding of the acoustic environment (obstructions between the seine and acoustic transducers, such as propeller-generated air bubbles and the seine itself) and to thereby develop improved catch monitoring methods for purse seine fisheries. Our studies indicate that propeller generated air bubbles and the seine net significantly interfere with the acoustic beams, making catch monitoring with vessel mounted instruments difficult. A new approach is now being developed, whereby an echo sounder is deployed into the water enclosed by the seine net. Initial experiments were made in June 2018 in the North Sea, during the Atlantic herring fishery. The echo sounder (Simrad ES200 – 7CDK transducer and WBT mini transceiver – Figure 31) was deployed from a flying drone, and acoustic data were transferred and visualized in real time onboard the fishing vessel.



Figure 31. High frequency Aris and 120 kHz echosounder used in the research.

A single beam echo sounder will not give as good an overview of the school as a vessel-mounted multibeam sonar, but has the potential to provide more detailed information on school density and vertical distribution. This system combined with sonar may also provide more accurate school biomass estimates if used before the seine is set.

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Open source software for statistical models of gear selectivity

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

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

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

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

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

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Open Scientific Measurement Board (OpenSMB)

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

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

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

Under this premises, the 'open scientific measurement board' (openSMB) was developed, a scientific Open Source data acquisition system to be used in fisheries sciences (e.g. in Lab, at sea, at commercial vessels). The system includes a highly flexible, modular and future-proof software and hardware, which is easily adaptable to future needs in fisheries science (or even in other scientific fields, such as agriculture). Key design criteria are platform independency, use of standard industrial components, standard formats (e.g. JSON) and interfaces for data and scalable hardware (Figure 32). Due to the integrated SBC (single board computer) the openSMB is far more than a simple fish length measurement device with 1 mm resolution.

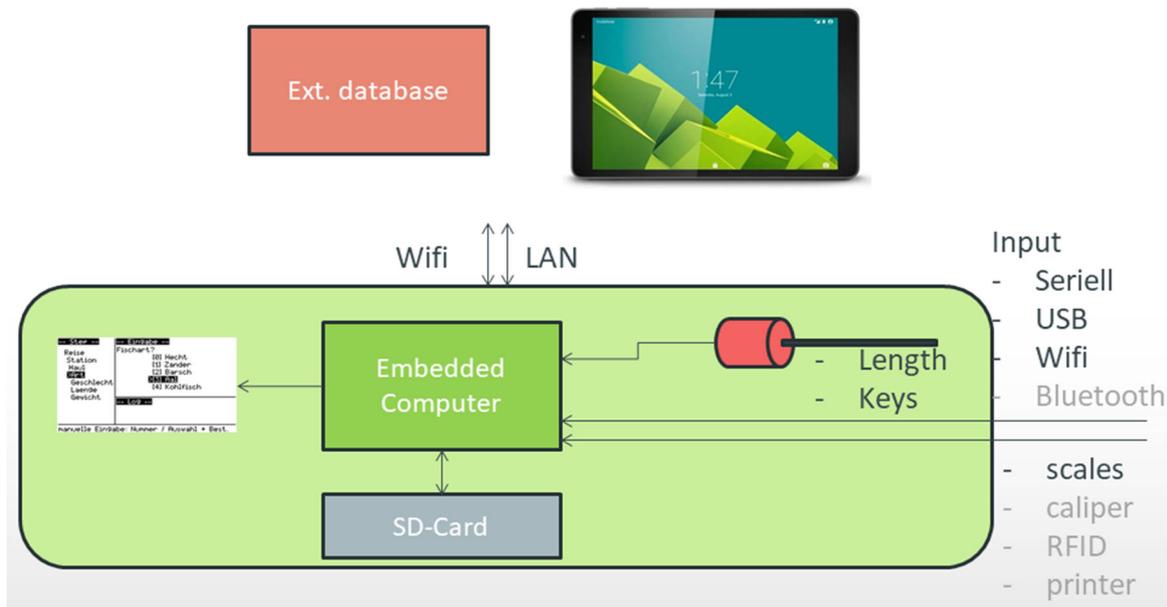


Figure 32. Concept used for the open SMB.

Moreover, it can act like a complete data acquisition system, managing user defined and complex sampling schemes, interact with other devices (e.g. scales, callipers, internal and external databases, other openSMB, external display devices). The device's interface can be accessed remotely via Wi-Fi or Ethernet using the fully documented API in JSON-format.

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

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Infrared Fish Observation

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

The use of infrared video surveillance at night is very common for onshore applications and therefore hardware became efficient and cheap. Nevertheless, the observation in a dark environment is also a frequent task in fishery science. In many cases the use of visible light is unacceptable to avoid bias of fish behaviour (Figure 33). Available acoustic cameras reach a high resolution at a medium range, but those are complex and expensive systems. Like humans, various fish species cannot see infrared light.

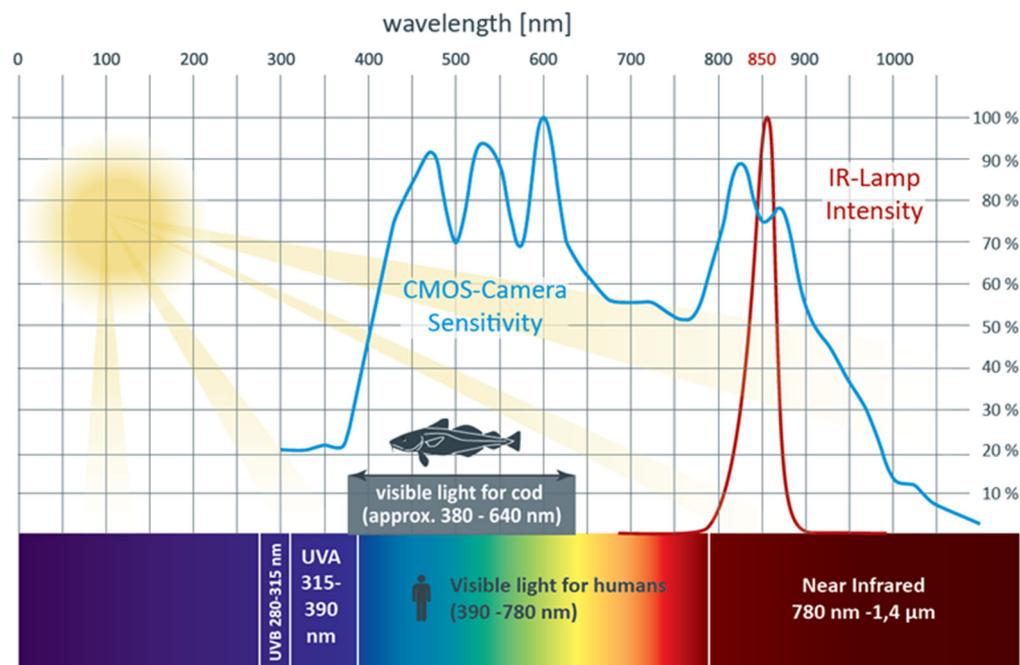


Figure 33. Wave length visibility for humans and fish.

So far, underwater infrared video observation is not very common. One major obstacle is the relative high attenuation compared to visible light. But, with the increasing effectivity of LED technology, even very cheap CMOS cameras can cover acceptable ranges suited for many application scenarios (Figure 34). Our task was to observe the behaviour of cod at the entrance of different fish traps. After first tests with IR-cameras, we developed our own infrared camera and light system from standard components. It delivers underwater videos in darkness at a distance up to 1.8m. We use a consumer single computer board (Raspberry Pi) and standard industry parts. A system consists of one camera and two lights, whereas parts are below 250€ including 100m depth rated housing. It uses open source software tools running on a Linux platform. The system offers a webserver, a comfortable scheduler, a motion detection unit, and can store internally more than one week's continuous video data.

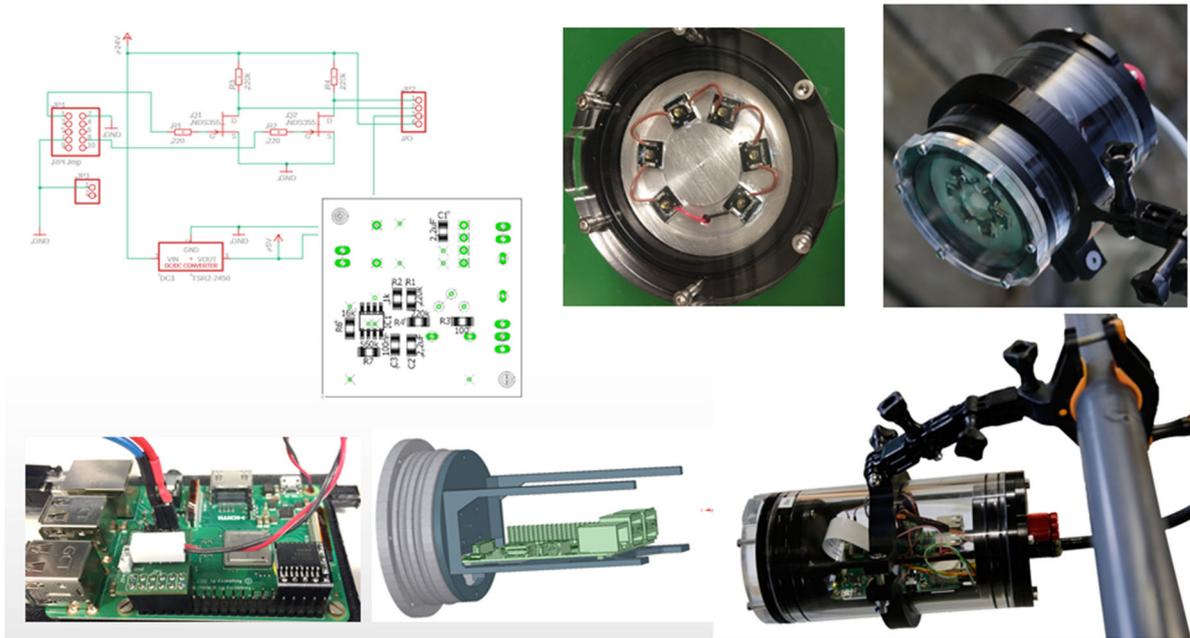


Figure 34. System camera and lights used in the research.

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

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

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

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

Following several high-profile tragedies in recent years on Australian commercial fishing boats, resulting in loss of multiple lives and several boats, a learning management system (LMS) using online software has been developed to provide safety training to fishers in the Australian fishing and

aquaculture industry. Funded by the Fisheries Research and Development Corporation (FRDC), the commercial fishing industry, and the Australian Maritime Safety Authority (AMSA), the LMS comprises multiple brief training modules that can be accessed by fishers at home, at sea, or elsewhere. Modules currently include training in workplace health and safety policy, risk assessment, emergency response, personal health and safety, operational safety, and fishery-specific safety hazards. They are specifically designed for the commercial fishing industry and each concludes with several brief questions that a fisher must complete and pass to an acceptable standard, thus filling an overlooked void in their safety training.

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

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Session 7: Energy, technology, analysis and simulation

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

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Recently the climate-abusing effects of exhaust gases from combustion processes are the focus of attention. This is underlining the importance of improving the energy efficiency. The fishing fleet is in most cases not efficient, because of outdated technology. Maintaining an adequate level of energy efficiency requires a continuous monitoring of the energy profile of the vessel. Causes of energy inefficiency can be identified, which enables prompt and effective action.

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

Measurement of energy consumption during vessel operations in different working conditions (sailing to and from the fishing ground, fishing operations or fish processing) might also lead to identification of potential fuel-savings and improving vessels' operating conditions. A proper system of energy use monitoring is therefore essential for maintaining high-energy efficiency. Once energy use has been related to each operating condition, fishers can minimize fuel use. Energy efficiency in fisheries can be investigated through an energy audit, which allows obtaining an extensive energy profile of the fishing vessels monitored (Figure 35). A vessel energy audit assesses the energy consumption of each energy user (e.g. propulsion system, electric- and hydraulic-user). Energy audits have been conducted for fishing vessels, which lead to recommendations for improved efficiencies to solve present and possible future fuel cost increases.

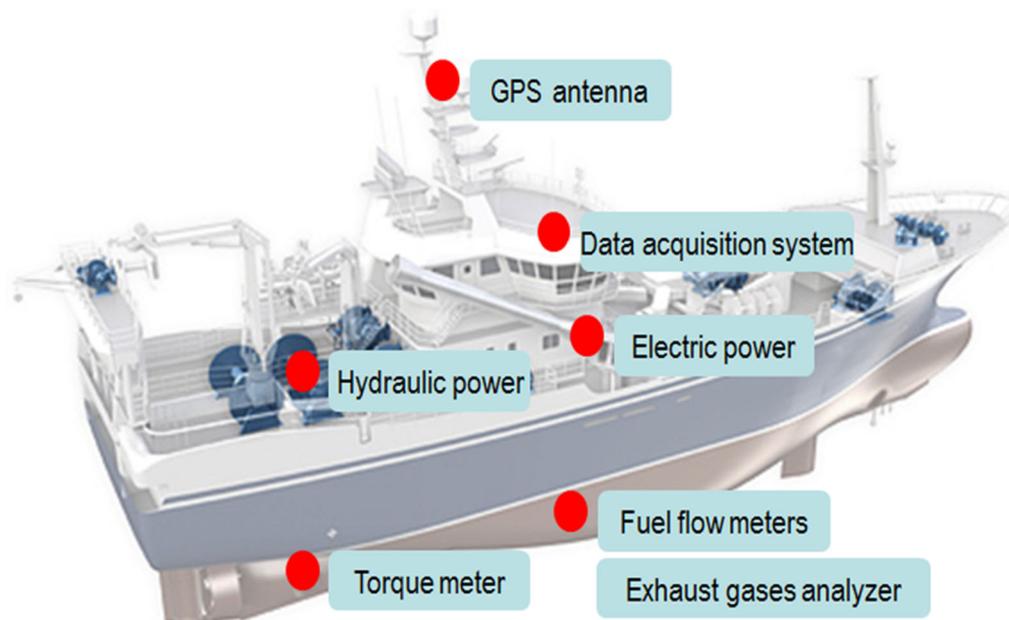


Figure 35. Energy monitoring system used in the fishing vessel research.

With regard to greenhouse gas (GHG) emissions, insufficient attention has been paid to the fisheries sector as a whole and to fishing operations in particular. Consequently, it is difficult to rank fishing gear and practices in terms of GHG emissions. However, using the consumption of fuel as a proxy for total GHG emissions can provide a good estimate. The fishing sector should strive to further

lower its fuel consumption and decrease ecosystem impacts. Despite a growing number of initiatives and experimentation with energy-reducing technologies, there is currently no viable alternative to fossil fuels for mechanically powered fishing vessels. However, it is well demonstrated that, through technological improvements, gear modifications and behavioural change, the fishing sector can substantially decrease the damage to aquatic ecosystems, reduce GHG emissions (which is a legal obligation for governments under existing international conventions) and lower operational costs for fuel without excessive negative impacts on fishing efficiency.

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CRISP - Eight years of innovation in fisheries technology

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

This has been done in several ways: by developing instruments for pre- and early-catch identification of fish species, size and school volume and for monitoring the fishing gear during capture; by development of environmentally friendly and selective fishing gears, as well as developing gentle capture and handling methods which improve catch quality and income. The pre-catch identification systems developed enables fishermen to avoid catching non-target species or sizes. Monitoring systems that visually and automatically identifies the catch inside the gear (Figure 36) may be linked to active selection devices and thereby reduce bycatch and discarding. Gear modifications and new handling methods may substantially affect fish welfare and thereby also the potential survival of released catch and improved quality of landed fish.

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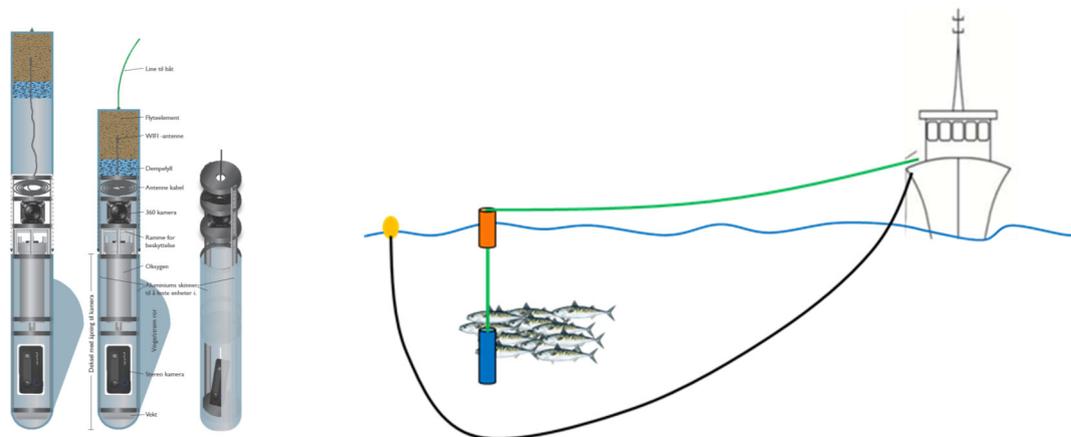


Figure 36. The Welfare Probe can monitor the catch inside a seine.

Large scale pontoon trap in cod fisheries, a retrospect

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

Since 2014, modified pontoon traps have been evaluated within the Swedish coastal fisheries both targeting cod (*Gadus morhua*) but also for multi species fisheries (Figure 37).



Figure 37. Pontoon trap tested in Ystad.

Beside catch efficiency our evaluation included studies on seasonality aspects, fish house positioning within the water column, size selectivity trials, attraction, target species behaviour in regards to the gear, discard survival analysis and comparison with gillnet fisheries and catch value evaluation. We put our results in a broader perspective of coastal fisheries and showed how pontoon traps may be used as a complement within the coastal fisheries in changing environments.

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

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The survey on Some Relationship of the Characteristics of Trawl Net, Otter Board and Trawlers in Thailand was carried out to gather data of trawl gear and vessels along the coast of the Gulf of Thailand in 2015. The survey was conducted through a collaboration between the Training Department of Southeast Asian Fisheries Development Center (SEAFDEC), Marine Fisheries Research and Development of Department of Fisheries Thailand and Thai local trawl fishers. Forty-six (46) bottom trawl nets of thirty-seven (37) otter board trawlers were surveyed (Figure 38). Technical data collected included: length overall (m), gross tonnage (GT), engine power (kW), otter board area (m²), otter board height (m) and head rope length (m).



Figure 38. Typical otter board trawler used in the Gulf of Thailand and net sampling for the research.

Results of the study revealed that gross tonnage, engine power, height of otter board, area of otter board, head rope, and ground rope, show correlation between 0.73 - 0.99 at confident level 95%. A very high correlation (0.986) was found in the comparison between height of otter board and length of otter board. The lowest correlation (0.727) was found in the comparison between gross tonnage and head rope. The study on the influence of independent variables *i.e.* length overall (m), gross tonnage (GT), engine power (kW), otter board area (m²), otter board height (m), and head rope length (m) to dependent variables showed an R-square value at confidence level 95% Range of R-square value between 21% - 91%. The highest R-square value (90.94) was found in comparison between area of otter board and length of otter board. The lowest R-square value (21.88) was found in comparison between engine power and head rope length.

Fisheries manager can apply the study result to control efficiency of trawl nets. Further data collection should be undertaken to generate more accurate results to serve better management.

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Numerical Simulation on the Mechanical Properties of Marine Float

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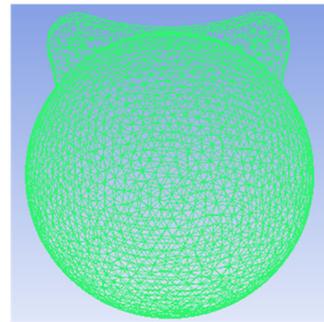
As the key structure of buoyance and dynamic lift generation, the float is one of the most important attachments of the fishing gear in ocean fishery. In the Ocean environment, the float may deform

and move under the hydrodynamic force when it works. At the same time, the motion may cause the impact from fluid and structures around. The investigation of the mechanical behaviour of the float is important for the structural design and performance optimization of the fishing gear, and even for the development of the ocean fishery. The three-dimensional numerical model of marine float working in a flow field was established based on the smooth particle hydrodynamics (SPH) method and the finite element (FEM) method (Figure 39). The hydrodynamic performance and impact resistance were analysed, and the response mechanism of float structure under the action of hydrodynamic load and impact load was summarized. The research aimed at providing basic theory support for the structure design and optimization of marine float and the related fishing gear.

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(a) Float structure



(b) Finite element model of the float

Figure 39. Float structure and numerical model of the float used in the research.

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

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It is known that currents induce a hydrodynamic transverse force on twisted ropes. This transverse force is perpendicular to the plane spanned by the tangent of the rope and the direction of flow. Its direction of action results from the twisting of the rope (z / s). The amount of this force obviously depends on the local angle of attack, the rope characteristic and the Reynolds number (Figure 40). If it is possible to increase this force in a targeted manner, this effect could be used to support the effect of the trawl doors for opening of pelagic trawls by a decreasing drag of the doors.

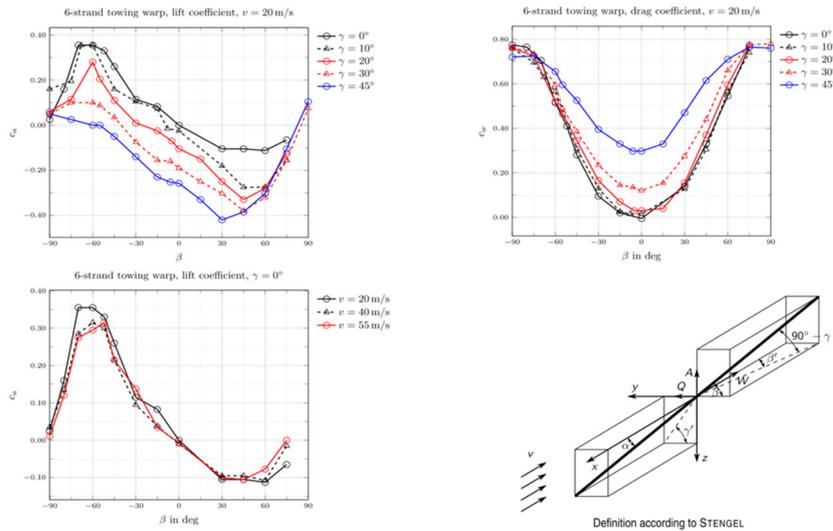


Figure 40. Force model used for testing twisted ropes.

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

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Flow simulation in and around a North Sea brown shrimp beamtrawl

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

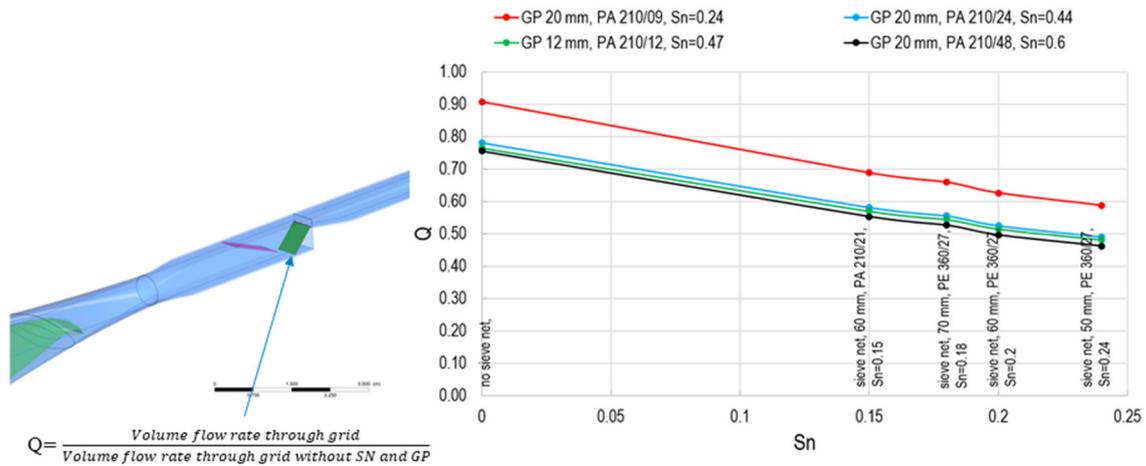


Figure 41. Computation fluid dynamics results, showing that the guiding panel and sieve net reduce the flow considerably.

Therefore, to investigate the effect of the sieve net and the guiding panel on the fluid flow in front of the sorting grid, the flow through and around a shrimp beam trawl was simulated using "Reynolds averaged Navier-Stokes" (RANS) methods (Figure 41). The dimensions of a trawl with a sorting grid section were provided by the Thünen Institute of Baltic Sea Fisheries. The width of the beam trawl was 7 m and the total length was approximately 20 m.

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

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Session 8: Chinese fisheries – Status, challenges and future

Research on fishing gear selectivity and its application in China

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China's Marine fishing output ranges from 12 million tonnes to 13.28 million tons between 2010-2016, of which the yellow and Bohai seas account for about 28 %, the South China sea for 32% and the East China sea for about 40 %. Most of China's offshore fishing grounds are multi-species fishing ground, the body shapes of the main targeting species in different waters vary greatly. Trawl nets, gill nets, stow nets and seine nets account for about 90 % of China's total catch of 12 categories of fishing gear, and the main targeting species of these types of fishing gears vary with the fishing waters. The fishing gear selective study in China began in the 1950s and has been paid more attention to due to the decline of offshore fishery resources in the 1980s, and was strengthened with an emphasis on fisheries management after 2000. The selective research on fishing gear in China mainly involves bottom trawl, shrimp trawl, stow net and gill net, etc. The research results mainly serve for the establishment of the minimum mesh size of fishing gear, and provide a scientific basis for the establishment of the fishery access system and the regulation of minimum mesh sizes for fishing gears.

The cover net method is the main method used in the comparative study of codend mesh selectivity of both trawl net and stow net at sea (Figure 42). Research included the effect of change in mesh size, mesh shape and structure, such as diamond mesh, square mesh and T90 on the selectivity of trawls. The selectivity research of the shrimp beam trawls also included a shrimp-fish separation device, separation netting, vertical separation codend and rigid grid inside the codend. In addition, some preliminary survival rate of catch escaped through the mesh size of the codend was also studied. The aim of gill net selectivity research is to determine not only the minimum mesh size for catching traditional economic species, but also the optimal mesh size for newly developed species.

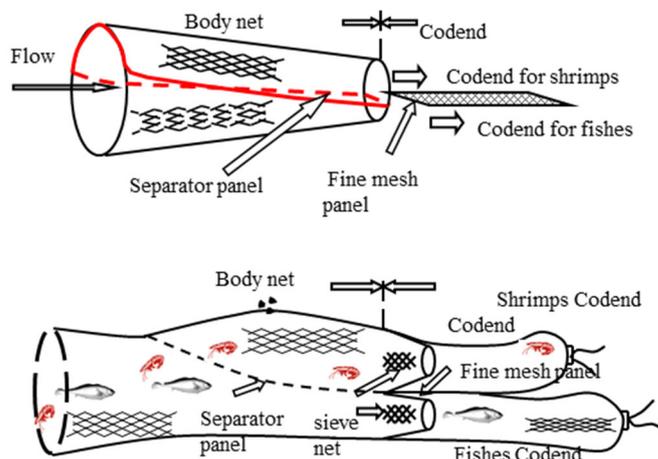


Figure 42. Tests with trawl nets included the use of a fine mesh panel and separator panel.

Research funding mainly comes from national nature funds, public welfare industry (agriculture) research projects and special finance projects of both the Ministry of Agriculture and Rural Affairs and provincial government, as well as the specialized research fund for the doctoral program, and provincial key discipline construction project funds. Compared with developed fisheries countries, China's research on fishing gear selectivity is generally not systematic and in-depth, and the research methods used are relatively simple. With the strengthening of China's fishery management system

and the implementation of the fishing gear access system in the offshore waters of China, research on fishing gear selectivity will be strengthened.

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Monitoring and assessment of China's coastal fisheries

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

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

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The status of distant water fisheries of China was reviewed in this report. In 2017, there were 2,491 fishing vessels approved for the fishing operation, involving 159 fishing companies. The total catch reached 2.09 million tons (Figure 43).

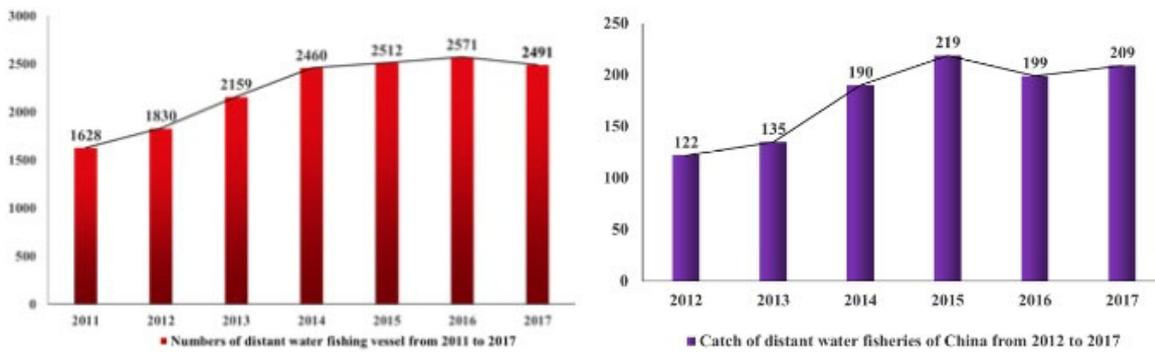


Figure 43: Trends in the number of China's distant water vessels and catch in 10 000 tonnes (period 2011-2017)

The challenges to China's distant water fisheries are: (1) The main tasks of fisheries administering authority of China are protecting the marine ecological environment, maintaining sustainable resource utilization, implementing responsible fisheries management, and combating IUU fisheries activities; (2) The capacity to comply with international regulations needs to be improved; (3) The comprehensive oversea fishery base is relatively simple and shortage; (4) The recruitment of fisherman engaged in distant water fisheries is decreasing. The technical level of the fishermen is declining; (5) The industrial structure is still relatively simple, the industrial chain is short, and the domestic market is not fully developed; (6) The scientific and technological support and comprehensive development capability need to be improved. The following strategies are proposed: (1) The capacity to comply with the international regulation should be improved by heavy training; (2) The domestic and international markets, and value chains should be developed and adjusted; (3) The intergovernmental fisheries exchange and cooperation should be strengthened; (4) The fishing capacity should be reduced or effectively controlled in the near future; (5) The profits of the industry should be increased by improving the management and using energy saving fishing strategies; (6) The technical training should be implemented to improve the technical level of the fishermen.

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

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

infraction. Only in such way would China promote healthy and sustainable development of its DWF, and become a responsible major fishing nation as it aims to be.

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

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In the past 20 years, IUU Fishing on the high seas has become increasingly rampant, which has caused serious impacts on the sustainable development of fish resources. The continuous increase in IUU fishing indicated the complexity of world fishery resource management. The trend of globalization prompted the international community to solve the existing fishery management issues in a global manner (Figure 44).



Figure 44. Jurisdiction over marine areas, rights and interests

By analysing the case of fishing vessel “Fu Yuan Yu Leng 999” of China which transferred unauthorized fishery species on the high seas outside the approved sea area, this article points out some challenges in combating IUU Fishing which China faces. It analyses international law-related issues and proposes countermeasures to regulate IUU fishing by China’s fishing fleet.

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

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The Liancheng Overseas Fishery (Shenzhen) Co. Ltd. operates locally-based pelagic longline fisheries in several Pacific Island countries. In collaboration with domestic management authorities, other companies in the supply chain, environmental non-governmental organizations and other stakeholders, Liancheng established Fishery Improvement Projects (FIPs) to gradually address deficits with an aim to improve the management and practices of the fisheries to a point where they

would pass an assessment against the Marine Stewardship Council's (MSC's) fisheries standard. The presentation described the experiences of these Chinese longline companies with establishing and implementing FIPs, and making gradual improvements, including the introduction of electronic monitoring programs; ecological risk assessments of the effects of fishing on endangered, threatened and protected (ETP) species; gear technology research to mitigate ETP bycatch; research on shark post-release survival; skipper training; and through participation in a regional alignment group, improvements to regional harvest strategies for principal market species of tunas. The presentation described the transition into the MSC program, and current improvement priorities to address conditions of MSC certification. Lessons learned demonstrate how other Chinese fishing companies can improve their environmental performance through participation in FIPs and MSC.

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POSTER ABSTRACTS

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

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Purse seiners deploy thousands of drifting fish aggregating devices (DFADs) in all tropical oceans to catch tropical tunas. Nowadays these FADs are constructed with synthetic netting, which are explicitly considered responsible for incidental mortality of sea turtles and sharks through entanglement, even causing ghost fish if they are lost and abandoned. The use of natural and/or biodegradable materials to build FADs can effectively mitigate marine pollution and bycatch issues so that they are currently made efforts to promote by fisheries management organizations. This paper presents some fragmentary results on degradability of three natural material ropes (3-ply 96-thread cotton, 3-ply 13-thread jute, and 3-ply 8-thread sisal) on the basis of an experiment measurement (currently ongoing). These samples were deployed at China's offshore waters attached to the floating frame of net cage in Dec 2018 and retrieved per month for testing breaking strength (N) in the laboratory. Results showed the maximum initial strength was from Jute rope with a linear density of 46898 tex, which however experienced the rapidest reduction of all in breaking strength over the first month. Cotton rope exhibited the most inertial degradation behaviour with the reduction ration by the third month at 58% of initial strength, compared to 3.5% and 12% for jute and sisal, respectively. Preliminary judge concluded that, in terms of limited data, jute and sisal rope are unable to satisfy the application criterion that is thought to vary from 5 months to 1year for their life span serving fishing.

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

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

gear. In addition, the fishing performance of nylon net was 90% of the fishing performance of the resin, and the catch rate was lower than that of the nylon net.

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

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

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

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

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There is a large amount of abandoned fishing gear around the world every year. The fishing nets made of polyethylene, nylon and other non-degradable synthetic fibres still cannot be degraded after decades in the seawater environment, becoming "ghost fishing gear" and causing great harm to fishery resources and ecological environment. Research and development of biodegradable materials for fishing is one of the effective approaches to reduce the phenomenon of "ghost fishing", protect marine fishery resources and ecological environment. Only in this way can sustainable development be realized. Starch based materials, polylactic acid (PLA), polycaprolactone (PCL),

poly (butylene succinate) (PBS) have so many good properties such as full biodegradability, good thermal processability, renewability, high mechanical performance and so on. It is an inevitable trend to replace the non-biodegradable synthetic fibre materials for fishing. Their appearance opens up a new way for the application of biodegradable polymer materials in the field of fishery. However, the mechanical properties of most biodegradable materials decline when they are used in seawater and high price are obstacles for the application and development of them. All of these results attract much attention in the research of modification of biodegradable materials for fishing. In this paper the performance, application status and research progress including blending with natural polymer and synthetic polymer of four kinds of biodegradable materials for fishing with starch-based materials, PLA, PCL, PBS were the focus. The effect of processing technology, surface treatment and additives on the composite material was presented. Finally, the development prospect of biodegradable materials was analysed in this paper to provide references for the research and development of biodegradable fishing gear materials with low price and excellent comprehensive performance.

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

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Sayram Lake is the largest cold-water lake in Xinjiang Uygur Autonomous Region of China. The area of the lake is 458 km², the maximum depth of the lake is 102 m, and the altitude is 2071 m. The main commercial fish in Sayram Lake is *Coregonu speled* that was imported from Russia in 1998. *Coregonus peledis* a fish with high oxygen consumption living in cold water. The main fishing methods applied in the lake were gill nets and small set nets before 2017. In order to protect the environment of this lake and the juvenile of this species, only the large set net was allowed as a fishing gear from 2017. Therefore, the behaviour characteristics of the fish around the set net is an important information for the structural design and improvement of the fishing gear. In order to grasp the fish behaviours in migration and swimming depth changing around the set net, ultrasonic biotelemetry experiment was conducted during Jun.23-Jun.29,2018. In this study, 10 fish were attached ultrasonic pingers for tracking 24 or 48 hours by 10 mooring receivers from Aqua Sound Inc.

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

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

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The shrimp beam trawl fishery in the northern South China Sea is characterized by high bycatch and poor selectivity problems. Among by-catch species, banded scad (*Caranx (Atule) kalla*) is economically the most important one. The aim of this study was to improve the selective properties of codends for banded scad. Size selectivity of 2 traditional diamond mesh codends, with mesh size 25 and 30 mm (defined as D25 and D30, respectively), and 4 new combined square and diamond mesh codends, with 25 mm square-mesh and 25 mm diamond-mesh (S25+D25), 30 mm square-mesh and 25 mm diamond-mesh (S30+D25), 35 mm square-mesh and 25 mm diamond-mesh (S35+D25), and 35 mm square-mesh and 18 mm diamond-mesh (S35+D18), were tested for banded scad in shrimp beam trawl fishery of the South China Sea. A total of 54 valid hauls were completed using the covered codend method, and 5750 banded scad were caught. Selective parameters were obtained using the logistic equation with the maximum likelihood method, by incorporating the between-haul variation. The results show that the present minimum mesh size for shrimp beam trawl in the South China Sea, 25-mm diamond mesh size, is insufficient to release immature banded scad. The S35+D25 codend proved to be the most effective codend to release immature banded scad, and its 50% retention length (L50) is larger than the minimum landing size (MLS=63.5 mm) of banded scad. However, the 95% confidence intervals of L50 overlap among the three combined mesh codends, the S25+D25, S30+D25 and S35+D25 codends. For a sustainable exploitation of banded scad, use of larger mesh sizes are to be investigated for the combined mesh codends.

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

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

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

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

The management measures of China in the NSCS include fishery zoning to limit trawl fishing in the inshore waters of <40m depth, and the closed fishing areas/seasons were established in the estuarine and coastal waters to protect breeding and nursery stocks. Fishing boat licensing system and policy of limiting fishing capacity are measures that have been in place since the late 1980s and the fishing capacity has tended to level off since the late 1990s. A 2-months (June/July) summer closed fishing season applying to trawl, purse seine and trammel gillnet in the NSCS, has been implemented since 1999. In 2018, the closed fishing season was extended to 3.5 months (from May 1 to August 15) and all fishing activities except hook-and-line are closed.

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

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

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

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As a key species of the Southern Ocean ecosystem, the thermal and saline tolerances of Antarctic krill (*Euphausia superba* Dana) are relatively unknown because of the challenging environment and complicated situations needed for observation have inhibited in-situ experiments in the field. Hence, the thermal and saline tolerance of krill were examined under in-situ aquarium conditions with different controlled scenarios. According to the experiments, the critical lethal times of krill were 24 h, 2 h and 0.5 h under 9 °C, 12 °C, and 15 °C, respectively, and the estimated 50% lethal times were about 17.1 h and 1.7 h under 12 °C and 15 °C, respectively. Additionally, the critical lethal times (the estimated 50% lethal times) of krill were approximately 14 h and 0.5 h (about 22.9 h and 1.7 h) under 19.7 ppt and 15.9 ppt, respectively. The observed critical and 50% lethal times of krill were 0.5 h and approximately 1.4 h, respectively, under 55.2 ppt. The critical and 50% lethal temperatures of krill were 13 °C and approximately 14.2 °C, respectively. Additionally, the critical and 50% lethal salinity levels were 19.6 ppt and approximately 17.5 ppt for the lower saline (below normal oceanic salinity [34.4 ppt]) environment and 50.3 ppt and approximately 53.2 ppt for the higher saline (above 34.4 ppt) environment, respectively. The upper thermal and saline preferences of krill can be considered 6 °C and 26.8 to 41.2 ppt, respectively. These results can provide potential scenarios for predicting the possible fate of this key species in the Southern Ocean.

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

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

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

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A study on net performance and structure adjustment can improve the fish catch, and is also a key point in the fishery research. In this paper, using the survey data from the fishing operation of Chilean jack mackerel trawl fishery in 2014 in southeast Pacific Ocean, we analysed the performance of the mid-water trawl. The data mainly came from the Scanmar System rigged on the net and the data of fishing operation at sea. We used these data to explore the relationships between the towing speed and net mouth height, towing speed and drag, towing speed and net horizontal opening, towing speed and the depth of net mouth, warp length and warp resistance, the depth of two otter boards and the horizontal opening of otter boards. By data processing and numerical analysis to get these parameters such as vertical opening coefficient, energy consumption coefficient, hydrodynamic performance and so on. When the towing speed ranges from 4.4 knots (kt) to 5.8kt, the formula of net drag was $F_s = 0.055833 (d/a) LCV 1.149116$ by the non-linear model. The correlation coefficient between predicted net drag and actual net drag was 0.835 ($P=0.000$) by correlation analysis. The average energy consumption coefficient of 1768 net was 0.088 kWh/104m³ less than them of the other nets. The ratio between length and circumference was 0.268, and the hydrodynamic performance was 31.93, which was the highest in the same type of nets. The vertical opening coefficient is also larger than the other net. Through the relationships between these parameters, we could understand and analyse the operational performance of the 1768 net to improve the fishing gear design and achieve effective energy saving.

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

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

S. oualaniensis in 2013-2015 shows a stable trend. The CPUE in 2016 shows a significantly declining trend affected by El Niño. The fishing ground of *S. oualaniensis* in the South China Sea was mainly located in the waters of 10°N~12°N and 114°E~116°E. The suitable SST ranged from 28□ to 30□. And the suitable CHL ranged from 0.10 mg/m³ to 0.15 mg/m³.

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

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

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

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

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

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Antarctic krill (*Euphausia superba*) is a key species in the Southern Ocean ecosystem, knowledge about its biomass and swarm dynamics are essential to understand the ecology and distribution of krill. The acoustic data was collected across extensive gradients in the South Orkney Islands based on commercial fishing vessel *Long Teng*. Krill targets were identified in acoustic data using a multi-frequency identification window and converted to krill density using the Stochastic Distorted-Wave Born Approximation target strength model. The average krill length was 33.01±4.06 mm, with a maximum length of 49.21 mm and a minimum length of 25.50 mm of this area. There was no significant difference between male and female krill length. The whole ecogram could be divided into 1338 integration units, of which 586 units were in daytime, 752 units were at night. The maximum krill density was 554.07 g/m² and the minimum density was 0 g/m². The Antarctic krill were mainly aggregated with 87.90% integration units had no biomass. There was no significant difference in diurnal NASC and SV values of the 9 transects, which suggested that the diurnal vertical movement had no effect on krill biomass estimate. The average krill density was 71.01 g/m² and the total biomass was 1.77×10⁶ t in this area. The krill were mainly aggregated in the 60~180 m water depth in the daytime and gradually moved upwards or downwards at night. Light intensity is one of the factors that influence the krill diurnal vertical movement. However, a proportion of the Antarctic krill were sunk to deeper water at night, which may be prey the deep-water foods. A total of 2539 krill swarms with swarm characters including swarm height and length, packing density, swimming depth, and inter-swarm distance were extracted, of which 1389 were daytime swarms and 1150 night swarms. Compared with those of the night swarms, krill aggregated in deep waters during the daytime with lower packing density and smaller inter-swarm distance. There were significant differences between day and night krill swarms. Through the multivariate analysis, the krill swarms were divided into three categories, which differed in both their dimensions and packing density. Group A presented the highest swarm density (19.24±27.00 ind·m⁻³), Group B swarms presented the deepest distribution depth (174.74±53.30 m), Group C presented the largest swarm area (2868.62±2149.75m²) with the longest swarm length (258.76±322.88 m). There was no significant difference in swarm length between Groups A and B and no significant difference in swarm depth between Groups A and C. Group A swarms were mainly distributed in deep water areas in the north and northwest regions of the South Orkney Islands at a depth of > 1000 m, and mainly occurred during daytime. Groups B and C swarms were distributed throughout the survey area; Group B swarms were aggregated in the continental shelf at a water depth of < 200 m. The results suggest that the majority of krill were contained within a minor fraction of the total number of swarms, and there was a positive correlation between packing density and inter-swarm distance. The results of this study provide abundant information on the krill distribution and its swarm characters in this area and basic data for the current feedback krill resource management of CCAMLR. In the future, the research on the correlation between krill biomass and external factors (environmental factors, predators) can help us understand the population structures more accurately and predict the distribution of krill resources.

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

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Gillnets are one of the most widely used fishing gear in the world, and there are nearly 97 thousand gillnets used in China offshore. With the decline of resource Fisheries, fishing quota has always been a topic of concern for the world's fishing nations. At the beginning of 2017, the Ministry of Agriculture and Rural Affairs of the People's Republic of China implemented the total management of marine fishery resources and started the quota fishing experiment. Vessel monitoring system (VMS) provides a new data source for fisheries scientific research. In China, Shipboard Beidou satellite navigation system terminal (SBNST) was installed on demonstration fishing vessels. It sends vessel identification and location information at 3 min interval and with 10 m spatial resolution. In this paper, through the analysis of spatial intersection relations between port area and fishing vessel trajectory, more than 15 hundred fishing trips of 56 vessels were extracted. The duration of the trips was: 16.91 % one day, 38.87 % of one to two 2 days, 12.65 % 2-3 days. 80.80 % were completed within 4 days. There were some long trip days at Linhai, Sanmen, Shengsi and Taizhou, and there were few long trip days at Wenling, Xiangshan and Zhoushan. Speed threshold information was used to select the state of hauling nets. The speed thresholds of vessels were from 1.7 to 2.4 m/s. Hauling hours of 56 vessels were distributed in 8 fishing grounds in 2017. The average hauling hours was 1.7 h, and the maximum value was 41.5 hours. There were about 514 thousand net hauling points, and the catch weight was estimated at about 4.7 million kg in 2017.

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

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It is essential to conduct hydrodynamic experiments for fishing gear at small attack angles along the flow direction to better understand the hydrodynamic characteristics of netting and application of gear. The hydrodynamic characteristics of netting panels made of different materials at small attack angles were investigated by a self-designed setup; this is essential for the effective use of netting on different types of gears. As confirmed by experiments, the measured drag of designed frame without netting accounted for less than 20% of the total setup drag including experimental netting and remained in a steady state under various current speeds and small attack angles, indicating that the self-designed frame setup is suitable for such trials. The drag coefficient was determined by varying the attack angle, solidity ratio, Reynolds number, knot types, weave pattern, and twine materials at small attack angles. The results indicate that the drag coefficient increased as the attack angle increased, but decreased as the solidity ratio and Reynolds number increased. The drag generated by knot accounted for 21% of the total drag of nylon (PA) netting. For braided knotless netting, the

drag coefficient of PA netting was about 8.4% lower than that of polythene netting (PE) and 7% lower than that of polyester netting (PES). Compared with twined netting, the braided netting exhibited a higher resistance to flow, corresponding to higher values of drag coefficient.

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

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Understanding the distribution patterns and habitat characteristics of ecologically or economically important species in marine protected areas is critical for identifying the ecological boundaries and optimizing the management strategies. However, studies on groundfish resources around marine protected areas are often limited because of economic, geographic, or jurisdictional constraints. This study investigated the seasonal distributions of Crimson Seabream (*Parargyrops edita*), an important demersal fish species in the Beibu Gulf, northern South China Sea, based on bottom trawl surveys inside and outside the experimental zone of marine protected area, and examined the habitat preferences of Crimson Seabream in terms of eleven abiotic and biotic factors (sea bottom temperature, salinity, dissolved oxygen, pH, depth, transparency, zooplankton biomass, eastings, northings, season, and zone) using generalized additive models (GAMs). The density of Crimson Seabream was highest in spring with a mean density of 50 700 ($\pm 15\ 100$) ind./km² (\pm indicates standard deviation) and an occurrence frequency of 92.3%, and lowest in winter with a mean density of 20 (± 39) ind./km² and an occurrence frequency of 30.8%. Crimson Seabream was most aggregated in summer and least aggregated in winter. Results suggested that the distributions of Crimson Seabream were most influenced by season, sea bottom temperature, and salinity. Crimson Seabream was most likely to be distributed in area with sea bottom temperature of 22.8–25.0 °C, salinity of 31.5–32.0, dissolved oxygen of 4.4–6.8 mg/L, and zooplankton biomass of 114.0–2 717.5 mg/m³. Results from this study suggested that dynamic management strategies with more efforts on minimizing human activities around the marine protected area in winter and spring may provide more effective support for Crimson Seabream recruitment. The statistical approaches were applied, and related findings could serve as a basis for determining the spillover effects of marine protected areas and enhancing fishery management units.

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

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Pacific yellowfin tuna (*Thunnus albacares*) is widely distributed in subtropical and tropical waters, extending to 40°N in the North Pacific Ocean. Understanding the biology of tunas requires knowledge of where it lives and of its various movements between different habitats. However, the

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

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Fish collective behaviour: New research field and new progress

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

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

We describe a computer vision-based method for measuring the feeding activity of an Atlantic salmon (*Salmo salar L.*) shoal. Feeding activity analysis was based on the intensity summation of the difference frame due to the motions of the fish. An overlap coefficient was defined to calibrate

the error of calculation caused by the overlaps among fish bodies in images. Based on these data, a computer vision-based feeding activity index (CVFAI) was determined for measuring the feeding activity of the fish in arbitrary given duration. To assess the reliability of CVFAI, a manual observation feeding activity index (MOFAI) was determined by scoring each kind of feeding behaviour in the same recordings. The CVFAI and MOFAI presented a linear relationship at a correlation coefficient of 0.9195. CVFAI is therefore a potential indicator for measuring the feeding activity of an Atlantic salmon shoal, in a low-cost and rapid way.

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

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

How do the characteristics of the individual's behaviour differ when alone or when in a group? Which traits of the individual are adjusted for it to become part of the synchronized group, which are retained unchanged, and how are they manifested within the swarm? Based on these questions, we think future research should focus on how to quantify the characteristics of fish collective behaviour, how to identify ways of information transmission applied within cooperative group activities, how to determine the social hierarchy of a group, and to clarify the interaction mechanisms between fish behaviour and environmental factors.

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

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As a passive fishing gear, as well as a sustainable fishery, set net fishery has a few hundred years of history and plays an important role in coastal fishery. In a net-hauling system, migratory fish are guided to a box chamber net by a leader net and related net. Fish harvest requires lots of workers to visit the set-net and haul the box chamber net every dawn, however working in early morning is hazardous. A pipe-based automated net-hauling system was developed to reduce labour costs and risks. The system utilizes high density polyethylene pipes in which compressed air is injected or exhausted through water tank testing. Models of set nets and four high-density polyethylene pipes

are constructed taking in consideration the required stiffness and force use, and they were installed in water tank. Air was injected and exhausted in the pipe models, and the motion of pipes and the formation of the box chamber net were examined by underwater video camera. In the experiment, the similar motion of pipes could be observed. Then the first and second high-density polyethylene pipes were made and tested. It was concluded that pipes made of PE materials can be used safely, because it will not break due to bending. The detailed motion of the pipes needs to be analysed in the future. The third and fourth testing of the high-density polyethylene pipes will be carried out at sea.

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The 2019 annual meeting of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) was held from 8 to 12 April 2019 in Shanghai, China. The meeting was hosted by FAO in close collaboration with the Shanghai Ocean University. More than 120 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 four-day symposium, on “Responsible Fishing Technology for Healthy Ecosystems and a Clean Environment Technology Development and Sustainable Fisheries”, which was organized as part of the 2019 annual meeting of the ICES-FAO WGFTFB. The symposium comprised eight thematic sessions: (i) abandoned, lost and otherwise discarded fishing gear (ALDFG): Assessment of quantity and measures to prevent ALDFG and its impact; (ii) interactions of protected species in capture fisheries; (iii) light, fish behaviour and fishing; (iv) technology and management to reduce bycatch and discards; (v) selectivity of fishing gear; means and methods; (vi) new technologies for fisheries research and education; (vii) energy, technology, analysis and simulation; and (viii) Chinese fisheries-status, challenges and future.

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 Asia and Latin America. Many new research findings and examples from field tests of gears were presented, including ways to systematically collect and recycle used fishing gear, options to reduce bycatch in trawl fisheries through modifications to the gears, fuel efficiency gains in fisheries through lighter gears, technologies to monitor fish behaviour with underwater cameras on fishing gear, and many other innovations.



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