ICES Journal of Marine Science, 2025, Vol. 82, Issue 5, fsaf057
https://doi.org/10.1093/icesjms/fsaf057
Received: 6 January 2025; **revised:** 31 March 2025; **accepted:** 2 April 2025
Stories from the front lines

ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Codeveloping on deck conservation technology with tropical tuna purse seine fishers to mitigate elasmobranch bycatch

Jefferson Murua [1,*], Maitane Grande[1], Gala Moreno[2], Hilario Murua[2], Nagore Cuevas[1], Jose M. Ferarios[1], Alexander Salgado[1], Victor Restrepo[2], Josu Santiago[1]

[1]Sustainable Fisheries Management Tuna Department, AZTI-Tecnalia, Sukarrieta, 48395, Spain
[2]International Seafood Sustainability Foundation, Pittsburgh, PA, 15201, United States,

*Corresponding author. Sustainable Fisheries Management Tuna Department, AZTI-Tecnalia, Txatxarramendi Irla, Sukarrieta, 48395, Spain.
E-mail: jmurua@azti.es

Abstract

Current efforts to mitigate impacts on threatened elasmobranch species in tuna fisheries focus primarily on best handling and release practices for individuals caught in the gear or arriving on deck. Releasing elasmobranchs fast is key as prolonged ventilatory restriction results in reduced survival. Yet, because handling large sharks and mobulid rays can be very demanding and dangerous for crew, release times can be significantly delayed. To address these challenges, we developed and improved a series of novel bycatch release devices (BRDs) such as release ramps, stretchers, shark velcros, hoppers, lower deck gutters, mobulid sorting grids, and straps in close collaboration with Spanish tropical tuna purse seiner fishers. Our BRDs minimize contact between fishers and elasmobranchs for increased crew safety and release time acceleration to improve postrelease survival thus resulting in a win–win formula. Long-term cooperation between Spanish fleet fishers and our scientific group has been key to fine-tuning BRD performance, and more importantly, generating trust and promoting readiness for their voluntary uptake. Increasing sustainable fishing requirements by markets have also favoured adoption willingness. Several tuna Regional Fisheries Management Organizations have begun endorsing the new BRDs, potentially leading to greater implementation across purse seine fleets globally. The success of our case study offers insights for researchers and managers seeking to achieve effective conservation outcomes through fisher involvement.

Keywords: bycatch mitigation; elasmobranchs; bycatch release device; tuna purse seiner; fisher collaboration

Introduction

In recent decades, keystone elasmobranch species have experienced sharp declines, undermining ocean ecosystem biodiversity and functionality (Oliver et al. 2015, Pimiento et al. 2020, Juan-Jorda et al. 2022). The primary conservation threat to sharks and rays stems from artisanal and industrial fleet captures, targeted or incidental (Dulvy et al. 2021, Sherman et al. 2023, Worm et al. 2024). Although the interaction rate between elasmobranchs and tuna purse seiners is significantly lower than that of other fishing gears such as gillnets or longlines (Murua et al. 2021a, Peatman et al. 2023), urgent action is still needed to mitigate their decline due to the magnitude of the purse seine fisheries and the species' life history traits—such as late maturity and low reproductive output (Pacoureau et al. 2023, Pons et al. 2023, Dumont et al. 2024).

To tackle this problem several interventions exists (Poisson et al. 2022, Gilman et al. 2023), with one of the principal solutions being best handling and release practices (BHRPs) that facilitate unharmful and speedy removals of non-target species reaching the vessels to minimize physiological stress responses (Poisson et al. 2014a, 2016, Restrepo et al. 2018, Swimmer et al. 2020). In tropical tuna purse seiner operations, most incidentally caught elasmobranchs are brought onboard, alongside tunas, inside a brailer used to scoop the catch from the net's sack. Prolonged time in the sack, where shark movement is restricted, negatively affects shark survival due to their need to swim to ventilate their gills (Hutchinson et al. 2015). For this reason, it is paramount to release sharks arriving on deck as fast as possible since their physiological condition at this point might be already suboptimal. Currently, several regional fisheries management organization (RFMO) regulations require fishers to promptly release unharmed all sharks and rays, but often adding the condition 'to the extent practicable.' However, the same regulations provide few practical, safe alternatives to address frequently encountered challenges by fishers, such as how to extract very active adult sharks or large heavy mobulid rays from the brailer without serious injury exposure for crew. In some cases, it becomes totally unfeasible for fishers to manually extract from the brailer certain adult individuals, which can measure up to 7 m and weigh more than 1000 kg (Couturier et al. 2012). This disconnect between current BHRP recommendations and the reality of high risk experienced by crew, may lead to fishers considering regulations unfair and opting to apply poor, but safe for them, release practices. For example, using hooks and nooses to lift and release large elasmobranchs, while detrimental to the animals' survival, increases fishers' safety on deck (Maufroy et al. 2020).

Developing safe technologies to minimize risky interactions between fishers and elasmobranchs can significantly increase live release rates (Zollet and Swimmer 2019). However, most fishing industries have been slow to accept new bycatch mitigation equipment, often resulting in weak or absent adoption (Eayrs et al. 2014, Eayrs and Pol 2018). This problem is partly due to researchers often focusing primarily on the experimental performance of developed selective gears and overlook critical human dimensions necessary to overcome barriers to their adoption (Suuronen, 2022). In the few instances where such selective technologies have been adopted, fishers have been deeply involved in the design and testing process (Tookes et al. 2022, Jenkins 2023). Factors such as economic feasibility, social approval, and safety concerns of fishers with bycatch mitigation technologies are seldom carefully considered (Suuronen 2022), thus preventing fisher readiness for their uptake (Jenkins et al. 2023).

We present the ongoing case study of close cooperation between Spanish tuna purse seine fishers and our group of scientists, focusing on both human and technical aspects to develop specialized on-deck release equipment aimed at improving both crew safety and elasmobranch survival. We discuss encountered challenges and driving factors for the voluntary uptake of bycatch release devices (BRDs) in this fleet, and potential future steps for their expansion to other fleets globally.

Establishing a fisher-scientist collaborative culture

The Spanish tropical tuna purse seine fleet, with over 60 large-scale industrial vessels, including those vessels operating under other flags, is one of the most important globally in terms of catches (Justel-Rubio et al. 2024). The vessels operate globally in all tropical oceans, but fishing companies are based in Spain and are organized into two associations (OPAGAC and ANABAC) (Moreno et al. 2007).

In 2020, we started collaborations with Spanish tuna purse seiners with a greater focus on release equipment innovation to increase elasmobranch postrelease survival (PRS). Prior to this, for over a decade, our small group of researchers (i.e. <12 fisheries scientists and technologists) had consistently engaged with fishers from this fleet through various ecosystem impact mitigation initiatives. For instance, beginning in 2009, through the International Seafood Sustainability Foundation sponsored 'Skippers Workshops' (ISSF SWs), captains, crew, ship-owners, fleet managers, etc. discussed face-to-face with scientists best sustainable fishing practice options (Murua et al. 2023a), along with other state and European Union funded participatory conservation projects (Moreno et al. 2019, Airaud et al. 2020). In the last decade, we have conducted over 150 in-person meetings and workshops on sustainable fishing topics with the Spanish purse seine fleet (Table 1). During our earliest interactions, fishers were less open to sharing their knowledge with us, fearing it could be used to inform management measures that work against them. At this initial stage of engagement, fishers lacked both cognitive and affective readiness for change (*sensu* Jenkins et al. 2023), despite our best efforts to clearly explain to them the benefits of collaborating with us. However, our frequent and transparent interactions with them overtime, both at workshops and research cruises, fostered an increased awareness of sustainability issues among many fishers and gradually built trust in our work to help them in addressing external pressures (e.g. increasing conservation measures and sustainable fishing market demands). We should point out that working on bycatch reduction solutions once the catch has arrived on deck is luckily among the least contentious mitigation strategies for fishers, as at this stage the fish catch is secured and they also want non-target species to be off deck as soon as possible. Reaching voluntary agreements on bycatch mitigation actions that can potentially negatively affect tuna catches, such as fishing closures in bycatch hotspots or significant modifications in the purse seine net, would have likely been more challenging. Initially, we partnered with the more progressive and innovative skippers, often high-rank fishers well-respected in their community, to move forward with conservation research. Strengthening this relationship paved the way for several successful joint research projects since mid-2010s. Initiatives included the development and uptake of non-entangling Fish Aggregating Devices (NEFADs) to minimize ghost fishing impacts on turtles and sharks, and large-scale trials with biodegradable FADs to reduce marine pollution (Moreno et al. 2023, Zudaire et al. 2023, Murua et al. 2023b).

Growing external societal and economic pressures, might have also increasingly driven the fishing industry's involvement in marine ecosystem conservation projects (Moreno et al. 2016). Specifically, for tuna purse seiners, critics have at times called for bans on FAD fishing due to potential negative ecological impacts (Gomez et al. 2020). However, some proactive purse seine fleets, like the Spanish have long been striving to mitigate such effects by promoting transparency and sustainable practices (Báez et al. 2020). For instance, in 2014, the Spanish purse seine associations and their affiliated companies voluntarily adopted a Code of Good Practices (CGPs) programme to reduce FAD fishing ecosystem impacts. Our group of scientists has been actively involved in monitoring and providing guidance on best practices within this programme, which remains active (Goñi et al. 2015). In the CGP, we assess the implementation of a series of voluntary conservation commitments by member vessels, including the use of NEFADs and state-of-the-art BHRPs (Grande et al. 2020).

More recently, the Spanish tuna purse seiner fleet has embarked on the Marine Stewardship Council (MSC) certification process and attained it for several of its target tuna stocks. The benefits of obtaining MSC certification include enhanced market access and improved sale prices (Peiró-Signes et al. 2020). To obtain a passing score against MSC's Principle 2, which focuses on minimizing environmental impacts, vessels must demonstrate that they do not pose a significant risk to or hinder recovery of endangered, threatened, and protected (ETP) species. As new BRDs can assist fishing companies in meeting such requirements, this provided a strong incentive for their uptake.

Development and testing of BRDs at sea

Notably, almost all BRDs originated from ideas suggested by fishers in face-to-face participatory workshops (Murua et al. 2023a). For example, BRDs such as stretchers and ramps for sharks and sorting grids and crossed straps for mobulid rays were fishers' conceptions (Fig. 1; Table 2). Some fishers even fabricated early basic versions of release equipment onboard. Having conservation technologies originating from experienced problem-solving fishers, sometimes described as successful fisher-inventors (Jenkins 2010) or projective fishers (Barz et al. 2020), was critical as this can positively influence BRD adoption. Subsequently, through various research technology projects, our team of scientists and technologists designed and constructed more refined BRD prototypes based on their ideas and trial feedback. Concurrently, we also

Table 1. Number of workshops and fisher participations (i.e. captains, navigators, officers, chief engineers, deck bosses, and deck crew) and fleet managers (i.e. ship-owners, fleet managers, and fishing association managers) from the Spanish tropical tuna purse seine fleet between 2009 and 2024.

Year	Participatory events	Type of event	Number of Fishers	Number of Fleet Managers
2009	1	a	17	12
2010	3	a, b	53	-
2011	1	a	14	-
2012	9	a, b, c, f	116	21
2013	7	a, b, c, g	67	9
2014	10	a, d, h, i	101	26
2015	11	a, d, i	72	49
2016	8	a, b, d, i	136	19
2017	10	a, d, i	105	31
2018	11	a, b, d, i	190	32
2019	9	a, b, d, i	104	33
2020∗	3	h, i	-	36
2021	6	a, d, i	42	19
2022	18	a, b, d, i	182	50
2023	27	a, d, e	229	40
2024	29	a,b, d	175	47

a. ISSF Skippers Workshops, b. Non-entangling biodegradable FAD workshops, c., EU GAP2 project workshops, d. Code of Best Practices Workshops, e. ISSF Bycatch Release Device Workshop, f. EU MADE workshop, g. FAD buoy data meetings; h. FAD limit verification meetings; and i. Code of Good Practices Steering Committee meetings. ∗ Online meetings. No in-person participatory fisher workshops were conducted in 2020 due to COVID-19 pandemic.

reevaluated equipment originally conceived for non-commercial fish discards, for their potential assistance in elasmobranch releases. Specifically, we examined large-sized equipment like hoppers with doors, which are large metallic trays for sorting bycatch on deck, and gutters (or waste chutes), which are doors in a vessel's lower (well) deck to return unwanted catch to the water directly (Murua et al. 2023c).

By the time BRD research commenced, our team had already identified from previous projects several proactive skippers in this fleet with strong problem-solving skills, well-suited as allies for marine conservation research. Partnering with them for initial BRD tests proved advantageous, as they were more likely to objectively evaluate test results and suggest improvements if early prototypes performed suboptimally. Based on the BRD information collected at sea in research cruises by human observers (HO) and/or electronic monitoring (EM) data, and the feedback from fishers at the workshops, adjustments followed. The primary criteria for BDR modifications were utility aspects (e.g. safer and faster release, easier to employ, and cheaper to build) to promote fisher acceptance. Leading skippers who championed BRD developments positively influenced other fleet members to adopt new devices.

During early BRD experimental phases, most prototypes originated from public or industry-funded research projects and were given to fishers free of charge for testing, as in these initial stages fishing companies were still not willing to invest in BRDs without further proof of their utility. Although no single long-term research project financed all BRD developments and trials in the Spanish fleet, consistent funding from agencies for research over the last 5 years generated sufficient momentum for fisher readiness to uptake the BRDs. The trials have always been on a voluntary basis, never imposed, leading to more open and objective fishers' attitudes. Importantly, fishers were allowed to discontinue the use of BRDs if they found them detrimental to fishing operations (e.g. unsafe, slow, and non-functional). Some BRD ideas failed, for instance, we quickly dismissed experimental tools like poles to manipulate sharks or semi-rigid frame grids for mobulids after their first trials at sea. During early tests, some skippers opted out of using particular BRDs, such as the larger equipment like hoppers that required more amendments during brailing. Smaller and simpler tools, like velcros, ramps, or mobulid sorting grids, require fewer protocol adjustments.

As BRDs became more refined, evidence of their utility for elasmobranch survival was assessed based on release time and animal condition at release recorded by HO or EM, with 100% coverage, and 15 dedicated BRD research cruises since 2020 (e.g. 4 Atlantic, 4 Eastern Pacific, 3 Western and Central Pacific, and 4 Indian Ocean) collecting physiological parameters (e.g. over 2000 vitality index records, 400 lactate blood samples) and deploying pop-up satellite tags (e.g. over 170 tags). It is important to note that other factors, in addition to the type of release practice applied on deck, influence the overall survival rates of caught elasmobranchs, including biological (e.g. species, age, and size) and operational (e.g. time in the sac, size of the catch) parameters (Hutchinson et al. 2015, Mandelman et al. 2022). Unfortunately, we could not perform that research to appraise the impact of those other factors in the survival rate of caught and released animals with BRDs, but this clearly should be a future line of investigation.

During our frequent meetings, we presented fishers BRD trial updates in plain, non-scientific language avoiding technical jargon, and with empathy, acknowledging fishers' risks encountered during the release of dangerous species and their efforts to trial the BRDs. To support the acceptance of BRDs, photo and video footage of BRD release operations in different vessels were also collected and shared with fishers during instructional workshops. These visual aids were highly useful, providing irrefutable proof that BRDs worked effectively in many purse seiners, which was especially heplful when engaging with more skeptical fishers. Additionally, guides with construction instructions and step-by-step illustrations for the correct use of each BRD were distributed to inform Spanish fleet company members.

The final say on purchasing BRDs for industrial fleet vessels lies in the hands of ship owners, who are at the top of the fishing companies' hierarchy (i.e. they are the skippers' bosses). We conducted regular in-person meetings with Spanish ship-owners and their assistant fleet managers to inform about

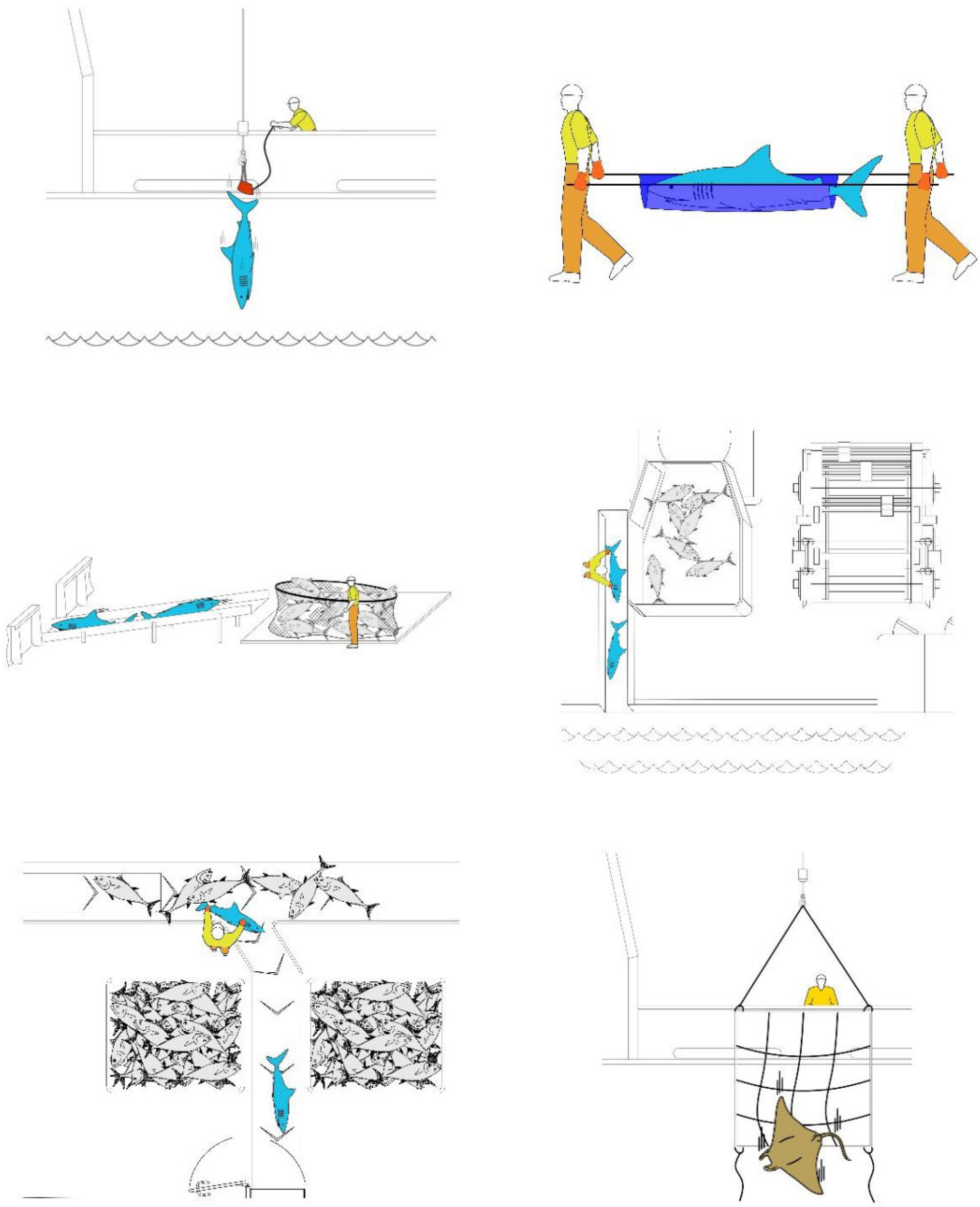

Figure 1. Tuna purse seiner BRDs (top left) shark velcro, (top right) stretcher, (centre left) release ramp, (centre right) hopper with ramp, (bottom left) lower deck gutter with conveyor belt, and (bottom right) mobulid sorting grid. Illustrations from new BHRPs for tropical tuna purse seiners guide (AZTI©).

BRDs. Although some more proactive ship-owners adopted BRDs faster than others, by 2022–2023 several Spanish companies committed to implementing small BRDs such as velcros, release ramps, and mobulid sorting grids in all their vessels (Table 3). Once a critical number of vessels employed them, many others followed, in part due to normative social influence.

Win–win strategies for adoption of BRDs

For fishers to embrace bycatch mitigation technologies, strategies must directly benefit them. The new BRDs offer safer and faster releases of non-target species that are challenging to handle, ensuring minimum direct contact solutions for lifting large and heavy animals out of the brailer without resorting to prohibited methods such as hooks and nooses (Table 2). Ensuring rapid removal of bycatch was crucial for industry acceptance, as in hot tropical conditions catch loading operation delays can quickly lead to histamine buildup, rendering tuna unfit for sale.

From an elasmobranch conservation perspective, reduced manipulation and quick return to the water are critical to minimizing physiological stress and improving PRS (Mandelman et al. 2022). For instance, Stewart et al. (2024) identified that short release time on deck (i.e. <3 min) as the principal factor increasing mobulid ray PRS in purse seiners. Mobulid sorting grids enable the release of large individuals in record times (i.e. 1–2 min), compared to slower methods such as releases by hand or with cargo nets (Murua et al. 2021b).

Fleet acceptance of many BRDs was significantly influenced by their practical characteristics, such as construction cost, ease of use, and deck space occupation when stored away.

Table 2. Commonlyrecommended practices for the release of sharks and mobulid rays by Regional Fisheries Management Organizations (RFMOs) and BRDs tested by the Spanish tropical tuna purse seine fleet to solve release difficulties.

Bycatch group	RFMO recs.	Release difficulty	BRD description	Location	BRD size	Function	Limitations	Price	Viability
Large sharks	Prohibit gaffing, lifting by gills/tail with ropes, avoid leaving on deck, use a cargo net or canvas sling for release.	Sharks must be extracted from the brailer before placement on a cargo net/canvas.	**Shark Velcro** Cushioned, non-incisive strap to wrap around the caudal peduncle and lift via crane.	Working deck	Small	Lifts shark from the brailer without manual handling; prevents tail injuries.	May require different velcro sizes for different shark species.	Low	Very high
		Moving sharks from brailer to water.	**Stretcher*** Canvas/net bed with handles to safely transport bycatch.	Working deck	Small	Allows two crew members to safely and quickly transport sharks from brailer/hopper to water.	Requires prior manual extraction of the shark from the brailer.	Low	Very high
			Ramp* Inclined slide connecting brailer/hopper to water's edge for smooth release.	Working deck	Small to medium	Minimizes contact and stress during shark release.	Requires manual extraction first; additional deck space needed for mounting/storage.	Low	High
Small sharks	Release carefully by hand from the brailer.	Many individuals are not visible in the brailer and may fall to the lower deck.	**Hopper with ramp*** Large metallic tray to sort bycatch before it reaches the lower deck; includes stoppage door to reduce accidental falls.	Working deck	Large	Improves bycatch visibility; prevents sharks from falling below deck; enables quick and safe release.	Requires manual extraction; takes up deck space; setup and storage require extra effort; higher cost.	Medium to high	Medium
			Gutter with conveyor belt* Lower deck opening near sea level to release bycatch.	Lower deck	Large	Faster release of fallen sharks with minimal manual handling.	Requires strict permits to prevent sinking hazard; high cost.	Medium to high	Low
Large mobulid rays	Prohibit gaffing, punching holes, lifting by gill slits/spiracles; recommend cargo net or canvas for release.	Mobulid must be extracted from the brailer before placement on net/canvas.	**Mobulid sorting grid*** Metal frame with rope grid to allow fish to pass while retaining mobulids for crane-assisted release.	Working deck	Small	Enables faster release without manual extraction.	Requires crane for lifting; needs dedicated storage space.	Low	Very high
			Crossed straps* Two intersecting straps with a cushioned base in the middle to lift mobulid rays with a crane.	Working deck	Small	Enables faster release without manual extraction.	Requires crane; mobulid must be positioned in the upper brailer section for proper placement.	Low	Very high

*Devices originating from fishers' ideas.

Table 3. Percentage of BRDs for sharks and mobulid rays employed by Spanish tropical tuna purse seine fishing association vessels as of December 2024.

Company	No. of purse seiners	Stretcher (%)	Velcro (%)	Ramp (%)	Hopper (%)	Gutter (%)	Mobulid sorting grid (%)	Mobulid strap (%)
A	18	100	94	94	6	11	94	11
B	4	100	0	100	100	0	100	0
C	6	100	66	100	33	0	100	33
D	1	100	100	0	0	0	100	0
E	7	100	86	100	14	86	86	43
F	5	100	0	100	40	0	100	0
G	5	100	0	60	20	0	100	0
H	7	100	100	71	14	43	71	14
I	6	100	100	100	0	67	100	100
J	6	100	100	100	33	0	83	17

More refined BRDs, mostly reached after the third year of trials (e.g. 2022 onwards) prompted a higher adoption rate. For example, later release ramps and mobulid sorting grids became three times lighter and occupied half the storage space of original prototypes. Most BRDs are economical for industrial purse seiner standards, costing from less than 100 USD per unit for velcros, stretchers or mobulid crossed straps, to under 1000 USD for sorting grids and 5000 USD for ramps. Meanwhile BRDs, such as hoppers with ramps, which can cost between 15 000 and 40 000 USD depending on size and materials, represent a long-lasting effective tool. However, we observed that the feasibility of implementing larger BRDs varied based on a vessel's construction plan, especially in smaller boats with limited free space. Therefore, while the integration of larger BRDs is encouraged, it must be carefully evaluated on a case-by-case basis.

Expansion of BRDs to other tuna purse seine fleets

In addition to the Spanish fleet, other purse seine fleets have begun voluntarily trialing and uptaking these BRDs. The ISSF SWs, conducted globally in key tuna ports by members of our team, have facilitated the rapid transfer of BRD knowledge across multiple fleets. In these workshops we often feature devices ready for inspection and show videos of commercial vessels using them (Murua et al. 2023a). We also organized BRD specific Fisher Learning Exchanges (FLEs), enabling fishers already working with BRDs to reassure peers from other fleets about their benefits, thus increasing adoption readiness (Murua et al. 2023c). For instance, the Ecuadorian fleet, which is among the most active in the ISSF SWs and FLEs, has equipped more than ten large-scale purse seiners with ramps and/or mobulid sorting grids and plans to scale up BRD implementation (Cronin et al. 2022). Similarly, the USA fleet, has hoppers in most vessels, and has now fitted mobulid sorting grids in all vessels and starting to implement ramps (Cronin et al. 2024). Fleets like the French are also working in improving their BHRPs with the help of release equipment (Wain and Maufroy 2023).

Recent studies on our BRDs have been presented at tuna RFMOs to inform scientific staff and policymakers of the improved PRS rates achieved with these devices (e.g. Onandia et al. 2021, Murua et al. 2024a). Additionally, because Poisson et al. (2012) key guide for elasmobranch BHRPs in purse seiners, referenced in most RMFO release measures, was produced before the development of our BRDs, an updated BHRP guide incorporating the new BRDs for the first time has been disseminated among industry stakeholders and fisheries managers (Murua et al. 2024b).

Recently some tuna RFMOs have passed conservation measures that encourage the use of release ramps (e.g. IOTC Res. 19–03; ICCAT Rec. 21–09; IATTC C-16–05; and WCPFC CMM-22–03) and even hoppers, if the vessel layout permits (e.g. ICCAT Rec. 21–09; WCPFC CMM-22–03). We recommend fisheries managers to consider mandating the use of certain BRDs in a similar way tuna longliners are required to carry onboard release tools such as long handled dehookers and line cutters. For example, stretchers, velcros, and ramps for sharks and mobulid sorting grids, could be required as they are low cost BRDs that work in every large-scale purse seiner. For larger BRDs, if it is not viable to currently implement them in some operating vessels, we recommended that newly constructed vessels incorporate release equipment such as hoppers with ramps and lower deck gutters, as their integration would be much simpler.

Discussion

The rapid and widespread buy-in of elasmobranch BRD conservation technologies in the Spanish tropical tuna purse seine fleet is built on the committed involvement of key fishers and stakeholders from the early development stages and at sea trials. Although we are aware that successful lessons described in many studies with fisher cooperation might be identied post hoc, in our case, a decade of prior trial and error experiences in collaborative research with this fleet had taught us which approaches were more conductive for sustainability results. Because each fishery has its own complex socio-ecological circumstances, application of recommended best practices for uptake of bycatch reduction fishing gear may not always guarantee widespread change (Suuronen 2022, Jenkins et al. 2023). In our case, we invested considerable time and effort not only in technical BRD aspects but also in the human dimensions required to prepare fishers for change, both cognitive and affective, as voluntary adoption is more likely if they feel it is necessary (Jenkins et al. 2023). The trust we built with this fleet, thanks to genuine engagement through frequent activities such as the ISSF SWs, the CBP, and other research projects, greatly raised fishers' environmental awareness and reduced their fears and concerns to work with scientists on bycatch mitigation. In addition, the general view by the Spanish fleet that BRDs could help them better respond to increasing ETP species conservation requirements by regulators and markets played a role in the acceleration of their uptake.

For persistent positive impacts, stable face-to-face cooperative platforms conformed by researchers and representation from all fishing fleet ranks (i.e. vessel associations, shipowners, fleet managers, skippers, and crew) are paramount. Our regular feedback loop with fishers to understand their challenges and perspectives, with multiple in person meetings per year, increased empathy and readiness to accept BRDs. Importantly, most of the tools originated from fishers themselves during brainstorming exercercises in participatory workshops. In our case the local inventor effect, described by Jenkins (2010), was instrumental in providing more practical BRD designs and leading uptake even among more conservative fleet members.

Continued funding, whether public or private, is required to maintain long-term interdisciplinary stakeholder communication channels and building bridges with the fishing sector to support sustainability objectives. The positive conservation outcomes derived from permanent science-industry cooperative programmes outweigh the costs (Hall et al. 2017, Gammage et al. 2024). Implementation costs of such programmes will be highly dependent on the scale and needs of each fishery, but in multistakeholder international industrial fleet platforms with associated research programmes, it might cost several hundred thousand USD per year.

We worked to provide fishers with safer, practical, and in most cases low-cost, elasmobranch BRDs to improve on deck release options that are unharmful to threatened species. The use of BRDs on deck, with devices such as hoppers with ramps and lower deck gutters with conveyor belts, yielded PRS rates of 40%–60% for sharks examined in various research cruises (see Onandia et al. 2021, Murua et al. 2024a). This represents a two-to-three-fold increase in PRS rates compared to other studies on purse seiners without release tools or with suboptimal BRDs (e.g. hoppers with small trays or no stoppage doors and no release ramp) (Poisson et al. 2014b, Hutchinson et al. 2015, Eddy et al. 2016). While avoidance strategies are still preferable and should continue to be pursued (Gilman et al. 2023), for species of sharks and rays facing marked population declines (Dulvy et al. 2021, Juan-Jordá et al. 2022), investing in BRDs to maximize their prompt live release is justifiable even if only a few individuals arrive on deck. Furthermore, despite the diverse configurations of purse seiners, the simpler BRDs are widely implementable, as observed in vessels from multiple oceans (Cronin et al. 2022, 2024). The growing voluntary uptake of such BRDs by several international fleets like USA, Ecuador, and others demonstrates their usefulness. Moreover, these novel tools support the fleets in their objectives of eco-certification for improved market access by mitigating impacts on threatened species.

Ensuring that fishers are well-informed about BHRPs with BRDs, e.g. through dedicated training programmes, is crucial for their socialization and correct implementation (Wosnick et al. 2023, Murua et al. 2023a). In addition, support from decision-makers through conservation policies requiring BRDs would accelerate their universal adoption. These new BRDs align with RFMO management recommendations for scientific research investigating at-vessel and post-release mortality of ETP species and the development of more effective live release methods. At a national level, policymakers can promote the implementation of BRDs in their fleets through their National Plan of Actions for the conservation of sharks and rays.

If advances in mitigation technologies for elasmobranchs only occurs in purse seiners, conservation benefits will be partial, as other fishing gears with higher interaction rates might prevent meaningful population recoveries. We believe that better tools for elasmobranch BHRPs should be developed and adopted in other fishing gears as well, both artisanal and industrial, and fisher involvement through inclusive processes like the one presented here can help, with management bodies endorsing and monitoring their application.

Conclusion

Our case study on the codevelopment of BRDs with the Spanish tuna purse seine fleet to reduce elasmobranch impacts illustrates the added value of long-term integration of fishers' knowledge and concerns for the production of novel sustainable fisheries solutions. As conservation regulations for threatened bycatch species expand and market access becomes more reliant on compliance with stricter sustainable fishing standards, the fishing sector must adapt to minimize their ecosystem impacts. Employing bycatch mitigation technologies is a crucial way to reduce their environmental footprint. We argue that for the successful development and voluntary implementation of selective technological solutions, fishers' knowledge and cooperation is crucial. Founding and maintaining stable communication platforms for harvesters and researchers to engage, although costly, is necessary to foster trust and a willingness to reach common grounds for environmental sustainability objectives. Identifying win-win research that is beneficial both to fishers and marine species will favour the uptake of conservation actions. Support from management bodies for best practices validated by fishers may also contribute to their application across less proactive fleets. We believe that the collaboration principles described in this case study are generally applicable across fisheries of different sizes and gears. We hope our story encourages other researchers and managers, especially those working in fisheries with higher impacts on ETP species, to build strong collaborative connexions with fishers for better marine conservation outcomes.

Acknowledgements

Special thanks are due to members of the purse seine associations OPAGAC and ANABAC, including fishers, shipowners, fleet managers, and representatives. We also thank IATTC scientific staff for their collaboration in trials with OPAGAC vessels operating in the eastern Pacific Ocean and Manta Trust for the provision on satellite tags during research trials. We extend our gratitude to the anonymous reviewers for insightful suggestions to improve the manuscript. BDR development and trials have been conducted under several projects funded by Eusko Jaurlaritza, European Union Next Generation, Secretaria General de Pesca, and ISSF.

Author contributions

Jefferson Murua (Conceptualization [lead], Formal analysis [lead], Investigation [lead], Writing – original draft [lead], Writing – review & editing [lead]), Maitane Grande (Conceptualization [equal], Formal analysis [lead], Investigation [lead], Writing – original draft [equal], Writing – review & editing [equal]), Gala Moreno (Conceptualization [equal], Investigation [equal], Writing – original draft [equal], Writing

– review & editing [equal]), Hilario Murua (Conceptualization [equal], Investigation [equal], Writing – original draft [equal], Writing – review & editing [equal]), Nagore Cuevas (Formal analysis [equal], Investigation [equal], Writing – original draft [equal], Writing – review & editing [equal]), Jose M. Ferarios (Conceptualization [equal], Investigation [equal]), Alexander Salgado (Conceptualization [equal], Investigation [equal]), Victor Restrepo (Conceptualization [equal], Investigation [equal]), and Josu Santiago (Conceptualization [equal], Investigation [equal], Project administration [lead], Writing – original draft [equal], Writing – review & editing [equal]).

Conflict of interest: None declared.

Funding

This work has been funded by the Basque Government (PESAC programme), Next Generation Funds from the European Union and the Spanish Secretaría General de Pesca. In addition, OPAGAC and ANABAC have provided funds to research projects. Also, ISSF has financed the construction of several prototype BRDs for trials. In addition, NOAA have provided funds for satellite tag studies with mobulid sorting grids and release ramps in the USA fleet and Manta Trust, IATTC, and Tunacons in the Ecuadorian fleet.

Data availability

There are no new data associated with this article.

References

Airaud M, Tezenas L, Moreno G. *et al.* Action research in tropical tuna purse seine fisheries: thoughts and perspectives. In: P. Holm, M. Hadjimichael, S. Linke, S. Mackinson (eds), *Collaborative Research in Fisheries: Co-creating Knowledge for Fisheries Governance in Europe*. Cham: Springer International Publishing, 2020, 193–212.

Báez JC, Ramos ML, Herrera M. *et al.* Monitoring of Spanish flagged purse seine fishery targeting tropical tuna in the Indian Ocean: timeline and history. *Mar Policy* 2020;**119**:104094. https://doi.org/10.1016/j.marpol.2020.104094

Barz F, Eckardt J, Meyer S. *et al.* 'Boats don't fish, people do'- how fishers' agency can inform fisheries-management on bycatch mitigation of marine mammals and sea birds. *Mar Policy* 2020;**122**:104268. https://doi.org/10.1016/j.marpol.2020.104268

Carrier JC, Simpfendorfer CA, Heithaus MR. *et al. Strategies to Reduce Fisheries Bycatch Mortality in Chondrichthyans. Biology of Sharks and Their Relatives*: Boca Raton: CRC Press, 2022, 737–66. https://doi.org/10.1201/9781003262190

Couturier LIE, Marshall AD, Jaine FRA. *et al.* Biology, ecology and conservation of the Mobulidae. *J Fish Biol* 2012;**80**:1075–119. https://doi.org/10.1111/j.1095-8649.2012.03264.x

Cronin MR, Moreno G, Murua J. *et al.* Progress in addressing key research to inform Mobulid ray conservation in the Pacific Ocean. WCPFC-SC20-2024/EB-IP-18, WCPFC 20th Regular Session of the Scientific Committee, Manila, Philippines, August 2024 2024. https://meetings.wcpfc.int/node/22967. (18 April 2025, date last accessed).

Cronin MR, Croll DA, Hall MA. *et al.* Harnessing stakeholder knowledge for the collaborative development of Mobulid bycatch mitigation strategies in tuna fisheries. *ICES J Mar Sci* 2023;**80**:620–34. https://doi.org/10.1093/icesjms/fsac093

Dulvy NK, Pacoureau N, Rigby CL. *et al.* Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. *Curr Biol* 2021;**31**:4773–4787.e8. https://doi.org/10.1016/j.cub.2021.08.062

Dumont A, Duparc A, Sabarros PS. *et al.* Modeling bycatch abundance in tropical tuna purse seine fisheries on floating objects using the Δ method. *ICES J Mar Sci* 2024;**81**:887–908. https://doi.org/10.1093/icesjms/fsae043

Eayrs S, Cadrin SX, Glass C. Managing change in fisheries: a missing key to fishery-dependent data collection?. *ICES J Mar Sci* 2014;**72**:1152–58.

Eayrs S, Pol M. The myth of voluntary uptake of proven fishing gear: investigations into the challenges inspiring change in fisheries. *ICES J Mar Sci* 2019;**76**:392–401. https://doi.org/10.1093/icesjms/fsy178

Eddy C, Brill R, Bernal D. Rates of at-vessel mortality and post-release survival of pelagic sharks captured with tuna purse seines around drifting fish aggregating devices (FADs) in the equatorial eastern Pacific Ocean. *Fish Res* 2016;**174**:109–17. https://doi.org/10.1016/j.fishres.2015.09.008

Gammage LC, Longo CS, van Putten I. *et al.* The power of collaboration in multifishery improvement initiatives. *ICES J Mar Sci* 2024;**81**:833–49. https://doi.org/10.1093/icesjms/fsae038

Gilman E, Chaloupka M, Booth H. *et al.* Bycatch-neutral fisheries through a sequential mitigation hierarchy. *Mar Policy* 2023;**150**:105522. https://doi.org/10.1016/j.marpol.2023.105522

Gomez G, Farquhar S, Bell H. *et al.* The IUU nature of FADs: implications for tuna management and markets. *Coast Manag* 2020;**48**:534–58. https://doi.org/10.1080/08920753.2020.1845585

Goñi N, Ruiz J, Murua H. *et al.* System of verification of the code of good practices on board ANABAC and OPAGAC tuna purse seiners and preliminary results for the Atlantic Ocean. WCPFC-SC11-2015/EB-IP-11 2015. https://meetings.wcpfc.int/libraries/pdf.js/web/viewer.html?file=https%3A%2F%2Fmeetings.wcpfc.int%2Fsystem%2Ffiles%2FEB-IP-11%2520Verification%2520code%2520good%2520practise%2520PS.pdf

Grande M, Ruiz J, Murua H. *et al.* Progress on the Code of Good Practices on the tropical tuna purse seine fishery in the Atlantic Ocean. *Collect Vol Sci Pap ICCAT* 2020;**76**:193–234.

Hall M, Gilman E, Minami H. *et al.* Mitigating bycatch in tuna fisheries. *Rev Fish Biol Fish* 2017;**27**:881–908. https://doi.org/10.1007/s11160-017-9478-x

Hutchinson MR, Itano DG, Muir JA. *et al.* Post-release survival of juvenile silky sharks captured in a tropical tuna purse seine fishery. *Mar Ecol Prog Ser* 2015;**521**:143–54.

Jenkins L. Profile and influence of the successful fisher-inventor of marine conservation technology. *Conserv Soc* 2010;**8**:44–54.

Jenkins LD, Eayrs S, Pol MV. *et al.* Uptake of proven bycatch reduction fishing gear: perceived best practices and the role of affective change readiness. *ICES J Mar Sci* 2023;**80**:437–45. https://doi.org/10.1093/icesjms/fsac126

Jenkins LD. Turtles, TEDs, tuna, dolphins, and diffusion of innovations: key drivers of adoption of bycatch reduction devices. *ICES J Mar Sci* 2023;**80**:417–36. https://doi.org/10.1093/icesjms/fsac210

Juan-Jordá MJ, Murua H, Arrizabalaga H. *et al.* Seventy years of tunas, billfishes, and sharks as sentinels of global ocean health. *Science* 2022;**378**:eabj0211. https://doi.org/10.1126/science.abj0211

Justel-Rubio A. A snapshot of the large-scale tropical tuna purse seine fishing fleets as of June 2024 (Version 12). *ISSF Technical Report 2024-05*. Pittsburgh, PA: International Seafood Sustainability Foundation, 2024.

Moreno G, Dagorn L, Sancho G. *et al.* Fish behaviour from fishers' knowledge: the case study of tropical tuna around drifting fish aggregating devices (DFADs). *Can J Fish AquatSci* 2007;**64**:1517–28. https://doi.org/10.1139/f07-113

Moreno G, Herrera M, Morón J. To FAD or not to FAD: a challenge to the Marine Stewardship Council and its Conformity Assessment Bodies on the use of Units of Assessment and Units of Certification for industrial purse seine tuna fisheries. *Mar Policy* 2016;**73**:100–7. https://doi.org/10.1016/j.marpol.2016.08.001

Maufroy A, Gamon A, Vernet A-L. *et al.* 8 Years of best practices onboard French and associated flags tropical tuna purse seiners: an overview in the Atlantic and Indian Oceans. IOTC-2020-WPEB16-11. 2020. https://www.researchgate.net/publication/363367755

Moreno G, Salvador J, Zudaire I. *et al.* The Jelly-FAD: a paradigm shift in the design of biodegradable fish aggregating devices. *Mar Policy* 2023;**147**:105352. https://doi.org/10.1016/j.marpol.2022.105352

Moreno G, Boyra G, Moreno G. *et al.* Towards acoustic discrimination of tropical tuna associated with Fish Aggregating Devices. *PLoS One* 2019;**14**:e0216353.

Murua J, Moreno G, Dagorn L. *et al.* Improving sustainable practices in tuna purse seine fish aggregating device (FAD) fisheries worldwide through continued collaboration with fishers. *Front Mar Sci* 2023a;**10**. https://doi.org/10.3389/fmars.2023.1074340

Murua H, Zudaire I, Tolotti M. *et al.* Lessons learnt from the first large-scale biodegradable FAD research experiment to mitigate drifting FADs impacts on the ecosystem. *Mar Policy* 2023b;**148**:105394. https://doi.org/10.1016/j.marpol.2022.105394

Murua H, Dagorn L, Moreno G, *et al.*. *Questions and Answers about FADs and Bycatch (Version 3)*. ISSF Technical Report 2021-11. International Seafood Sustainability Foundation, . . https://www.iss-foundation.org/about-issf/what-we-publish/issf-documents/issf-2021-11-questions-and-answers-about-fads-and-bycatch/

Murua J, Ferarios JM, Grande. *et al.* Developing solutions to increase survival rates of vulnerable bycatch species in tuna purse seiner FAD fisheries. 2nd Ad-Hoc Working Group on FADS Meeting. IOTC-2021-WGFAD02-11_rev1. 2021b

Murua J, Ferarios JM, Moreno G. *et al. ISSF Workshop on Deck Bycatch Reduction Devices (BRDs) for Vulnerable Species in Tropical Tuna Purse Seiners*. ISSF Technical Report 2023-11A. Pittsburgh, PA, USA: International Seafood Sustainability Foundation, 2023c

Murua J, Ferarios JM, Grande M. *et al.* Silky shark post release survival evaluation in tropical tuna purse seiners using hoppers with ramps. WCPFC 20th Regular Session of the Scientific Committee, Informative Document, Manila, Philippines, August 2024. 2024a.

Murua J, Ferarios JM, Grande M. *et al.* Incorporating bycatch release devices in guidelines for best bycatch handling and release practices in tropica tuna purse seiners. *Collect Vol Sci Pap ICCAT* 2024b;**81**:1–22.

Oliver S, Braccini M, Newman SJ. *et al.* Global patterns in the bycatch of sharks and rays. *Mar Policy* 2015;**54**:86–97. https://doi.org/10.1016/j.marpol.2014.12.017

Onandia I, Grande M, Galaz J. *et al.* New assessment on accidentally captured silky sharkpost-release survival in the Indian Ocean tuna purse seine fishery. IOTC-2021-WPEB17(DP)-13, 2021. 1–10. https://iotc.org/documents/WPEB/1701/13

Pacoureau N, Carlson JK, Kindsvater HK. *et al.* Conservation successes and challenges for wide-ranging sharks and rays. *Proc Natl Acad Sci* 2023;**120**:e2216891120. https://doi.org/10.1073/pnas.2216891120

Peatman T, Allain V, Bell L. *et al.* Estimating trends and magnitudes of bycatch in the tuna fisheries of the Western and Central Pacific Ocean. *Fish Fish* 2023;**24**:812–28. https://doi.org/10.1111/faf.12771

Peiró-Signes A, Miret-Pastor L, Segarra-Oña M. Effects of green certification and labelling on the Spanish fisheries industry. *Aquac Rep* 2020;**17**:100396. https://doi.org/10.1016/j.aqrep.2020.100396

Pimiento C, Leprieur F, Silvestro D. *et al.* Functional diversity of marine megafauna in the Anthropocene. *Sci Adv* 2020;**6**:eaay7650. https://doi.org/10.1126/sciadv.aay7650

Poisson F, Vernet AL, Séret B. *et al.* Good practices to reduce the mortality of sharks and rays caught incidentally by the tropical tuna purse seiners. EU FP7 project #210496 MADE, Deliverable 7.2., 30p 2012. https://www.iccat.int/Documents/SCRS/Manual/CH4/Annex%203%20to%20Chapter%204.pdf..

Poisson F, Budan P, Coudray S. *et al.* New technologies to improve bycatch mitigation in industrial tuna fisheries. *Fish Fish* 2022;**23**:545–63. https://doi.org/10.1111/faf.12631

Poisson F, Crespo FA, Ellis JR. *et al.* Technical mitigation measures for sharks and rays in fisheries for tuna and tuna-like species: turning possibility into reality. *Aquat Living Res* 2016;**29**:402. https://doi.org/10.1051/alr/2016030

Poisson F, Filmalter JD, Vernet A. *et al.* Mortality rate of silky sharks (*Carcharhinus falciformis*) caught in the tropical tuna purse seine fishery in the Indian Ocean. *Can J Fish Aquat Sci* 2014;**71**:795–8. https://doi.org/10.1139/cjfas-2013-0561

Poisson F, Séret B, Vernet A. *et al.* Collaborative research: development of a manual on elasmobranch handling and release best practices in tropical *tuna purse-seine fisheries*. *Mar Policy* 2014;**44**:312–20. https://doi.org/10.1016/j.marpol.2013.09.025

Pons M, Kaplan D, Moreno G. *et al.* Benefits, concerns, and solutions of fishing for tunas with drifting fish aggregation devices. *Fish Fish* 2023;**24**:979–1002. https://doi.org/10.1111/faf.12780

Restrepo V, Dagorn L, Moreno G. *et al.* 2018 Compendium of ISSF At-SeaBycatch Mitigation Research Activities as of September 2018. ISSF Technical Report 2018-20. Washington D.C: International Seafood Sustainability Foundation. https://doi.org/10.13140/RG.2.2.18625.10085

Sherman CS, Simpfendorfer CA, Pacoureau N. *et al.* Half a century of rising extinction risk of coral reef sharks and rays. *Nat Commun* 2023;**14**:15. https://doi.org/10.1038/s41467-022-35091-x

Stewart J, Cronin M, Largacha E. *et al.* Get them off the deck: straightforward interventions increase post-release survival rates on manta and devil rays in tuna purse seine fisheries. *ICES J Mar Sci* 2024;**79**:1015. https://doi.org/10.1016/j.biocon.2024.110794

Suuronen P. Understanding perspectives and barriers that affect fishers' responses to bycatch reduction technologies. *ICES J Mar Sci* 2022;**79**:1015–23. https://doi.org/10.1093/icesjms/fsac045

Swimmer Y, Zollett E, Gutierrez A. Bycatch mitigation of protected and threatened species in tuna purse seine and longline fisheries. *Endanger Species Res* 2020;**43**:517–42. https://doi.org/10.3354/esr01069

Tookes JS, Yandle T, Fluech B. The role of fisher engagement in the acceptance of turtle excluder devices in Georgia's shrimping industry. *ICES J Mar Sci* 2023;**80**:407–16. https://doi.org/10.1093/icesjms/fsac062

Wain G, Maufroy A. An update on best practices onboard French tropical tuna purse seiners of the Atlantic Ocean. SCRS/2023/077. *Collect. Vol. Sci. Pap. ICCAT*, 2023;**80**:139–54. https://www.iccat.int/Documents/CVSP/CV080_2023/n_7/CV080070139.pdf

Worm B, Orofino S, Burns ES. *et al.* Global shark fishing mortality still rising despite widespread regulatory change. *Science* 2024;**383**:225–30. https://doi.org/10.1126/science.adf8984

Wosnick N, Giareta EP, Leite RD. *et al.* An overview on elasmobranch release as a bycatch mitigation strategy. *ICES J Mar Sci* 2023;**80**:591–604. https://doi.org/10.1093/icesjms/fsac164

Zollett EA, Swimmer Y. Safe handling practices to increase post-capture survival of cetaceans, sea turtles, seabirds, sharks, and billfish in tuna fisheries. *Endanger Species Res* 2019;**38**:115–25. https://doi.org/10.3354/esr00940

Zudaire I, Moreno G, Murua J. *et al.* Biodegradable drifting fish aggregating devices: current status and future prospects. *Mar Policy* 2023;**153**:105659. https://doi.org/10.1016/j.marpol.2023.105659

Handling Editor: Michael Pol