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Editorial: Innovations in fishing technology aimed at achieving sustainable fishing

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Editorial on the Research Topic
Innovations in fishing technology aimed at achieving sustainable fishing

Introduction

In the context of fisheries, “innovation” refers to the development and adoption of new ideas, technologies, practices, and approaches that lead to improvements in the sustainability, efficiency, and overall performance of the fishing industry. According to International Council for the Exploration of the Sea (ICES), innovation in fisheries is an improvement of the *status quo*, regardless of the improvement being incremental, transformative, or disruptive (WKING; ICES, 2020). Innovations in fisheries date back thousands of years, and used to be mostly driven by maximizing catch efficiency, led by an increasing understanding of habits and behaviours of the marketed species. In the modern era, the industrialization of fisheries in the 19th and 20th centuries brought technological innovations such as steam-engine vessels, onboard refrigeration, and freezing of catches, synthetic netting materials and information technologies to help communications, navigation, location of fish, and monitoring of gear performance while fishing (Squires and Vestergaard, 2013). These innovations led to the rise of substantially larger vessels and fishing gears, allowing exploitation of fish stocks in previously inaccessible ocean locations and depths and at substantially higher levels of productivity. Such unregulated technical progress contributed to the growth and development of fisheries, but also contributed to their overexploitation and concomitant environmental impacts. Therefore, driven by management requirements, and changing consumer preferences for “sustainable” seafood, recent innovation in fisheries turned toward promoting sustainable practices, reducing bycatch and minimizing environmental impacts (Squires and Vestergaard, 2013; Lewison et al., 2014; Kennelly and Broadhurst, 2021; Hilborn et al., 2023).

Intense research activity has been sparked in the last 50 years by a growing concern over the environmental effects of fishing impacts (fishing mortality, catch of juveniles, habitat damage, etc.) and more recently on the ecosystem effects of fishing (Jennings and Kaiser, 1998; Kaiser, 1998; Lindeboom and de Groot, 1998; Collie et al., 2000). Overfishing, declining fish stocks, and environmental concerns have created a demand for more selective fishing gears. The imperative to reduce bycatch, minimize the impact on non-target species, and adapt fishing practices to changing ocean conditions due to climate change has prompted the development and adoption of advanced fishing technologies (Cheung et al., 2013). Moreover, economic factors, such as rising fuel costs and the need for increased operational efficiency, serve as powerful drivers for the continuous improvement of fishing vessel design and navigation systems (Kasperski and Holland, 2013). The desire to enhance transparency and traceability in seafood supply chains, driven by consumer demand for sustainable seafood, has led to innovations in data collection and management technologies. Trawl fisheries have been under particular scrutiny due to their impact on benthic habitats and ecosystems, especially where complex biogenic structures are prevalent (Watling and Norse, 1998; Hall, 1999), and public opinion is pushing towards a shift to less impactful, albeit often less effective, fishing gears. Nonetheless, recent studies show that through technological innovation and careful management, all gear types can be fished sustainably (Hilborn et al., 2023).

This Research Topic called for fisheries technologists worldwide to present their latest innovation efforts. Twenty-two contributions were published, with topics ranging from modifications of gear designs to improve the species and size selectivity of trawls, traps, gillnets, and longlines, to the development of methodologies for a quantitative study of fish behaviour to inform gear development, to new frontiers of technological innovation such as the application of Artificial Intelligence (Figure 1). Here, we present and summarize the main results of the contributions to this Research Topic into 5 main drivers of innovation in fisheries technologies: i) improving the species and size selectivity, ii) preventing interactions between fisheries and protected species, iii) improving fishing performance, iv) adapting to environmental and socio-economic changes, and v) studying fish behaviour.

Driver 1: improving species and size selectivity

Active gears

Simple codend modifications such as changes in mesh size and/or orientation have been among the most popular and effective gear modifications to improve size-selectivity of target and bycatch species (Wienbeck et al., 2011; Madsen et al., 2012; Sala et al., 2016; Lucchetti et al., 2021). Yet, scientific knowledge is lacking for many fisheries, and conflicting results have been reported in the literature regarding the effectiveness of these simple innovations in gear design.

Petetta et al. investigated changes to the codend extension piece in the Mediterranean bottom trawl fishery, reducing the number of meshes in the circumference and rotating the meshes by 90 degrees (T90), finding no significant improvements to gear selectivity. Similar results were obtained by Sbrana et al. and Ferragut-Perello et al. confirming that the use of T90 meshes in the trawl extension piece had no effect compared to the commercial net. Broadhurst et al. tested T90 meshes in an Australian trawl fishery, detecting only a slight improvement to the quality of the deepwater flathead, *Neoplatycephalus conatus*, but no improvements in selectivity. The studies in this Research Topic discourage further investigation of the effect of T90 meshes in the extension piece and we congratulate the authors for publishing these negative results (this is not always the case), as they will prevent a waste of future research efforts in this direction. In contrast, similar modifications in the codend section have led to improvements in selectivity. Yang and Herrmann showed that the use of T90 meshes in the codend of bottom trawls in China can make trawling for an important commercial species (mantis shrimp, *Oratosquilla oratoria*) more sustainable. Yang and Herrmann provided useful insights for fisheries management in China, demonstrating that the legal codend mesh size (25 mm) fails to protect the undersized individuals of the cocktail shrimp (*Trachypenaeus curvirostris*). More than 40% of the undersized shrimp was retained and increasing the codend mesh size did not significantly improve the size selectivity and exploitation pattern, pointing towards the need for alternative gear modifications. Ferragut-Perello et al. investigated the effects of increasing mesh size in the codend in Mediterranean trawls (to 52 mm square mesh); this solution was highly selective compared to the traditional codend but also implied consistent economic losses (27%). Mytilineou et al. analysed the catch performance of three different codends, observing also the on-board practices adopted by fishermen in terms of species discarded. Fishers discarded species that were ranked highest in the diversity and vulnerability index, and the lowest in trophic level. The results suggested an urgent need for trawl modifications for the mitigation of the catch of highly vulnerable species (e.g. Elasmobranchs) is needed. Moreover, trawl species-selectivity should be improved by allowing the escape or avoiding the catch of the discarded fraction to minimize biodiversity losses.

When codend size-selection did not suffice, exclusion grids were introduced to either exclude unwanted bycatch species, or improve size-selection of the target species. For example, Geraci et al. tested a simple grid composed of an aluminium frame and a 40 mm square mesh net, demonstrating improved selectivity performance in Mediterranean deep water shrimp trawling. Sbrana et al. tried a flexible grid in the extension piece of the Mediterranean trawl and found promising results, with the grid allowing the escape of undersized specimens of the target European hake. These studies show the benefit of combining multiple selective processes to optimize both single-species and multi-species catch goals (Melli et al., 2020).

Passive gears

Passive gears are typically considered relatively selective, and thus, have been the object of less innovation in gear design; however, in some fisheries, unwanted catches are not only an operational problem (e.g., time-consuming to remove from the net), but also an environmental problem (removal of protected species or specimens that are the primary food for many bottom species; Hilborn et al., 2023). Therefore, increasing research efforts have been directed towards testing gear modifications aimed at improving the selectivity of passive gears. For example, Sardo et al. tested the use of a guarding net to reduce discards in a gillnet fishery in Southern Italy. The solution was promising, significantly reducing discards, but it also involved commercial loss. Kim et al. applied a tie-down gillnet to the catch of blackfin flounder (*Glyptocephalus stelleri*) in a more sustainable way with respect to other set net configurations. The results demonstrated that the fishing performance of trammel nets and tie-down gillnets is much higher than that of single gillnets. The study suggested that tie-down gillnets are an option for sustainable fishing given that it performed better than the single gillnet and reduced bycatch of immature blackfin flounder when compared to trammel nets. With the increasing public focus towards these fishing methods, research and innovation in this area is bound to accelerate in the future.

Driver 2: preventing interactions between fisheries and protected species

Fisheries bycatch is widely proven to be a major threat to vulnerable marine megafauna on a global scale (Lewison et al., 2004; Lewison et al., 2014). Due to the importance of this phenomenon, which seriously threatens the conservation of certain species, technological innovations in fishing gear to reduce bycatch have become a necessity and have been introduced into legislation in several countries. These innovations typically rely on differences in sensory ability between target and protected species, as well as morphological and behavioural differences.

Gautama et al. in the wake of some recent promising studies (Ortiz et al., 2016; Virgili et al., 2018 etc.), tested the use of illuminated set nets to reduce sea turtle bycatch in the Indonesian small-scale coastal gillnet fishery. Interestingly, they found that net illumination significantly reduced multi-species sea turtle bycatch by 61.4%, and specifically green sea turtles (Chelonia mydas) by 59.5%, while the catch-per-unit-effort (CPUE) for the total catch and target species remained similar. The use of lights therefore appears to be very promising for reducing turtle bycatch, leaving the challenge of optimising the technological solutions, and make them easier and more manageable for fishers. Carbonara et al. evaluated the effects on target and bycatch species caught by drifting longlines using circle hooks in the South Adriatic Sea (Central Mediterranean). They found no significant difference in CPUE or specimen lengths between the circle and traditional hook types. The hook type did not significantly affect the capture condition of swordfish, pelagic stingray, or loggerhead turtle specimens, but circle hooks positively affected the capture condition of blue sharks. Changing hook type shows potential, but different studies have shown conflicting results (Read, 2007). Therefore, standardization of the different technical parameters of hooks, known to affect catch performance (size, gap, barb etc.), should be given priority.

Driver 3: improving fishing performance

Improving the performance of fishing gear, especially towed gear, has become a priority worldwide, both from an environmental point of view (reducing bottom impacts) and from a socio-economic point of view, in light of rising fuel costs (Sala et al., 2023). Therefore, this driver includes both developments aimed at reducing the costs of fishing operations and at optimising catch performance (catch less but catch better), i.e. ensuring the highest quality and value of the catch. For example, Ingólfsson et al. investigated technical solutions to avoid excessive catches, and the associated loss of catch quality, in the blue whiting (*Micromesistius poutassou*) Northeast Atlantic pelagic trawl fishery. Catch limitation devices composed by a) escape opening(s) in front of the codend to release excess fish, b) a fish lock to prevent loss of fish through the escape opening(s) during haulback and at the surface, and c) a choking unit to match codend capacity to the desired size of catch were tested. The study demonstrated that controlling catch quantity in the blue whiting pelagic trawl fishery can be achieved effectively through relatively simple modifications to the codend section.

Other studies focused on investigating and/or improving the hydrodynamic performance of fishing gears. Previous studies focused mainly on the anterior gear components that interact more heavily with the seabed, such as otter boards, improving their hydrodynamic characteristics to reduce both fuel consumption and bottom impact (Prat Farran et al., 2008; Sala et al., 2009). Yet, as reflected by the studies in this Research Topic, increasing focus has been dedicated to the netting materials and construction. Li et al. studied the hydrodynamic performance of an stick-held dip (SHD) by means of numerical simulation and experimental testing. A mathematical model based on the lumped-mass method and principle of rigid body kinematics was developed to predict the net shape and tension of the cable. Chosid and Pol. tested a new trawl net design (helix twine off-bottom trawl) to catch the haddock (*Melanogrammus aeglefinus*) in the Eastern Georges Bank while reducing the catch of other commercial species. The net had very large meshes at the front end, made with innovative “helix” twine that produces lateral hydraulic forces while towing, resulting in self-spreading of the meshes. The results highlight not only the potential in improving hydrodynamic performance, but also in reducing unwanted bycatch while maintaining target catches of haddock. Among all innovation efforts, those that successfully combine economic and environmental drivers have the highest potential for uptake within the fisheries (Hammarlund et al., 2021).

Driver 4: adapting to environmental and socio-economic changes

Climate change is bringing about sudden and sometimes massive changes in marine ecosystems, with new species emerging in areas where they were not previously present, and other species moving towards northern latitudes. As an example, in the summer of 2023 the Adriatic coast of Italy witnessed an explosion in the abundance of an alien species, the blue crab (*Callinectes sapidus)*, with devastating consequences for the local fishing and aquaculture sector. In these cases, establishing fisheries that target alien species can be an effective method to control the population level, but it requires careful gear development to prevent undesired impacts on the local species. Harris et al. for example, tested three trap designs to catch the invasive deepwater lionfish (*Pterois volitans/miles*). They also studied the behaviour of this species through ROV surveys. They found the efficiency of all types of pot was low. Catch efficiency could increase with higher densities of lionfish on the nearby reefs, if traps were retrieved after approximately two days of deployment, and if traps were retrieved during dawn or dusk. Therefore, more studies are needed to improve the catch performance of traps for this species.

Similarly, the rapid growth of some species, such as the grey seal (*Halichoerus grypus*) population in the Baltic Sea, have led to a dramatic decline of many coastal fisheries (Lehtonen et al., 2022). Ljungberg et al developed a seal-safe trap net, the pontoon trap, to reduce grey seal bycatch (*Halichoerus grypus*) in the Baltic Sea coastal fisheries. The pontoon traps were modified for use in cod (*Gadus morhua*) fisheries. Results showed that there was no seal-induced damaged cod in the pontoon traps and that, during specific fishing occasions, multiple pontoon traps may have similar catch rates to gillnets.

Moreover, as climate change heats up oceans, fish are on the move, requiring fisheries to follow, with consequences in terms of rising fuel consumption and alteration of fishing treaties between nations in shared waters (Rogers et al., 2019). For example, Han et al. investigated how different factors related to fishing practices can influence catch per unit effort. They report on the light falling gear case study from the Indian Ocean with regard to: a) shift in the target species; b) spatial distribution of light falling gear in the Indian Ocean at different time scales; c) effects of different environmental variables; and d) effects of different time scales. This instability and rapidly changing environment calls for solutions that can increase the ability of fishers to adapt to change, including not only technical changes in fishing gear, but also shifts in fishing methods, target species and fishing practices. An example is provided by Königson et al. where the authors propose a multi-species coastal fishery in Sweden, to improve the economic viability of small-scale fishing methods while addressing challenges such as seal predation and changing abundance of target species. They tested and developed pots targeting European lobster (*Homarus gammarus*), Atlantic cod (*Gadus morhua*), and edible crab (*Cancer pagurus*).

Driver 5: studying fish behaviour

In addition to gear development, innovation in fisheries is needed also in terms of research approaches, relying on the progress and availability of new technologies, such as Artificial Intelligence (AI), and observation technologies, to automate the monitoring of fish behaviour in relation to fishing gears and support the development of new solutions.

In an innovative approach, Abangan et al. reviewed the use of AI as a means to process a large amount of imagery data (i.e., image sequence, video) on fish behaviour in a more time-efficient and cost-effective manner. This is an essential step for selectivity studies to advance and integrate AI methods in assessing the effectiveness of modified gears. The authors also discussed the advances, potential, and limits of AI to help meet the demands of fishing policies and sustainability goals. Indeed, quantitative analyses of fish behaviour in relation to fishing gears can provide critical insights regarding the effectiveness of BRDs, or in identifying which gear

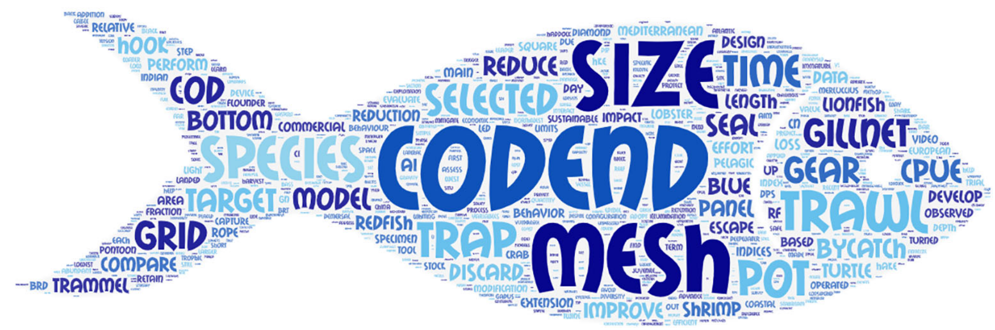

FIGURE 1
Word cloud generated from the abstracts of the 22 papers that contributed to the Research Topic [Generated through WordArt.com - Word Cloud Art Creator].

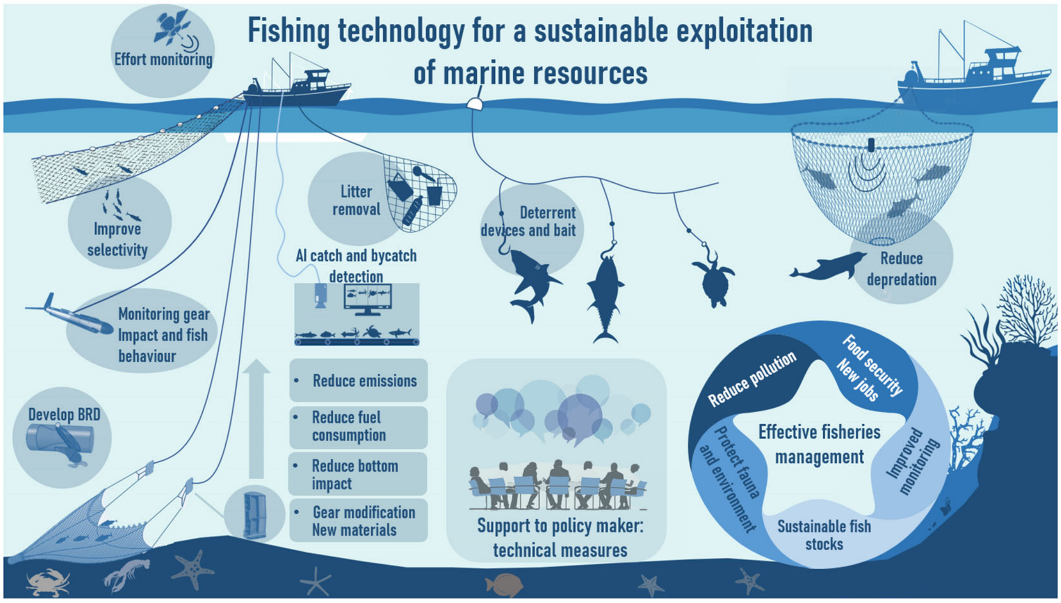

FIGURE 2
Potential of technological innovations in fisheries to benefit the environment, society, economy, and biodiversity.

design elements can lead to improvements in catching efficiency. For example, Araya-Schmidt et al. used self-contained underwater cameras and red lights to investigate the underperformance of the Nordmøre grid in excluding juvenile redfish (*Sebastes* sp.), based on their behaviour when approaching the grid. The results suggested that as time in front of the grid increased, and redfish had upward or steady grid reactions, retention was drastically reduced, thus providing useful information for perfecting or developing this BRD.

Improvements in catch efficiency and selectivity of passive gears could also be pursued by re-designing them based on the behaviour of the target species. This was exceptionally illustrated by Méhault et al. who designed a new prototype of fish pot for Black seabream (*Spondyliosoma cantharus*) following a step-by-step development process based on black seabream's natural behaviour. The method involved underwater video observations combined with quantitative analyses of the approaching and feeding behaviours of black seabream using ethograms.

Conclusions and future directions

The Research Topic, even in its limited duration, showed the vast, complex, and essential world of fisheries technology research and innovation. As shown by the 22 contributions published in the Research Topic, this field of research is highly inter- and trans-disciplinary, requiring a combination of engineering, biological and computational science, as well as a close collaboration with the stakeholders, such as fishers, managers, and environmental agencies. This Editorial highlights the importance and complexity of the topic and the number of researchers working worldwide on innovating fisheries, while raising attention to the importance of fishing technology as a fundamental science for ensuring a sustainable future (environmentally, socially, and economically) for human activities in the marine environment (Figure 2).

We hope that the success of the Research Topic will increase the focus of the scientific community on this area of research, and inspire future generations of scientists.

Author contributions

AL: Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. JB: Conceptualization, Investigation, Validation, Writing – review & editing. VM: Conceptualization, Investigation, Validation, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Cheung, W. W. L., Sarmiento, J. L., Dunne, J., Frölicher, T. L., Lam, V. W. Y., Palomares, M. L. D., et al. (2013). Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems. *Nat. Climate Change* 3 (3), 254–258. doi: 10.1038/nclimate1691

Collie, J. S., Hall, S. J., Kaiser, M. J., and Poiner, I. R. (2000). A quantitative analysis of fishing impacts on shelf-sea benthos. *J. Anim. Ecol.* 69, 785–798. doi: 10.1046/j.1365-2656.2000.00434.x

Hall, S. J. (1999). *The effects of fishing on marine ecosystems and communities* (Oxford: Blackwell Science Ltd.), 274 pp.

Hammarlund, C., Jonsson, P., Valentinsson, D., and Waldo, S. (2021). Economic and environmental effects of replacing bottom trawling with fishing with creels. *Aust. J. Agric. Resource Economics* 65, 94–118. doi: 10.1111/1467-8489.12409

Hilborn, R., Amoroso, R., Collie, J., Hiddink, J. G., Kaiser, M. J., Mazor, T., et al. (2023). Evaluating the sustainability and environmental impacts of trawling compared to other food production systems. *ICES J. Mar. Sci.* 80 (6), 1567–1579. doi: 10.1093/icesjms/fsad115

ICES (2020). ICES workshop on innovative fishing gear (WKING). *ICES Sci. Rep.* 2 (96), 130 pp. doi: 10.17895/ices.pub.7528

Jennings, S., and Kaiser, M. J. (1998). The effects of fishing on marine ecosystems. *Advance Mar. Biol.* 34, 201–352. doi: 10.1016/S0065-2881(08)60212-6

Kaiser, M. J. (1998). Significance of bottom fishing disturbance. *Conserv. Biol.* 12, 1230–1235. doi: 10.1046/j.1523-1739.1998.0120061230.x

Kasperski, S., and Holland, D. S. (2013). Income diversification and risk for fishermen. *Proc. Natl. Acad. Sci.* 110 (6), 2076–2081. doi: 10.1073/pnas.1212278110

Kennelly, S. J., and Broadhurst, M. K. (2021). A review of bycatch reduction in demersal fish trawls. *Rev. Fish Biol. Fisheries.* 31 (2), 289–318. doi: 10.1007/s11160-021-09644-0

Lehtonen, E., Lehmonen, R., Kostensalo, J., Kurkilahti, M., and Suuronen, P. (2022). Feasibility and effectiveness of seal deterrent in coastal trap-net fishing–development of a novel mobile deterrent. *Fisheries Res.* 252, 106328. doi: 10.1016/j.fishres.2022.106328

Lewison, R. L., Crowder, L. B., Read, A. J., and Freeman, S. A. (2004). Understanding impacts of fisheries bycatch on marine megafauna. *Trends Ecol. Evol.* 11, 598–604. doi: 10.1016/j.tree.2004.09.004

Lewison, R. L., Crowder, L. B., Wallace, B. P., and Safina, C. (2014). Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots. *Proc. Natl. Acad. Sci.* 112 (20), 6210–6215. doi: 10.1073/pnas.1318960111

Lindeboom, H. J., and de Groot, S. J. (1998). *IMPACT-II: The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems*. (Netherlands Institute for Sea Research), 404 pp. NIOZ-Rapport 1998-1. RIVODLO Report C003/98. Contract AIR2-CT94-1664 Financed by the European Community.

Lucchetti, A., Virgili, M., Vasapollo, C., Petetta, A., Bargione, G., Li Veli, D., et al. (2021). An overview of bottom trawl selectivity in the Mediterranean sea. *Mediterr. Mar. Science.* 22, 566–585. doi: 10.12681/mms.26969

Madsen, N., Herrmann, B., Frandsen, R. P., and Krag, L. A. (2012). Comparing selectivity of a standard and turned mesh T90 codend during towing and haul-back. *Aquat. Living Resources.* 25, 231–240. doi: 10.1051/alr/2012021

Melli, V., Herrmann, B., Karlsen, J. D., Feekings, J. P., and Krag, L. A. (2020). Predicting optimal combinations of by-catch reduction devices in trawl gears: A meta-analytical approach. *Fish Fisheries.* 21 (2), 252–268. doi: 10.1111/faf.12428

Ortiz, N., Mangel, J. C., Wang, J., Alfaro-Shigueto, J., Pingo, S., Jimenez, A., et al. (2016). Reducing green turtle bycatch in small-scale fisheries using illuminated gillnets: the cost of saving a sea turtle. *Mar. Ecol. Prog. Series.* 545, 251–259. doi: 10.3354/meps11610

Prat Farran, J., Antonijuan, J., Folch, A., Sala, A., Lucchetti, A., Sardà, F., et al. (2008). A simplified model of the interaction of the trawl warps, the otterboards and netting drag. *Fisheries Res.* 94, 109–117. doi: 10.1016/j.fishres.2008.07.007

Read, A. (2007). Do circle hooks reduce the mortality of sea turtles in pelagic longlines? *A Rev. Recent experiments. Biol. Conserv.* 135, 155–169. doi: 10.1016/j.biocon.2006.10.030

Rogers, L. A., Griffin, R., Young, T., Fuller, E., St. Martin, K., and Pinsky, M. L. (2019). Shifting habitats expose fishing communities to risk under climate change. *Nat. Climate Change* 9 (7), 512–516. doi: 10.1038/s41558-019-0503-z

Sala, A., Depestele, J., Gümüş, A., Laffargue, P., Rasmus Nielsen, J., Polet, H., et al. (2023). Technological innovations to reduce the impact of bottom gears on the seabed. *Mar. Policy.* 157, 105861. doi: 10.1016/j.marpol.2023.105861

Sala, A., Herrmann, B., De Carlo, F., Lucchetti, A., and Brčić, J. (2016). Effect of codend circumference on the size selection of square-mesh codends in trawl fisheries. *PloS One* 11, e0160354. doi: 10.1371/journal.pone.0160354

Sala, A., Prat Farran, J., Antonijuan, J., and Lucchetti, A. (2009). Performance and impact on the seabed of an existingand an experimental-otterboard: comparison between model testing and full-scale sea trials. *Fisheries Res.* 100, 156–166. doi: 10.1016/j.fishres.2009.07.004

Squires, D., and Vestergaard, N. (2013). Technical change in fisheries. *Mar. Policy.* 42, 286–292. doi: 10.1016/j.marpol.2013.03.019

Virgili, M., Vasapollo, C., and Lucchetti, A. (2018). Can ultraviolet illumination reduce sea turtle bycatch in Mediterranean set net fisheries? *Fisheries Res.* 199, 1–7. doi: 10.1016/j.fishres.2017.11.012

Watling, L., and Norse, E. A. (1998). Disturbance of the seabed by mobile fishing gear: a comparison to forest clear cutting. *Conserv. Biol.* 12 (6), 1180–1197. doi: 10.1046/j.1523-1739.1998.0120061180.x

Wienbeck, H., Herrmann, B., Moderhak, W., and Stepputtis, D. (2011). Effect of netting direction and number of meshes around on size selection in the codend for baltic cod (*Gadus morhua*). *Fisheries Res.* 109, 80–88. doi: 10.1016/j.fishres.2011.01.019