Bycatch guide

Understanding and addressing bycatch of sensitive species in EU fisheries

SEAS AT RISK

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Key recommendations from the guide

Fully implement the Technical Measures Regulation (TMR - EU/2019/1241) and include sensitive species in its evaluation

The Regulation should be fully implemented as some measures remain unimplemented, such as the mitigation measures for seabirds in Annex XIII. The Commission should also require the STECF to consider sensitive marine species in its evaluations of the TMR implementation, as the last evaluation considering sensitive species dates back to 2020.

Expand protections for elasmobranchs under EU regulations

To meet the 2024 targets set in the Marine Action Plan for reducing fisheries impacts on sharks and rays, the Council and Parliament should include protection measures for all critically endangered and endangered elasmobranch species. This would trigger corresponding obligations for bycatch monitoring and avoidance measures to reduce and remediate mortality in fisheries, regardless of whether they are retained and commercialised or discarded.

Leverage Article 17 of the Common Fisheries Policy (CFP)

Article 17 should be actively applied as a tool to encourage bycatch reduction by preferentially allocating fishing opportunities to operators without bycatch and those who demonstrate effective bycatch mitigation and monitoring practices.

Recommendations on monitoring and mitigation measures

Revise the ICES advice request to support Ecosystem-Based Fisheries Management (EBFM)

In accordance with Article 2.3 of the Common Fisheries Policy (CFP), the EU Commission's advice request to ICES should be updated to reflect an ecosystem-based approach. Bycatch mitigation strategies must not rely on single, isolated measures. Instead, they should be evaluated as part of an integrated matrix of complementary tools, assessed for their combined effectiveness across species groups and overall ecosystem health.

Improve bycatch monitoring and reporting requirements

The Commission must expand bycatch monitoring and reporting requirements under the Data Collection Framework (DCF) while requiring Member States to report fishing effort using standardized, gear-specific metrics (e.g., number of hooks, net size, soak time, trawl duration etc...).

Combine technical measures with time and/or spatial management measures in key habitats for endangered species

While technical measures can be appropriate for mitigating bycatch of endangered species, their deployment should be accompanied by further protection of key habitats through time and or spatial management measures, such as fishing closures. These are intended to mitigate the possible detrimental effects of technical measures and amplify conservation benefits. For example, pingers should not be used broadly at the fleet level without being complemented by the creation of MPAs or closures areas designed for marine mammal protection, in which pinger bans would apply.

Recommendations on funding

Facilitate access to EMFAF funds through bridging capital

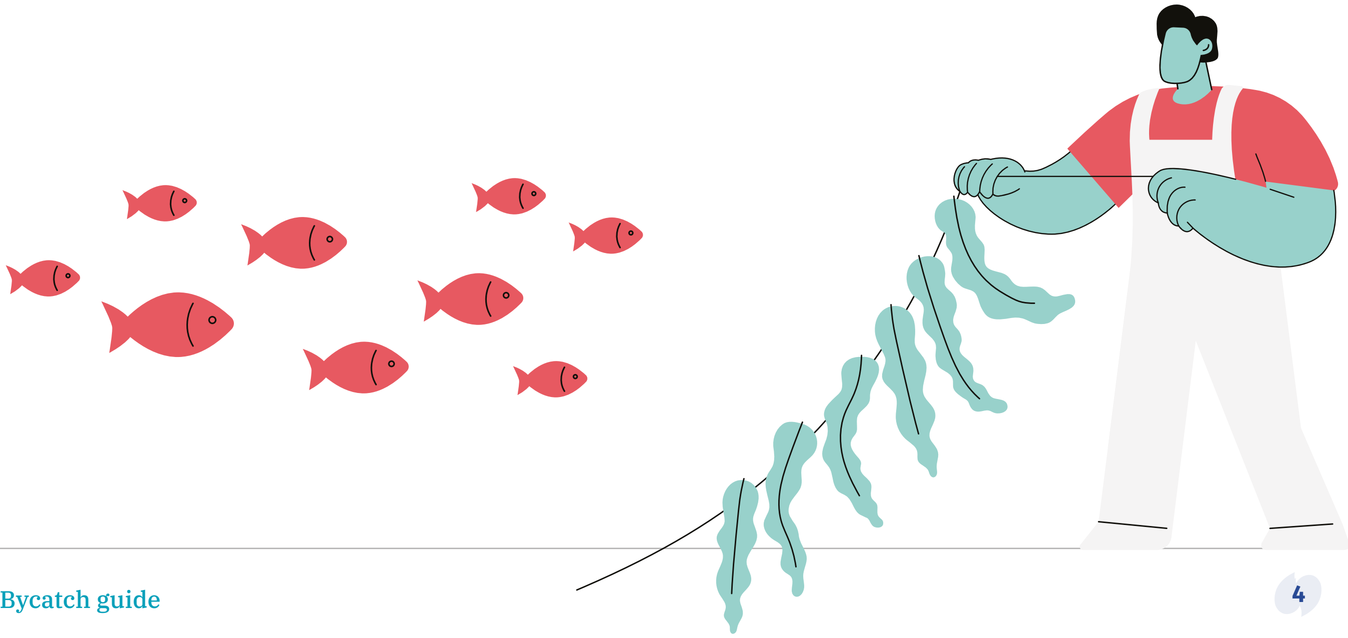
Member States and national financial institutions should ensure that fishers awarded EMFAF (European Maritime, Fisheries and Aquaculture Fund) support have access to the initial capital needed to activate their projects. As EMFAF operates on a reimbursement basis, its effectiveness is undermined when beneficiaries lack upfront financial resources. In cases where banks or other financial institutions refuse to accept EMFAF awards as collateral, national mechanisms should step in to provide bridge financing or guarantees.

Secure dedicated funding for bycatch mitigation and just transition in the next EU budget

The EU must ensure that the next Multiannual Financial Framework (MFF) includes strictly ring-fenced funding for marine biodiversity restoration and a fair transition within the fisheries sector, which include funding for effective bycatch mitigation strategies.

Embed socio-economic considerations and conditionality in mitigation funding

All funding for bycatch mitigation should be guided by socio-economic impact assessments and include conditional financial mechanisms, with priority given to small and medium scale fisheries and with subsidies structured to incentivise the adoption of sustainable practices and support sectoral diversification.



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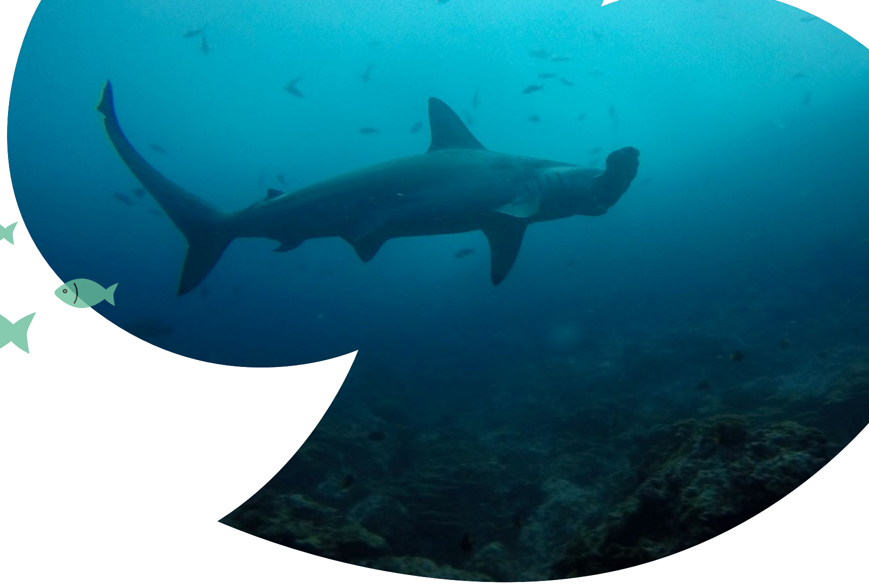

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Executive summary

Bycatch, which will here refer in this guide to the incidental catch of marine mammals, seabirds, sea turtles and sharks, is one of the main if not the main threat to all these species groups. Their bycatch in fishing gear can either lead to mortalities or long-term welfare consequences, putting pressure on species or populations that can already be at breaking point. The Baltic proper harbour porpoise is a sad example, with only a few hundred individuals left. Preserving this unique population demands immediate and effective action.

The aim of this guide is to provide a contextual overview of bycatch in its many aspects, providing an accessible baseline to stakeholders and policymakers interested in understanding and addressing bycatch issues. It compiles information from a variety of scientific literature and published reports.

The main takeaway is that there is no silver bullet solution for bycatch. What might work in one setting might be ineffective or worse, detrimental, in another. It is a complex topic with many moving parts, be it the involved fishing métiers, the local marine ecosystem or the dynamic between the target species and the bycatch-sensitive species.

Furthermore, certain mitigation measures can have detrimental side effects, such as widespread pinger use displacing populations out of key habitats. These side effects should be considered and mitigated through synergies with other measures. As such, the most effective solutions to reduce and eventually end/eliminate bycatch are:

- **an overall reduction in fishing effort, with effort actually decreasing overall rather than simply being geographically displaced.**
- **a combination of mitigation measures that are adapted to the local context and that consider bycatch as an issue across all species groups, rather than focusing on one at the detriment of the others.**
- **thorough training in best handling and release practices, maximising the survival of bycaught animals upon release.**

As a main player of fisheries in its own waters and worldwide, the EU has the legal responsibility and the need to drastically reduce or fully eliminate bycatch in all of its fisheries. The full implementation of the Common Fisheries Policy and of the Technical Measures Regulation (EU/2019/1241; TMR) are powerful levers that can be used to champion and fund bycatch mitigation initiatives throughout EU and global waters.

Introduction

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What is bycatch? Why is it a problem?

Fisheries bycatch refers overall to the catch of species or age and size classes that were not originally targeted by a fishing operation[1–3]. The scope of this best practice guide will be the incidental catch of sensitive species, namely marine mammals, seabirds and sea turtles found in EU waters or in non-EU waters fished by EU fleets. It is acknowledged that bycatch also includes fish species that are very commonly caught through fishing operations, which can cause issues regarding overfishing and stock status, as bycatch of a species is not always considered in the overall target quota[4]. However, this aspect of bycatch will not be considered in this guide, which will focus instead on incidental catch of sensitive species.

A non-exhaustive list of sensitive species and subpopulations that are bycaught by EU fleets can be found in Annex 2, with Table 1 being a strongly condensed version focusing on the vulnerable and endangered species and populations. These species are considered "sensitive marine species" and are protected by multiple EU regulations (Habitats Directive;92/43/EEC and Birds Directive;2009/147/EC), with Article 3.2.b of the Technical Measures Regulations (TMR; EU/2019/1241) stating that technical measures "should ensure that incidental catches of sensitive marine species [...] that are a result of fishing, are minimised and where possible eliminated so that they do not represent a threat to the conservation status of these species". This guide will briefly touch upon the bycatch of elasmobranchs (sharks and rays) in and outside of EU waters, focusing on sharks. They will be considered separately in this guide, as their catch may be targeted in some cases but a truly unwanted bycatch in others. Elasmobranchs also have much lower levels of protection compared to the other species groups considered in this report and that results in their bycatch having different dynamics[5].

Bycatch is a major issue for almost all sensitive marine species, but their vulnerability depends on the species group and between species of the same group[3,6]. They however all have some similar characteristics in common that make them especially sensitive to bycatch. They are long lived and make relatively little offspring, with slow growth and late sexual maturity[7–10]. Bycatch is the main threat to their populations, which are already under stress from climate change, habitat degradation and land-based threats[3,5,6,11,12]. To illustrate, it is estimated 146 000 seabirds are killed annually by bycatch in EU waters[12]. The Annex includes a more detailed section on the vulnerability of each species group to bycatch, while sharks are addressed in their dedicated focus box in the main body of the guide.

Table 1: Vulnerable and endangered species and populations (Condensed version - Detailed version in Annex 2)

Table 1 : This table is a condensed and non-exhaustive list of species and associated populations threatened by EU fisheries, inside and outside of EU waters. The table is reduced to the maximum and the full version can be found in the Appendix. The IUCN status is the status of the species or subpopulation on the IUCN Red List of species. Species can be assessed in their global range, at a regional level (Europe and/or Mediterranean) if available or at the subpopulation level. They are also given a predicted trend, meaning the species or population is increasing, decreasing or its dynamics are unknown. If an IUCN assessment is not available at the desired level, red lists of the relevant countries have been used.

LC – Least Concern: Low risk and does not qualify for VU, EN and CR

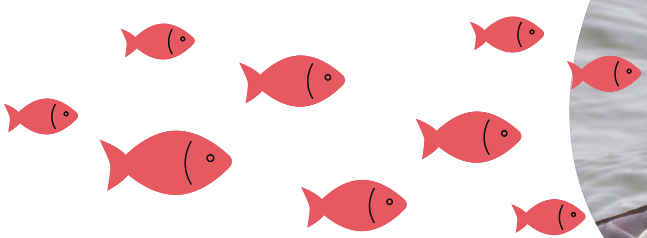
VU – Vulnerable: high risk of extinction of the wild

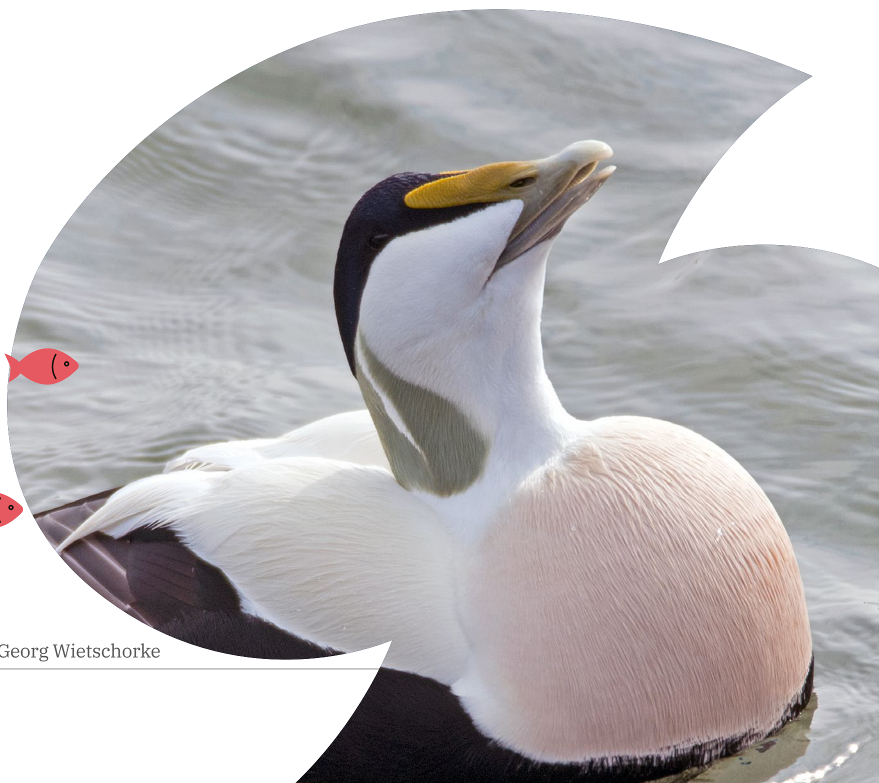
EN – Endangered: very high risk of extinction of the wild

CR – Critically endangered: extremely high risk of extinction of the wild

Species group	Example species	Assessments in EU waters and non-EU waters fished by EU vessels	IUCN Status	Trends
Marine mammals	**Dolphins and porpoises**			
	Harbour porpoise - *Phocoena phocoena*	Baltic subpopulation	CR	↘
		Black Sea	EN	↘
		Iberian Peninsula - in the process of assesment by IUCN	Portugal & Spain - CR	↘
	Bottlenose dolphin - *Tursiops truncatus*	Gulf of Ambracia	CR	↘
	Common dolphin - *Delphinus delphis*	Mediterranean	EN	↘
		Gulf of Corinth	CR	?
	Whales			
	Fin whale - ***Balaenoptera physalus***	Global - Atlantic, Arctic, Pacific, Indian and Southern oceans, along with the Mediterranean	VU	↗
		Mediterranean Sea	EN	↘
	Sperm whale - ***Physeter macrocephalus***	Global - Atlantic, Arctic, Pacific, Indian and Southern oceans, along with the Mediterranean	VU	?
		Mediterranean Sea	EN	↘
	Seals			
	Mediterranean Monk Seal - ***Monachus monachus***	Europe - Mediterranean and Northeast Atlantic	VU	↗
		Eastern Mediterranean	EN	?
	Harbour Seal - ***Phoca vitulina***	Europe - Northeast Atlantic and Baltic	LC	?
		Iceland	National - EN	?
	Ringed Seal - *Pusa hispida*	Europe - Northeast Atlantic, Baltic and Lake Saimaa	EN	↘

	Species	Region	Status	Trend
Seabirds	**Albatrosses, shearwaters and petrels**			
	Northern fulmar - ***Fulmarus glacialis***	Europe - North Atlantic and Baltic	VU	↘
	Balearic shearwater - ***Puffinus mauretanicus***	Global/Europe - Mediterranean and Eastern Atlantic	CR	↘
	Wandering Albatross - ***Diomedea exulans***	Global - Atlantic, Pacific, Indian and Southern Ocean	VU	↘
	Northern Royal Albatross - ***Diomedea sanfordi***	Global - Atlantic, Pacific, Indian and Southern Ocean	EN	↘
Sea turtles	**Sea turtles**			
	Loggerhead turtle - ***Caretta caretta***	Global - Atlantic, Pacific, Indian and Mediterranean	VU	↘
		Northeast Atlantic	EN	?
	Leatherback turtle - ***Dermochelys coriacea***	Global - Atlantic, Pacific, Indian and Mediterranean	VU	↘
	Green turtle - ***Chelonia mydas***	Global - Atlantic, Pacific, Indian and Mediterranean	EN	↘
Elasmobranchs	**Sharks, rays and skates**			
	Great white shark - ***Carcharodon carcharias***	Global - Atlantic, Pacific, Indian and Mediterranean	VU	↗
		Europe - North Atlantic and Mediterranean	CR	↘
	Sandtiger shark - ***Carcharhinus taurus***	Europe - North Atlantic and Mediterranean	CR	↘
	Blue shark - ***Prionace glauca***	Mediterranean	CR	↘
	Short fin mako - ***Isurus oxyrinchus***	Global - Atlantic, Pacific, Indian and Mediterranean	EN	↘
		Mediterranean	CR	↘





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Where and how does bycatch happen? Bycatch monitoring and assessment

Bycatch can be robustly estimated through multiple methods, such as data collection with on-board observers, Remote Electronic Monitoring (REM)[a] or investigation of stranding records[13–15]. Preliminary assessment of bycatch rates can also be completed through surveys and direct interviews with fishers, so called rapid assessment surveys[16,17]. Other data sources such as fishers' logbooks or vessel positioning data through AIS/VMS are essential to estimate fishing effort, which in turn is a key component of bycatch estimation[13].

OSPAR estimates bycatch numbers for certain fisheries by combining the two following sources: 1) the annual fishing effort, measured in numbers of days at sea 2) bycatch records from monitoring data from on-board observers or REM data[15]. In 2021, ICES issued an official data call to 18 ICES countries concerning bycatch data of grey seal, harbour porpoise and common dolphin in the OSPAR area from 2005 to 2020[18]. The process was the following: the observer/REM bycatch data collected by countries is collated over several years and observed bycatch numbers are divided by the number of fishing days for the concerned fishing activity.

Fishing effort is a concept used to measure the activity of fishers and in turn, measure the fishing pressure on the marine ecosystems. It is currently being measured in Days at Sea (DaS) as set out by the EU data calls but there is growing consideration that this is not the most appropriate metric for fishing effort, as it does not account for the size and actual effort of the different fishing vessels[19]. Using number of fishing days to infer fishing effort requires the least data but it can also lead to inaccuracies. One gillnet boat can place 500 meters of gillnets in a day whereas another can place 10 km in the same day. When using DaS as a metric for fishing effort, both fishers are considered to have the same effort when this is not the case. The fishing effort should instead be measured using gear-specific effort metrics, such as numbers of hooks, gillnet length, trawling time, which yield a much more accurate representation[18,20]. Table 3 provides elements to consider when designing metrics for gear-specific effort.

This produces a **bycatch rate** and different fleet segments have different bycatch rates, for different species, depending on a variety of factors. The **bycatch rate** of a fleet is then multiplied by the number of fishing days for that specific fleet for a whole year. The result is the **bycatch mortality**, describing the number of species individuals dying from bycatch by that fleet segment during one year.

a According to 2019 guidelines published by the European Fisheries Control Agency , the REM system is a system that acquires data and video footage using GPS, sensors and CCTV.

Bycatch glossary

Bycatch risk: The likelihood/risk that bycatch of a certain species will occur in an area, based on multiple factors (environmental conditions, fishing métiers, bycatch species behaviour etc...). Bycatch risk is normally based on models and is typically to determine bycatch hotspots where monitoring should be increased and mitigation measures should be taken, including implementation of fishing closures.

Bycatch rate: The estimated number of individuals bycaught per unit of fishing effort for a specific fleet. This is estimated through actual bycatch data collected over multiple years through observers and Remote Electronic Monitoring (REM), with the bycatch numbers being divided by the units of fishing effort observed. A concrete example36 : a bycatch of 80 harbour porpoises is observed over 1600 combined days of fishing for gillnets in the North Sea, leading would mean a bycatch rate of about 0.05 harbour porpoise/day of fishing for that métier.

Bycatch mortality: the estimated numbers of animals killed as bycatch by a specific fleet for a period of time, usually a year. This is calculated by multiplying the bycatch rate by the combined units of fishing effort completed by that fleet. Using the bycatch rate of 0.05 mentioned above and a combined fishing effort of 40 000 days for gillnets in the North Sea in 2017, the bycatch mortality could be estimated at 2338 harbour porpoises for 201736.

A big caveat of some bycatch estimates is that the reporting requirements for fishing vessels under 15 metres are minimal or non-existent[15,18]. As over 76% of the fishing fleet in the European Union is made of coastal small-scale vessels under 12 metres, this bycatch reporting and monitoring gap could lead to inaccurate estimation of bycatch mortalities, leading in turn to inappropriate or ineffective management measures[18,21]. Reporting and monitoring requirements for smaller vessels are likely to change with the enforcement of the newer Control Regulation (EU/2023/2842) but at the time of writing, there is no clarity about the possible evolution of bycatch monitoring and reporting requirements.

In order for bycatch reporting to be accurate, fishers must have detailed ID guides for the different sensitive species. Multiple recent publications have been developed in that sense, namely:

- 2024 bycatch and handling guide for deep-sea elasmobranchs caught in Portuguese bottom trawling fisheries, developed in the DELASMOP project[22]
- 2019 bycatch identification guide for the Mediterranean, published in the framework of the MedBycatch project[23]

How big is the bycatch problem? Assessing the impact of bycatch on a population

As mentioned previously, the bycatch mortality for a population is an important value in itself but its conservation impact can only be assessed by considering the status and dynamics of the impacted population[24]. There are a variety of methods and models for doing this, and certain models might be more appropriate than others depending on the situation, including the species and the chosen area amongst other factors. The ABIOMMED 4.3 deliverable[b] provides a useful overview of existing bycatch reference points, as well as the associated trade-off between convenience and level of precaution[25]. As such, it is important to consider the available data (e.g. bycatch mortalities, population dynamics, life history parameters, fishing effort etc...) and the underlying objective (how will the results of the models be used) to apply the appropriate methodology. Marine mammals, seabirds and sea turtles have different assessment methods which will be only mentioned in this guide, as it will focus on the Potential Biological Removal (PBR) approach.

b The ABIOMMED project (2017-2023) supported Member States in defining and achieving their MSFD targets, focusing on the Mediterranean. This included bycatch reference points for cetaceans. The deliverables of the project are available but only upon request to ABIOMMED.

Marine mammals

One of the simplest and most commonly used reference points for marine mammal bycatch mortality is the Potential Biological Removal, also known as PBR. In Europe, it is used by scientific advisory bodies and conventions such as ICES and OSPAR, as well as multiple Member States[15,25,27]. The PBR originated in the United States in the 1990's, as a standardised method to estimate the human impact on marine mammal populations[28]. PBR is an estimate of the maximum number of individuals that can be removed each year from a population by human activities while meeting specified conservation objectives[29,30]. It is not a perfect approach for all scenarios but it is a good trade-off between the level of precaution as well as the level of data needed to calculate it[25]. This guide does not argue for the use of PBR in all scenarios, but it is currently the most widespread reference point and it is therefore important to explain it properly, including its considerations.

PBR was developed to provide a workable implementation of the management objectives that were already enshrined in US law but it should not be considered as the number of allowable deaths. Indeed, PBR does not consider all the different indirect pressures that populations might be facing, such as climate change, habitat degradation or reduction in prey availability.

Additionally, bycatch is not the only direct cause of anthropogenic mortality that should be compared to PBR, since other threats including vessel collisions, military sonar, entanglement in marine debris can also result in death[25,28]. It is therefore important to understand that even if the bycatch mortality for a given species in a given fishery is within PBR, bycatch in other fisheries and other human impacts can still be major threats to the population. Marine mammal populations may therefore still be endangered or take decades to recover. In conclusion, it is essential to keep mortalities under the PBR and consider it as a maximal limit to avoid at all costs. Mortalities always have an impact, even under the PBR. Independently of much needed efforts to reduce other sources of mortality, the ultimate objective should be to completely eliminate bycatch and if not possible, reduce it to the maximum extent while adapting the relevant fisheries to operate accordingly.

If not for the conservation objective, there is an essential argument regarding the importance welfare in management decisions of all sensitive species but particularly for cetaceans. Conservation and management decisions tend to consider that bycatch only becomes an issue when it impacts population levels of a given species, without any consideration for welfare[31]. PBR does not have any consideration of welfare and exclusively focuses on mortality. Indeed, mitigation measures might be effective at reducing immediate visible mortality but might have long-term health and welfare consequences on the animals[32]. Even when mortalities are minimised to the greatest extend and possibly eliminated, the pain and suffering associated with bycatch and release should also be reduced to the greatest extent[33]. An animal released alive from fishing gears still suffered drastically more than an animal that was not bycaught in the first place. Management and conservation decisions regarding bycatch should reflect that and integrate welfare into their objectives[31–33].

With these objectives in mind, there are multiple fisheries in which the estimated bycatch mortality reaches or exceeds the PBR or mPBR, which is highly problematic. mPBR (m stands for modified) is a modified version of the original US PBR, which is a more precautionary than the original formula and is used by ICES and OSPAR to meet EU conservations objectives[c],[15,18,34]. To showcase the difference, the PBR for the common dolphin in the Northeast Atlantic in 2023 was 4926, whereas the mPBR was 985[15,18,35]. The PBR would allow about 5 times more mortalities than the mPBR if used as management objective. The mPBR is more ambitious in what it considers to be a healthy population and should therefore be prioritised over the standard PBR.

c The difference between the PBR and mPBR lies in the conservation objective. The original PBR has the objective for a cetacean population to reach at least 50% of carrying capacity with a probability of 0.95 over 100 years. In contrast, the modified mPBR has the objective of reaching at least 80% of carrying capacity with a probability of 0.8 over 100 years [34].

For certain populations, the situation is much more severe. Indeed, the original more permissive version of the PBR has a value of 0.7 for the Baltic proper harbour porpoise and a value of 1 for the sperm whale in the Mediterranean[25,36]. In fact, the modified more conservative mPBR has a value of 0 for these populations since they are under 2500 mature individuals[15]. For these populations, a single human-induced death (bycatch, military sonar, collision, offshore renewables) in a whole year can endanger the population and threaten its long-term viability.

While the PBR has been created with marine mammals in mind, it can also be applied for seabirds, turtles and other sensitive species with certain considerations. Any important considerations regarding PBR that were developed in the section above also apply to other species groups. PBR should not be considered as the number of allowable deaths, but an absolute red line, and implications of welfare should be considered in management decisions.

Seabirds

PBR can also be applied to seabirds, especially in preliminary assessments to estimate the conservation implications of a bycatch issue[24,37–40]. As it was originally conceived for marine mammals, it does not take the specificities of the seabird life cycle into account and therefore should only be used in the preliminary phases[39]. It has been previously used by ICES for this purpose, notably for the Balearic shearwater (*Puffinus mauretanicus*), Europe's most threatened seabird[41,42]. After establishing seabird bycatch as a severe issue using a preliminary PBR, OSPAR and ICES advise to use a more complete method such as Population Viability Analysis to properly estimate the impact of bycatch on population dynamics[42,43]. Independently of the model used, BirdLife International and OSPAR advise that bycatch mortality for protected[d] seabird species should be kept under 1% of the annual adult mortality rate as blanket rule[43,44].

Sea turtles

As for sea turtles, PBR can also be applied similarly to seabirds[45,46]. The basic PBR concept can work as a simplistic model in the early phases to assess the conservation implications of the bycatch issue. It can also be improved by applying PBR values to each age group instead than one general value across the population[45]. PBR has been proposed as an indicator for the D1C1[e] criteria of the Marine Strategic Framework Directive (MSFD), which states that "the mortality rate per species from incidental bycatch is below levels which threaten the species, such that its long-term viability is ensured"[46]. Alternatives include the Reproductive Value Loss Limit (RVLL) approach, which considers the strong age-dependant dynamics in sea turtles[47]

d Per the OSPAR List of Threatened and/or Declining Species & Habitats and Annex I of the EU Birds Directive (2009/147/EC)
e The 2008/56/EC Marine Strategic Framework Directive (MSFD) sets out general descriptors for Good Environmental Status of certain species and ecosystems. Each descriptor has multiple criteria, who are measured by indicators.

Table 2: PBR and bycatch mortalities for sensitive species in different sea regions

Table 2 : The table lists multiple species and populations, with their associated PBR or mPBR values as well as the annual bycatch mortality estimates. This table focuses on PBR or mPBR values as reference points to allow for comparison and maintain clarity. Bycatch mortality estimates and PBR values have not been widely estimated and are sparsely available, which explains the disparity of species and area covered in the table. It is a non-exhaustive list of examples rather than a fully comprehensive table, focusing on European waters as data is very patchy in RFMOs and cannot be specifically linked to EU vessels .

Colour scheme :
Red : The bycatch mortalities have been proven to be over PBR/mPBR or are almost certainly over
Yellow : Bycatch mortality or PBR estimates are uncertain but it is likely mortality values close or above PBR/mPBR
Grey : Estimates are not available

Species	Population	PBR or mPBR value[f]	Annual bycatch mortality estimates
Marine mammals			
Fin whale - *Balaenoptera physalus*	Mediterranean	PBR: 2 (2018)[25]	Not available
Sperm whale *Physeter macrocephalus*	Mediterranean	PBR: 1 – (2018)[25]	Not available
Common bottlenose dolphin *Tursiops truncatus*	Western Mediterranean	PBR: 182 (2018)[25]	Not available
Common dolphin *Delphinus delphis*	Northeast Atlantic	PBR : 4927 (2020)[35] mPBR: 985 (2020)[15,18]	6406 (2020)[15,18]
Harbour porpoise *Phocoena phocoena*	Baltic Sea	PBR: 0.7 (2019)[36] mPBR : 0	7 (2017)[36]
	Iberian Peninsula	mPBR : 0 (2020)[15]	Not available
Seabirds			
Balearic shearwater *Puffinus mauretanicus*	Mediterranean and North Atlantic	PBR: 100 (2016)[41]	842 (2024)[12]
Common guillemot *Uria aalge*	North East Atlantic	Not available	27 667 (2024)[12]
Northern fulmar *Fulmarus glacialis*	North East Atlantic	Not available	22 883[12]
Velvet scoter *Melanita fusca*	Polish EEZ Baltic Sea	PBR: 1485 (2010-2018)[38]	2000 (2010-2018)[38]
Greater scaup *Aythya marila*		PBR: 545 (2010-2018)[38]	3500 (2010 – 2018)[38]
Long-tailed duck *Clangula hyemalis*		PBR: 3272 (2010-2018)[38]	9000 (2010 – 2018)[38]

f The difference between the PBR and mPBR lies in the conservation objective. The original PBR has the objective for a cetacean population to reach at least 50% of carrying capacity with a probability of 0.95 over 100 years. In contrast, the modified mPBR has the objective of reaching at least 80% of carrying capacity with a probability of 0.8 over 100 years 34. mPBR has a value of 0 if the population is under 2500 mature individuals [15]

Sea turtles			
Loggerhead turtle *Caretta caretta*	North Atlantic and North Sea (OSPAR)	Not available	Not available
Loggerhead turtle *Caretta caretta*	Mediterranean	PBR : 1501 – 48722[g] (2016)[8]	29 500 (2016)[8]
Green turtle *Chelonia mydas*	Mediterranean	PBR: 496 – 69 200[g] (2016)[8]	8450 (2016)[8]
Leatherback turtle *Dermochelys coriacea*	North Atlantic and North Sea (OSPAR)	Not available	Not available

Focus on the Mediterranean – Challenges and opportunities

The nature of fisheries in the Mediterranean provides a unique context, riddled with challenges but also full of opportunities. When considering the whole Mediterranean area, 82% of all fishing boats are small-scale vessels under 12 metres[48]. As for the EU Mediterranean, it is home to 30 000 fishing vessels, of which 80% are small-scale[21]. They represent 42% of the total EU fleet as well as 45% of employment[21]. The small-scale fleet tends to be multi-gear and multi-species, with individual fishers using multiple gears to target a variety of species seasonally or during the same fishing trip[21,49].

According to the methodology applied by Lewison et al (2014), the Mediterranean is the ocean region with the highest bycatch intensity for megafauna at the global scale[6]. While this doesn't mean that the Mediterranean has the highest bycatch mortalities worldwide, its small size compared to other oceans does lead to fishing effort being concentrated and overlapping with megafauna. As such, the Mediterranean is estimated to be a global bycatch hotspot for marine mammals and sea turtles[6]. Indeed, bycatch is estimated to be the main anthropogenic threat to Mediterranean Sea turtles whilst in marine habitats, with the Mediterranean being one of the three global hotspots for turtle bycatch[6,9]. Estimates mention the annual bycatch in the Mediterranean of 130 000 turtles across all métiers, causing around 40 000 mortalities[5,9]. As for marine mammals, Mediterranean populations are in dire states and multiple species have a PBR value lower than a few hundred, including a PBR of 1 and 2 for the sperm whale and fin whale populations[25]. The Mediterranean is also home to the Balearic shearwater, which is Europe's most threatened seabird with an estimated total population of 30 000 individuals[41,50]. Fisheries bycatch, especially in gillnets and purse seines, are still important threats to this critically endangered species[50].

The multi-gear and multi species nature of Mediterranean fisheries poses a challenge but also means that the Mediterranean could be an appropriate to test for gear alternatives as a bycatch mitigation measure. Indeed, small-scale fishers in the Mediterranean tend to operate a variety of different gears (longlines, pots, seine, gillnets) to target different species through the year or even in the same fishing trip[21,49]. As such, they may be already familiar with a variety of gears and could be more open to switching to an alternative fishing gear, provided there is enough target catch or existing incentives to support this transition. This versatility could also prove useful in terms of allowing transition to gears with less bycatch, either temporarily, by area with gear-specific closures or permanently. Gear change incentives have been implemented, for example, in an Australian gillnet fishery, which is discussed further in the report.

g The study referenced for the turtle PBR values estimated a range of PBR values for different populations depending on their conservation levels and age classes most susceptible for bycatch.

Photo: ©Henning Kunze

Fisheries outside of EU waters and RFMOs

Outside of EU waters, fisheries, including bycatch in fisheries, can be managed through multiple frameworks. They can be managed through agreements with non-EU countries (Norway, United Kingdom, Senegal, etc.), allowing EU vessels to fish in their Exclusive Economic Zone (EEZ) waters[51]. This aspect will not be considered but the main point is that EU vessels fishing under agreements are still subject to EU law and regulations[51].

If fisheries take place in the high seas, then they are managed by Regional Fisheries Management Organisations, RFMOs for short, in which national governments that have stake in the fishing ground are involved. RFMOs are an essential arena for discussions and decisions about bycatch mitigation and elimination, and they can set binding regulations that have to be followed by all contracting parties. The EU is considered one single contracting party and is involved in 18 RFMOs worldwide at the time of writing[52]. The main RFMOs that cover waters close to the European continent are namely:

- ICCAT - International Commission for the Conservation of Atlantic Tunas
- NEAFC - North East Atlantic Fisheries Commission
- NAFO - North Atlantic Fisheries Organisation
- GFCM - General Fisheries Commission for the Mediterranean, which is an affiliate body of the UN - Food and Agriculture Organization (FAO)

However, EU vessels are also extensively fishing in other RFMOs globally and are specifically a main actor in all tuna RFMOs, where they are among the main fishing fleets for tuna, swordfish and sharks. The main tuna RFMOs besides ICCAT are:

- IOTC - Indian Ocean Tuna Commission
- WCPFC - Western Central Pacific Fishery Commission
- IATTC - Inter American Tropical Tuna Commission

Multiple studies have assessed the performance of RFMOs in terms of bycatch governance and observer coverage[53–56]. Performance can be quite variable across different elements of bycatch monitoring and mitigation.

Indeed, NAFO has an extensive on-board observer program, which also requires observer to monitor all bycatch, but has no binding requirements for bycatch mitigation outside of fish species and sharks[54,55,57]. On the other hand, the GFCM has a small to non-existent observer monitoring program but multiple binding requirements for bycatch mitigation across different species groups[54,55,58]. GFCM itself is a good example of how RFMOs can improve with sufficient backing or pressure from civil society, scientists and policymakers. It had scored 3rd worst amongst the 13 considered RFMOs in a 2014 study assessing governance of bycatch and discards across RFMOs[56]. While its observer program is still minimal, the GFCM has shown considerable improvement efforts since then. Indeed, it has directly or indirectly:

- published extensively about bycatch monitoring guidelines and bycatch ID guides[23,59]
- updated its Data Collection Reference Framework, with included sections about bycatch reporting[1]
- produced an extensive overview of the bycatch mortalities associated with different gears in GFCM waters[5]
- published an extensive overview of bycatch mitigation measures and specific guidelines for bycatch mitigation for marine mammals[60,61]
- produced handling guides for seabirds, cetaceans, marine turtles and elasmobranchs caught in fishing gear[62–65]
- adopted binding recommendations about bycatch of seabirds, cetaceans, marine turtles and elasmobranchs, which were renewed in 202[66–69]
- conducted pilot projects about bycatch mitigation and elimination throughout the Mediterranean[70]

There are multiple improvements still needed from the GFCM, namely a more extensive observer/REM program, the setting of bycatch mortality limits and increased bycatch data transparency. But the aforementioned list of actions undertaken is commendable and a step in the right direction, as the GFCM was rated 4th best among 14 RFMOs for cetacean bycatch management in 2023[54]. It is important to mention that many of these publications were collaborations in the scope of the MedBycatch project 2017-2022, which was financially supported by the MAVA foundation.

Photo: ©Ida Carlén

Focus on sharks and rays in fisheries

Over the past decade, an increasing number of shark species have been listed as threatened by the IUCN, with only 7% of the 1,186 assessed species considered not threatened by fishing[71]. In 2024 the IUCN has classified 392 species as threatened, all of which are threatened specifically by fisheries impacts, and of which 124 are Endangered and 92 are Critically Endangered. To put this into perspective, the global abundance of sharks and rays has declined by half over the last 50 years, with their risk of extinction increasing by 19% since 1970[72].

Total fishing related shark mortality has increased from 76 to at least 80 million sharks between 2012 and 2019 out of which 25 million were from threatened species, with the EU being a major player in this issue[73]. Indeed, it is estimated that 3 million of the shark fisheries-related mortalities in 2019 took place inside the EEZ of France and its overseas territories[73]. Additionally, the EU is a contracting party and major player in multiple RFMOs with high shark mortalities, which cover the Atlantic, Indian and Pacific oceans[73,74]. The Mediterranean shark populations are under substantial threat, despite being covered by multiple regulations by the EU, the GFCM, ICCAT and national governments[75,76].

Regulations are patchy, cover only certain areas or certain species and offer different levels of protection, which can lead to ineffective protection in practice. Indeed, under the yearly quota regulations (Article 21 for the 2025 TAC Regulation EU/2025/202) and Annex I of EU Deep Sea Fisheries Regulation (EU/2016/2336), only a certain number of shark species are protected while less than 30% of elasmobranch species in the Mediterranean and Black Sea are protected under GFCM recommendations[5]. Under the TMR, it is stated that even limited fishing activity on some rare species of sharks and rays can pose serious risks for their conservation and there should be a general prohibition on fishing for them. But in practice, the TMR applies only to deepwater sharks listed in Annex I of EU Deep Sea Fisheries Regulation as well as the prohibited shark species in the Annex I of the TMR. Article 9 of the TMR also prohibits the use of driftnets and bottom gillnets to target certain species of shark, but that protection does not apply to other fishing gears such as longlines. The Shark Finning Regulation (EU/605/2013) makes it illegal to retain and land only shark fins, which must remain naturally attached to the shark until the first point of landing. Sharks and rays are therefore not protected in majority under EU law if they are landed with their fins naturally attached. A retention ban exists for some shark species in one or several RFMOs, e.g. for the Atlantic, ICCAT retention bans apply to shortfin mako sharks, oceanic whitetip sharks and silky sharks amongst others. As a contracting party to ICCAT, these retention bans are also applicable within EU waters but in the absence of binding targets for mortality reduction, retention bans only remove the economic incentives for deliberately catching these sharks. They do not provide protection per se if not combined with measures to avoid their bycatch and to reduce bycatch mortality. This lack of protection is in contrast to elasmobranchsh showing the highest percentage of threatened marine fish species in EU waters (40.4%) and with 15 species being categorised as critically endangered including 3 endemic species[77]. Additionally, the **EU's Marine Action Plan had identified sharks among the most vulnerable species in need of further protection by technical measures to reduce or where possible eliminate incidental catches[78].** It listed species among the sensitive species that requires Member States to improve fishing selectivity and reduce the impact of fisheries on these species by end of 2024[78.]

Due to this lack of protection, EU fisheries in the Mediterranean were estimated to have caught more than 3000 tons of elasmobranchs in 2022[79]. EU fisheries reported catches of 248 392 tonnes of sharks between 2019 and 2021, an average of 82 797 tonnes per year with blue sharks being the single most important species accounting for 56% of catches[80]. 87% of the blue shark catches and 88% of the shortfin mako catches were made outside of EU waters and almost exclusively within the area of competence of the RFMOs[80].

Two different types of shark bycatch

Shark and ray catches in fisheries need to be generally differentiated into two main categories:

Elasmobranchs, which includes sharks, rays and skates, can be a specific target species in certain fisheries, such as the thornback ray, tope shark and gummy shark[81,82]. In European waters, smooth hound shark and piked dogfish can be targeted by fisheries in the Mediterranean or the Black Sea[h]. If not openly targeted with allocated quotas, elasmobranchs and more specifically sharks might be considered targeted bycatch. This is the case in multiple RFMOs, especially tuna RFMOs, in which pelagic sharks such as blue sharks and shortfin mako sharks compose the majority of catches e.g. in the Spanish and Portuguese pelagic longline fisheries for tuna and tuna like species. But all other pelagic sharks can also be a targeted species unless there is a retention ban in place for the species in the specific RFMO. A retention ban is a measure that prohibits the landing and sale of a species, which must therefore be released alive as unharmed as possible or discarded even if dead. Contrary to marine mammals, turtles or seabirds, sharks can be a lucrative bycatch due to their fins and operators might not be incentivised to reduce their bycatch if retention is allowed. A retention ban therefore aims to reduce the targeted bycatch of certain species since it prohibits their sale.

In another scenario, sharks can be truly unwanted bycatch if they are caught in fisheries that do not land sharks, are protected by international treaties or are covered by a retention ban. In this situation, sharks will be released alive if possible or discarded dead. However, it is important to note that such elasmobranch bycatch may still be massive and can make up substantial amounts of the catch resulting in high mortality rates as fisheries and RFMOs fail to implement adequate bycatch mitigation and safe handling measures[84].

Under the yearly quota regulations (Article 21 of the 2025 TAC Regulation EU/2025/202), which applies to EU fishing vessels both inside out and outside of EU waters, certain species or groups such as the oceanic whitetip shark or hammerheads sharks are subject to a retention ban. As such, they are unwanted bycatch since they have no legal value to fishers and their catch should be reduced, as well as their mortality.

Relevant management or bycatch mitigation strategies

Due to the different dynamics, targeted and unwanted bycatch must be managed differently with appropriate response strategies or mitigation measures. In the case of targeted bycatch, shark mortalities should be managed the same way as for other targeted stocks by the initiation of a Management Strategy Evaluation (MSE) process for the development of Management Procedures. While no RFMO has developed Management Procedures for sharks so far, both ICCAT and IOTC have included the start of MSE for the development of Management Procedures for blue sharks into their program of work. IOTC has even assigned it as a priority species for this during its 2025 Meeting of the Technical Committee for Management Procedures (TCMP).

Targeted catch of sharks should only be allowed for species that are resilient enough to sustain some level of fishing mortality and only under strict monitoring and regulation enforcement. Management procedures include pre-agreed measures for exceptional circumstances which should include predefined mitigation measures in case mortality limits for one or several shark species are exceeded. Additional mortality mitigation measures should then be triggered, including e.g. gear modifications, gear changes, and spatial or time closures of the fishery. A secondary mitigation measure could also be a temporary or permanent retention ban for one or several shark species, but this on its own will not reduce shark mortality if not combined with mitigation measures to reduce physical stress, injury and mortality of the sharks during release[85]. Multiple tuna RFMOs, which cover the fisheries with most shark bycatch, have existing monitoring and management plans in place but gaps and inappropriate measures persist[83,85].

h In the 2015, the European Red list of marine fishes considers 40.4% of Chondrichthyes to be threatened, which includes elasmobranchs (sharks and rays, totalling 1226 species) as well as chimaeras (56 species).

ICCAT is currently the only tuna RFMO with allocated TACs for blue shark which amount to 27 711 tons in the South Atlantic, with 17 405 tons allocated to the EU, and 30 000 tons in the North Atlantic, with 24 499 tons allocated to the EU[90,91].

In the case of unwanted bycatch, retention and trading bans are useful for improving conservation awareness but they are not efficient for reducing the bycatch rate and mortality of shark species. Instead, mitigation measures should be implemented to reduce the bycatch rates of sharks, which must be appropriate for the area, métier and shark species and size. Pelagic longlines, purse seines and gillnets tend to have the highest bycatch risk for pelagic sharks but bottom trawling or demersal longlines may also have significant elasmobranch bycatch[5,22,92]. An overview of bycatch risk per gear and associated mitigation measures can be found in Table 3. The priority should always be the avoidance of the bycatch in the first place followed by measures to reduce bycatch mortality, but this can prove difficult as mitigation measures to reduce shark bycatch and mortality may negatively impact other target catch yield or increase costs for fisheries.

Most mitigation measures are therefore focused on reducing on board and post release mortality rates rather than the initial bycatch rate. To illustrate, wire leaders and buoy lines (shark lines) are hook lines separated from the hook mainlines, which are made of stronger materials. These lines with stronger material reduce the chance of the shark biting through the line after being caught compared to normal leaders made out of monofilament[93]. With monofilament lines, bigger sharks with serrated teeth such as oceanic whitetip sharks and shortfin mako sharks can bite through the line and release themselves before being hauled on board and are are therefore still alive with higher survival rates[94]. Extensive studies have therefore demonstrated that banning wire leaders and shark lines can be able to reduce longline mortality of oceanic whitetip sharks and silky sharks by more than 40% and more than 30% respectively[95].

Additionally, the use of different types of fishing hooks can reduce shark mortality with the use of large circles hooks reducing the severe injury rate as sharks get hooked on the jaw rather than in the gut[86–89]. Indeed, they are less likely to swallow the large circle hook down in the oesophagus[86–89]. For longlines, additional mitigations measures may help reduce shark bycatch in fisheries where sharks are unwanted, including changing setting depth or the type of bait used[96]. Reduced soak times will generally increase chances of survival of hooked sharks[97,98]

Combining such gear and practice modification with the application of mandatory best handling and release guidelines, can help to substantially reduce the mortalities of bycaught sharks during their hauling and release when they are caught incidentally and are specifically effective for sharks for which a retention ban exists[99]. To this effect, the IATTC has published such guidelines for sharks caught as bycatch in purse seine and longline and gillnet fisheries[94]. Several but not all of these guidelines, along with monitoring requirements and mitigation measures were then translated in 2024 into a binding IATTC resolution on shark conservation[100]. An important takeaway of those guidelines is to limit direct manual interference to the maximum and leaving sharks in the water or returning them as quickly as possible, thereby improving survival rates while safeguarding the safety of the crew.

To conclude, the dynamics of shark and elasmobranch bycatch are quite different to the rest of the sensitive species considered in this report. They are only partially or not covered by most international regulations and their exploitation can still be intentional in the form of targeted bycatch. As the dynamics are radically different to actually unwanted bycatch, both types require different management plans and mitigation measures. Some RFMOs are starting to take first steps into the right direction but much improvement is still needed to tackle both issues adequately and in time to prevent the collapse of elasmobranch populations. As a whole, the adequate solution to protect shark species is to grant increased protected status under the TMR to endangered species or those most severely impacted by fisheries. This increased protection would then be a lever to enforce fishing closures, require gear modifications and define mortality reference points, which can trigger additional mitigation measures if reached.

Overview of the fishing gears, associated bycatch risk and mitigation measures

IIn order to talk about fisheries and bycatch, it is essential to discuss the concept of "métier"[101]. A métier is a technical–economic unit that describes a group of fishing operations characterised by 4 criteria:

- Gear type: Fishers in the EU use a wide variety of gears, trawlers, gillnets, longlines and pots amongst others. Table 3 provides a quick overview of the main gears used but a much more extensive fishing gear handbook was published by the European Parliament in 2024[102].
- Target species: The same gear can be polyvalent in terms of catch species; it is therefore important to consider the specie(s) targeted when defining a métier. This guide does not focus on defining the variety of target species but there is again a very extensive target species handbook that was published by the European Parliament in 2024[103].
- Fishing area: A fishing area can be defined at different scales depending on the accuracy required.
- Season & duration: Certain fisheries can either linked to migratory species, which might not be present in the fishing year-round (such as bluefin tuna in the Mediterranean), or they might need to operate during or outside of spawning periods.
- Examples of métier: "cod gillnets in the Baltic Sea" or "octopus pots in the Mediterranean".

Defining métiers is important because each métier can have different levels of bycatch, depending on the criteria of said métier. Indeed, the vulnerability of the bycatch species to the gear used is a crucial component, as gears have varying risk on marine mammals, seabirds, marine turtles and elasmobranchs. Table 3 provides an overview of the main gears in the EU as well as the vulnerability of sensitive species in terms of bycatch. The main takeaway from this table, which will be repeated throughout this guide, is that there is no silver bullet when it terms to bycatch. Certain gears might have close to no impact on one species group but might have strong impacts on another. For example, pots cause relatively little bycatch for seabirds but can cause entanglement mortalities for marine turtle and cetaceans[106–108]. Additionally, different métiers of same gear can cause different levels of bycatch risk, since they are used differently or in different settings.

Regardless, bycatch rates which may appear low can still be problematic for certain species or populations if the total fishing effort is large or if the population is small. Indeed, purse seiners in the Portuguese Atlantic cause an estimated bycatch mortality of 1.75 seabird per fishing trip, which may seem relatively low[112]. But when you consider this métier alone has 160 boats, for an annual 117 fishing trips per boat, the estimated seabird mortality adds up[112]. As such, the bycatch mortality of the critically endangered Balearic shearwater very likely exceeds its fishery-exclusive PBR, which has been estimated at 100 individuals for its full Western European range[41]. **As such, even métiers with relatively low bycatch rates can become problematic at the fleet or regional levels if no management and mitigation measures are put into place**.

Métier is a useful definition but overlooks two important components of fishing that need to be considered, mainly fishing effort, which can in turn be dependent on vessel size. Fishing effort, as explained earlier in the report, is a metric used as proxy for the impact of fisheries on the ecosystem, including bycatch. While small-scale vessels (≤12 meters, 1-4 crew) will tend to have smaller effort than large-scale vessels (≥ 12 up to 50+ meters and 4-30+ crew), **vessel size is not the main element when it comes to bycatch. Attention should instead be on the gear-specific fishing effort for a métier and the associated bycatch rate rather than vessel size.** With that in mind, small-scale vessels tend to use more passive gears such as gillnets, pots and longlines whereas larger-scale vessels usually rely on more active gears, such as trawls, purse seines and longlines. Passive gears tend to have less physical impact on the ecosystem and on fish stocks than active gears for a similar amount of effort but both passive and active gears can be problematic in terms of bycatch.

Large-scale and small-scale vessels there pose different issues in terms of bycatch management. The individual fishing effort and yield for one small-scale vessel is minimal compared to one large-scale vessel but small-scale vessels are in much higher number but are not subjected to any bycatch monitoring requirements as they are under 15 meters. The individual bycatch caused by one vessel might be very low but the aggregation at the fleet level might cause an issue. To illustrate, it was estimated that an average small-scale Scottish pot fisher might witness less than 1 entanglement per decade[104]. However, this level entanglement represents a serious welfare and conservation issue at the métier level[105]. Work on mitigating large whale and basking shark entanglement in the Scottish pot fishery is ongoing.

Compared to small-scale vessels, the concentration of fishing effort into a much lower number of larger vessels might appear easier in terms of oversight and implementation of mitigation measures. However, large-scale vessels are able to fish during days, weeks or months at a time with more power and higher yields. Bycatch monitoring requirements for certain métiers currently only apply to large-scale vessels as they are above 15 meters. They are therefore likelier to either embark an observer or be equipped with Remote Electronic Monitoring equipment (REM) but coverage is still low. STECF estimated in 2021 that observer coverage was well under 1% of total effort in most fisheries[109].

Observers are considered the most reliable source of information considering bycatch monitoring and are therefore essential to provide base data to develop models and ultimately implement appropriate bycatch mitigation measures[110]. REM is also considered reliable if complemented by at-sea observers for crosschecking bycatch records. REM may also be more cost effective in general and easier to deploy on smaller vessels than observers[19]. Indeed, the REM guidelines published by the European Fisheries Control Agency in 2019 include an overview table of the requirements for an REM system, which are adapted to the métier and size of the vessel[111]. Regardless, ICES has noted that no single monitoring design can be effective to estimate bycatch across the range of sensitive species, and coverage must be adjusted to bycatch probabilities[19].

Photo: ©Stefan Menzel

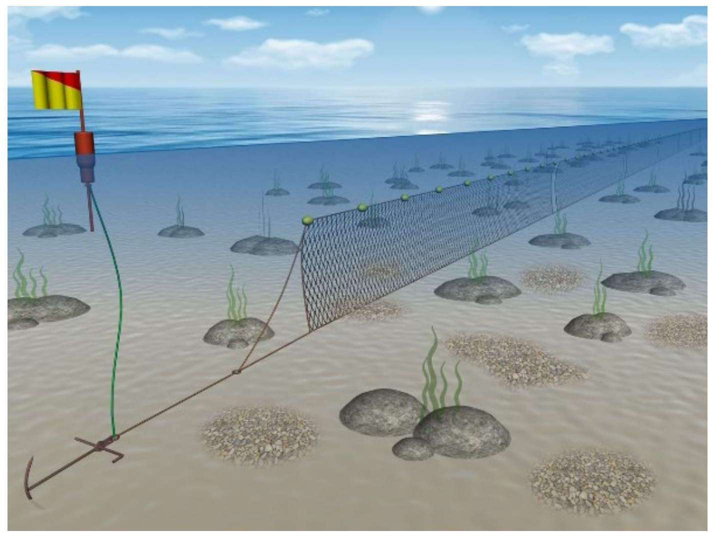
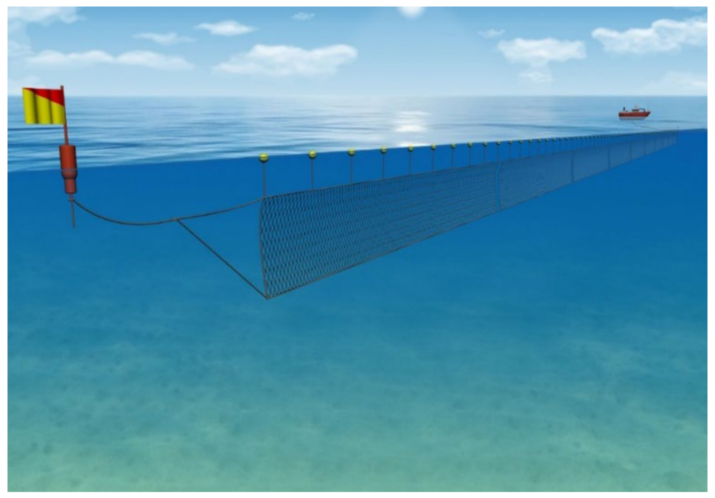
Table 3: Condensed overview table of fishing gears, associated bycatch risk per species group and mitigation measures

All mitigation measures listed in this table are associated with one or more sources supporting its use, which might be a scientific study, research body advice or government report. **Not one bycatch mitigation measure is a silver bullet and multiple measures should be taken in complementarity to properly address a bycatch issue. Measures should also be taken while considering the local context (fishing métier, sensitive species, local ecosystem etc…), as not all measures are appropriate for every situation.**

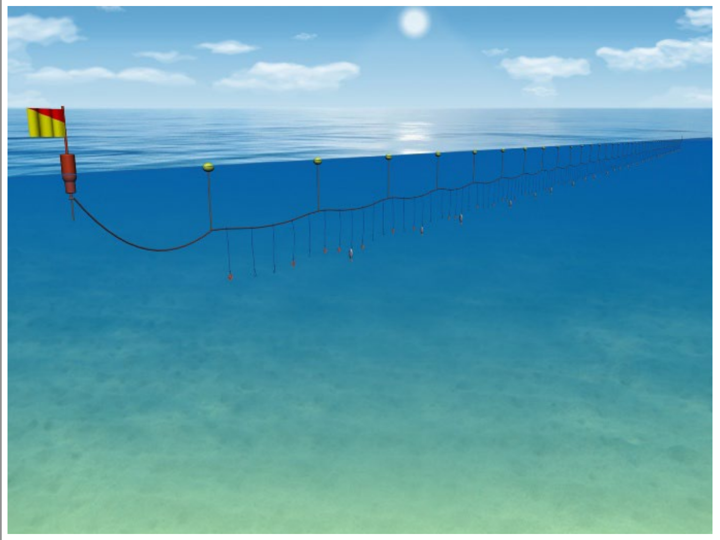
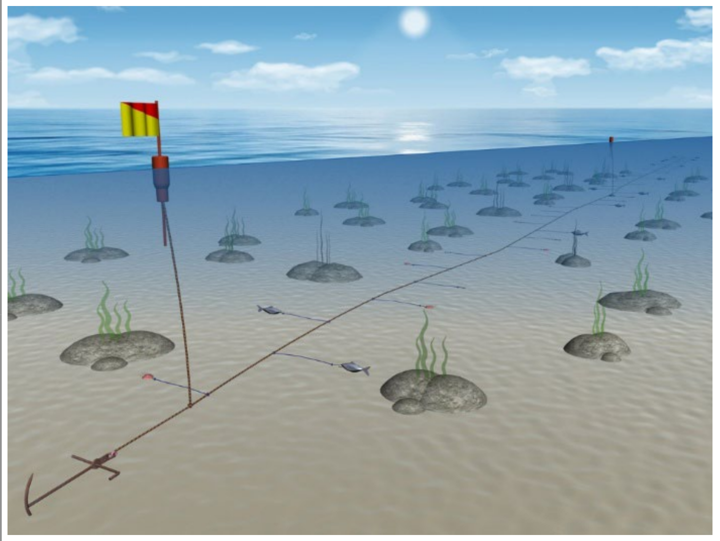
The bycatch risk column is colour-coded using the following scale:

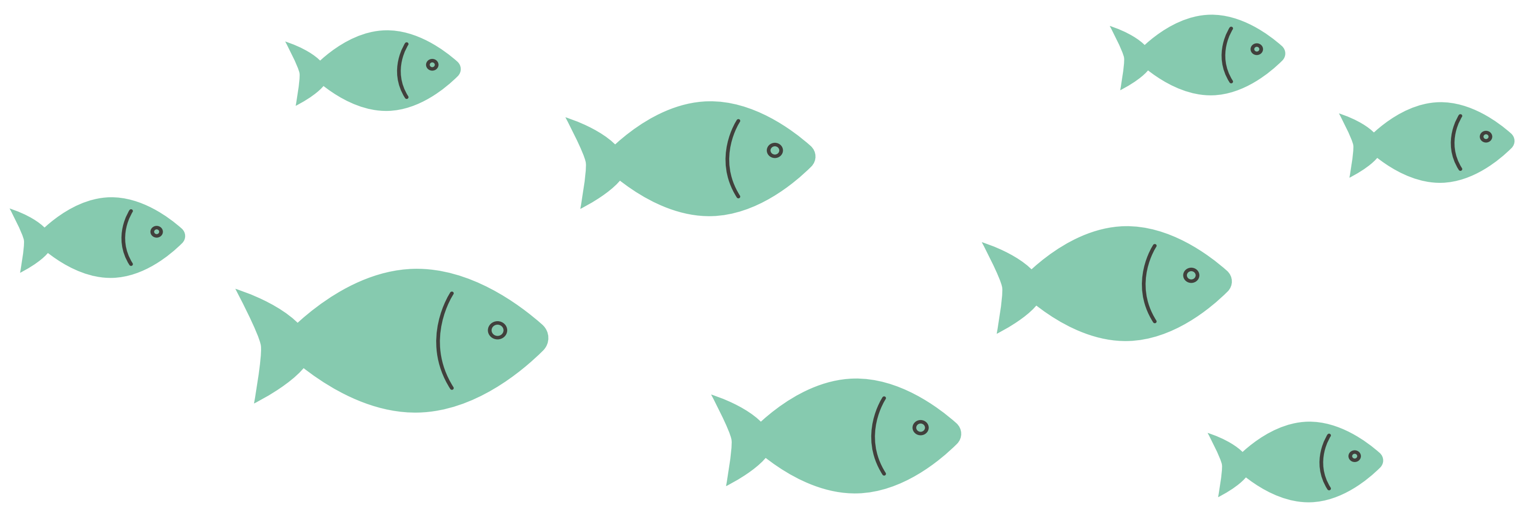
- **Non-existent to low bycatch risk – No specific actions needed**
- **Low to intermediate bycatch risk – Preventive mitigation measures should be applied to avoid escalation of the issue and protect vulnerable populations**
- **Intermediate to high bycatch risk – Mitigation measures needed to reduce the bycatch risk, which can threaten the long-term viability of populations**
- **High bycatch risk – Urgent need for a mix of mitigation measures to curb bycatch risk, which can otherwise lead to population collapse if not addressed**

Important consideration for bycatch risk: The bycatch risk scale used in this guide is simplified and is meant to compare the bycatch rates of gears relative to each other, to identify priorities for implementation and funding. This table is not meant to be not read in absolute. **Even gears with low bycatch risk can be problematic for endangered and critically populations in general or to stable populations if fishing effort is very high**.

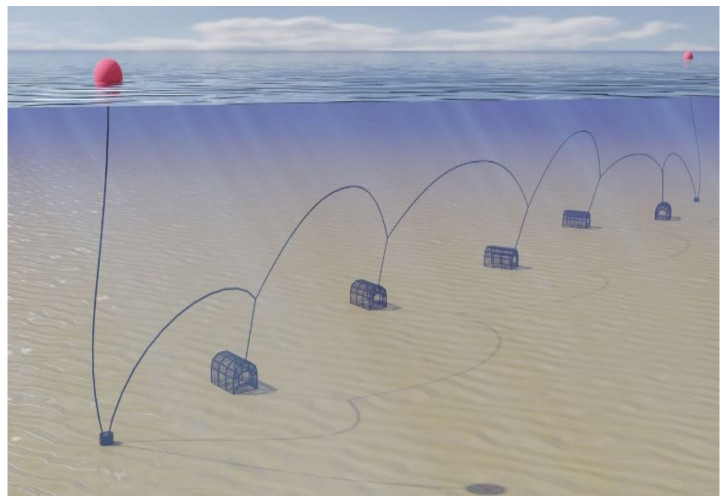
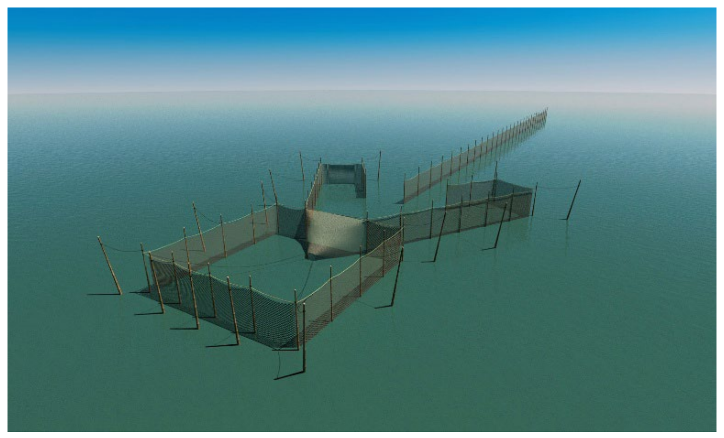
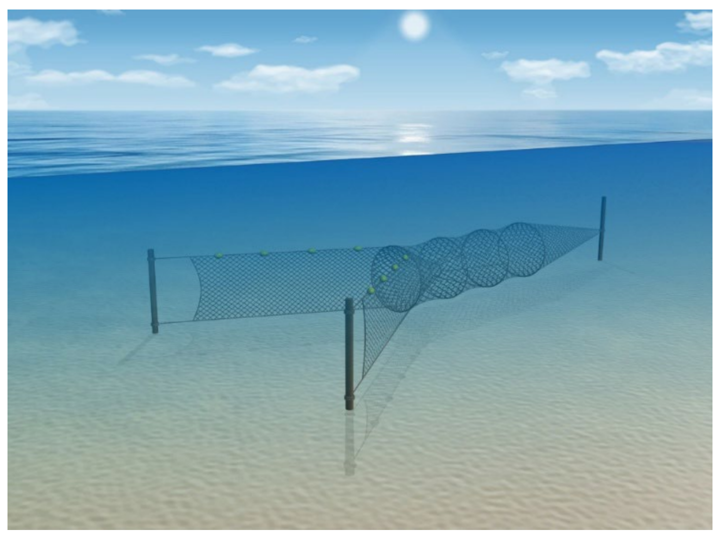
Gear	Target species, métiers and area of use	Advantages	Disadvantages	Bycatch risk	Examples of successful mitigation measure
Passive gears: The fish and animals get caught in the gears by their own movement					
Entangling nets, which includes gillnets & trammel nets: long net mesh that relies on catch entangling itself in the net, being left to soak for a certain period, before being hoisted up.   Images ©Seafish	Gillnets can either be anchored at the bottom or left drifting at the surface (drift nets[i]) Used commonly in a various number of fisheries. **Métiers examples include:** - Cod bottom gillnets in the Baltic and North Sea - Mixed gillnet fishery in the Mediterranean **Elements to consider when measuring gillnet fishing effort :** - Net length and if available, multiply it by net height to get net surface. Net surface, as well as the number of nets set in a time span (usually a day) give a good estimate of what surface is exposed to species for them to get caught in. - Soaking time : This is a measure of how long a gillnet is left to soak in the water. It tends to be a minimum of 6 hours, lasting up to a few days.	- High fuel efficiency - Relatively cheap for the fishers, easy to replace and store - Low impact on benthic habitats	- Low selectivity in terms of catch - Ropes can break and lead to ghost nets - High levels of marine mammals, seabird, sea turtle and elasmobranch bycatch	**Marine mammals** - Get entangled in the net during swimming due to low echolocation visibility and drown[113–116]	- Pingers[j] generate noise, driving marine mammals from the net[113,114,117–119]" - Closure[k] of areas to gillnets[118,120] - Setting driftnets lower than the surfa[ce121]
				Seabirds - Get entangled and drown[12,122–124]	- Closures[k] of areas to gillnets[123,125,126] - Setting bottom gillnets in areas of deeper waters[123,127]
				Marine turtles[18] - Entangled while swimming and drown[122,128,129]	- Gillnet illumination with LEDs[128–130] - Closures[k] of areas to gillnets[131] - Increasing gillnet tension[61]
				Elasmobranchs[132,133], [l] - Entangled while swimming	- Increasing bottom tension[132] - Gillnet illumination with LEDs[134]

i Driftnets are limited to a length of 2.5 kilometres and under per the Technical Measures Regulation (EU) 2019/1241. The TMR implements a blanket ban on driftnets in the Baltic Sea and for fishing in the species mentioned in Annex I of the TMR, which are tuna-like species, sharks and a few others.
j As touched upon in the dedicated section, pingers do come with an important set of considerations. They are not efficient for every species and if coverage is minimal, pingers might increase bycatch rather than reduce it. Noise pollution is also an important issue and therefore why pingers should be complemented by static closures for gillnets.
k Fishing closures also come with an important set of consideration, which is touched upon in more detail in the dedicated section. If poorly designed, closures can have no reduction on bycatch rates, or worse increase them, if effort is displaced and intensified in other areas.
l Elasmobranchs, meaning sharks and rays, have different dynamics to other sensitive species, which is discussed in the dedicated box in the guide. They can be target bycatch and even when they are true bycatch, existing measures are oriented at reducing mortality. Almost all researched on bycatch mitigation measures for elasmobranchs are related to longlines.

Longlines: Extensive main line, with suspended thinner lines for individual baited hooks, up to thousands of hooks for one set.   Images ©Seafish	Longlines can either be anchored at the bottom to target cod, halibut and flatfish. They can also be left at the surface to target pelagic fish, such as tuna or swordfish. The hooks are usually baited with squid, mackerel or sardines and the leader material connecting hooks to the main line differs depending on target species and fleet. **Métiers examples include:** - Demersal seabass longlines off the coast of Britanny, France - Tropical tuna longlines in the South East Atlantic - Pelagic longlines for swordfish in the Mediterranean - Swordfish and blue shark fisheries in the Atlantic, Pacific and Indian oceans **Appropriate metrics for fishing effort :** - Number of hooks, with one measure of fishing effort being 1000 hooks e.g bycatch rate /1000 hooks. Hooks are exclusive and one hook will in vast majority have only one individual animal caught on it. - Soak time : While it has not been found to be a major factor for all target catch and bycatch rate, it is a factor for survival rates of bycaught species.	- High fuel efficiency and can be done with very small vessels - High selectivity for target catches, including size - No noise pollution	- High levels of bycatch for seabirds, sharks , rays, and turtles - Depredation and gear damage by seals and marine mammals	**Marine mammals** - Seals and baleen whales can get entangled[135]	- Catch protecting gear, which are physical or visual barriers to deter marine mammals from depredating on the target catch[136–140] purse seine, longline, gillnet and pot/trap fisheries. - Move-on rules and changing fishing area to avoid overlap with pods of marine mammals[135,141] - Fishing closures[k] which need to consider the high mobility of mammals[135,138] - Pingers have been found to be inefficient or detrimental in the case of longlines[135,138,142,m;n]
				Toothed whales, including dolphins - Depredate on the bait or target catch and get hooked[60,135,138]	
				Seabirds - Get hooked while diving for the bait and drown or suffer internal damage[12,125,143]	- Tori lines or bird scaring lines[124,125,143–145] - Weighted longlines or line shooters for rapid sinking[124,125,143,144,146]" - Night setting[124,125,144,147] - Fully retaining discards and offal and if not possible, discarding during non-fishing operations[147–149] - Devices that cover the hook until it reaches fishing depth[147,150,151]
				Marine turtles - Get hooked while predating on the bait and drown or suffer internal damage[152,153]	For marine turtles: - Wider circle hooks reduce the bycatch rate and the rate of internal injury through swallowing[88,152,153] - Using fish instead of squid for bait[152,153]
				Elasmobranchs[74,154] - Elasmobranchs have extremely high bycatch rates in longlines and mitigation measures are focused on reducing mortality rather than catch rate	- Banning buoys lines, which are hooks at a shallower depth than the main hook lines[94,95] - "Banning the use of wire leaders with reinforced hook lines[94,95] and instead requiring the use of monofilament leaders reduce bycatch and increase survival[93] - Several other gear configurations and setting practices can reduce elasmobranch bycatch and increase chances of survival (set time, set depth, bait, hook type, spacing of hooks, soak time) but effectiveness varies for different elasmobranchs and regions[96–98]

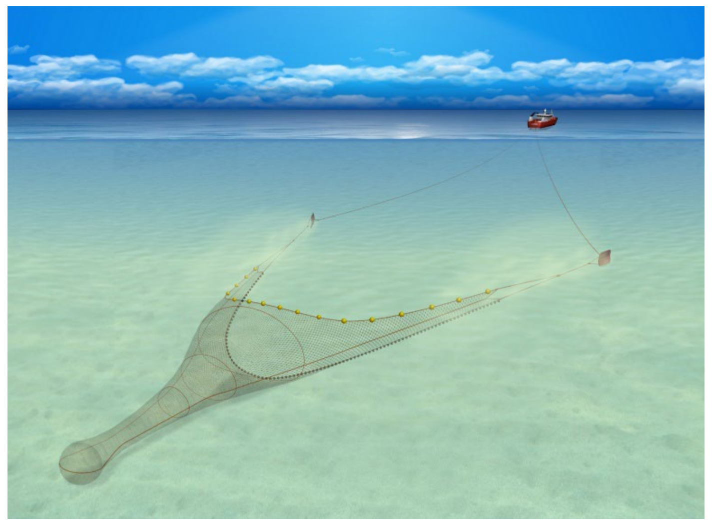
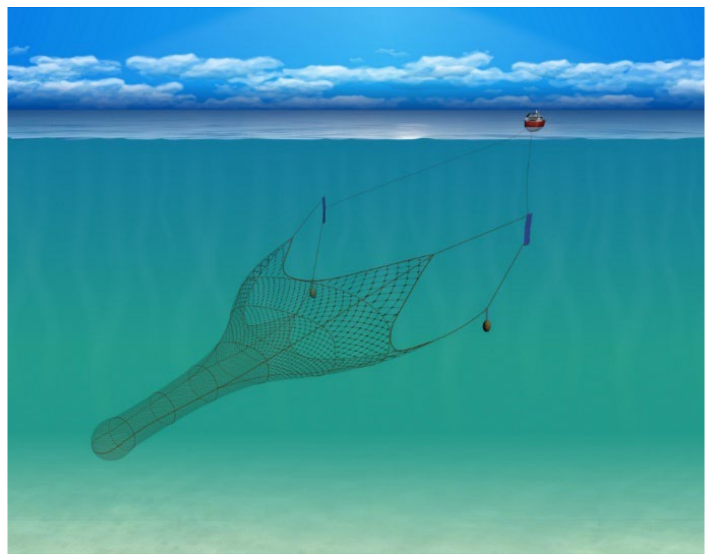


m In the case of pingers for longlines, the noise discomfort to toothed whales is minor compared to the food supply offered by the target catch hanging on the longline. Whales can get habituated to the pinger noise and they may use it to trace it the longlines vessel and depredate even more.

Pots: Box-like container with bait inside to draw in the catch. The entrance mechanism works only one way and leaves the catch trapped in the post. Tens of pots are connected through a groundline, which can span hundreds of meters  Image ©Leaper et al. (2022)	Pots are left to soak on the bottom, usually up to a few days. It is mostly used for invertebrates, including crabs, lobsters and octopus but can also be used for fish species. The bait will change on the target species but can include crab, fish, molluscs, a mix or no bait at all. **Métiers examples include:** - Crustacean (lobster, langoustine, crab) pots in the Irish coast - Octopus pots in the Spanish, Italian and Greek Mediterranean **Appropriate metrics for fishing effort:** - Number of pots : Pots will usually be rigged into fleets of 10 or more pots and multiple fleets will be hauled and shot during one fishing trip. - Soak time : Fleets of pots can be on the seabed for a few hours to a few days.	- High catch quality and size selective - Low impact and fuel efficient - No noise pollution	- Plastic pollution - Not suitable for open sea conditions	**Marine mammals:** - Smaller marine mammals might try and predate inside the pot[60,155] **Larger marine mammals such as humpback, minke and right whales** - Get tangled in the groundline or buoy line[107,159]	Marine mammals: - Replacing floating groundline with sinking groundline close to the seafloor[156] - Ropeless mooring, using on-demand flotation system[157,158] - Fishing closures for pots[159] - Devices excluding entrance for marine mammals inside the pot[60]
				Seabirds: - Little to no risk of depredation since pots are semi-enclosed and rest on the seafloor.	Seabirds: - Not applicable
				Marine turtles[106] - Entangled in the buoy line[106]	Marine turtles: - Ropeless mooring, using on-demand flotation system[61,106] - Fishing closure for pots[106]
				Elasmobranchs - Low entanglements rates but problematic for vulnerable species. Some species may enter the pot[105,160]	- Ropeless mooring, using on-demand flotation system[106] - Fishing closure for pots[106] - Adding magnetic elements to pots[61,160]
Traps: Stationary structure composed of multiple net chambers, guiding target catch towards a one-way entrance to a chamber that may or may not have bait.  Image ©He et al. (2021)  Image ©Seafish	Traps, such as a pound nets, pontoon traps and fyke nets, rely on the movement of fish through currents and through bait to attract them in the chambers. Due to their stationary nature, traps can only be used in relatively calm and shallow waters. - Fyke net for targeting eels in Swedish coastal waters - Herring pound net in German coastal waters **Appropriate metric for fishing effort :** Volume of trap/net and surface of the net on which species can get entangled : Traps tend to be composed of multiple chambers and sides that species animals can get entangled in. Traps are stationary and soaking time is therefore unlimited.	- Fuel and labour efficient - Low cetacean bycatch outside of harbour porpoises - Bycaught animals can be released alive if they are able to breathe	- Very dependent on fish behaviour, leading to low target species pool - Not suitable for open water conditions - Expensive to set up and maintain	**Marine mammals:** - Other marine mammals do not interact with traps but may get entangled[61] **Seals** - Follow into the trap to predate on fish[161,162]	- Pingers[n,o] generate noise, driving marine mammals from the traps[61,161] - Exclusion device[140]purse seine, longline, gillnet and pot/trap fisheries. Successfully implemented mitigation measures include acoustic deterrent devices (pingers) - Mechanisms that allow surface breathing[162] - Using pontoon traps[163,164] - Modifying trap design[162,163]
				Seabirds - Seabirds dive to predate on the fish and get stuck[61]	- Escape windows[61] - Increase mesh size on top of the trap[61]
				Marine turtles - Follow into the trap to predate on fish[165]	- Open roof traps to reduce mortality[165] - Exclusion devices[165]
				Elasmobranchs[166,167] - Can swim into the trap	- Adding magnetic elements to traps[166]

o If pingers are used to deter seals, they should be used at a higher volume which classifies them as Acoustic Harassment Devices. It is therefore not recommended to use them for pinnipeds, as other efficient mitigation measures are much less harmful.

Active gears: The fish and animals get caught by the movement of the gear

Trawl: Cone-shaped net being dragged behind one or two boats  Image ©Seafish  Image ©Seafish	The trawl can either be targeting species on the seafloor, such as flatfish, cods, shrimp in the case of bottom trawl, with the net being in contact with the seafloor. The pelagic trawl will instead target species in open water, such as mackerel, sardines, herring or whiting. - Shrimp *Nephrops* bottom trawling in the North Sea and Celtic Sea - Pelagic trawling for herring and mackerels in the English Channel - Mixed demersal trawling in the Mediterranean **Appropriate metrics for fishing effort:** - Number of trawls per day and trawl duration : the duration for one trawling operation is dependent on the level of catch but can last 3 – 8 hours. - Net dimensions : Trawls can be vastly different sizes depending on the power and size of the trawling vessel. Pelagic trawls also tend to be much larger than bottom trawls.	- High volumes of fishing - Large range of target species	- Low species and size selectivity - High fuel consumption - Damage to the seafloor in case of bottom trawl	**Larger cetaceans:** - Bycatch bas been known to occur but at low rates compared to other species groups[75,76]. Vessels should also be mindful of collisions[168,169].	- Exclusion grids complemented by escape hatches adapted to the species' behaviour[61,170–174] - Avoiding sharp turns or using systems that prevent collapse of the trawl entrance due to lower speed[174,175] - Pingers[j,176] can help in reducing dolphin interactions but this is very case dependant[140,174,176]purse seine, longline, gillnet and pot/trap fisheries. Successfully implemented mitigation measures include acoustic deterrent devices (pingers) - Trawling in deeper waters[177]
				Smaller cetaceans (dolphins, porpoises, pilot whales) and seals: - Caught during trawling or while they depredate on the catch[83,84,87]	
				Seabirds: - Get tangled while depredating during the setting or hauling of the trawl net and drown or get gravely injured[147,178] - Collisions with warp cables and that cause drowning or grave injuries[147,179,180]	- Fully retaining discards and offal and if not possible, discarding during non-fishing operations[147,179,181] - Cleaning the net between fishing operations to reduce depredation[147,178] - Bird scaring lines[147,180] - Minimising the surface time of the trawl net during setting and hauling[147,178]
				Marine turtles: - Caught during trawling[5,130,175]	- Exclusion grids complemented by escape hatches adapted to the species behaviour[130,175] - Avoiding sharp turns or using systems that prevent collapse of the trawl entrance due to lower speed[174,175]
				Elasmobranchs: - Caught during trawling[92]	- Removing tickler chains, which hang ahead of the trawl mouth and stir the seafloor[182] - Exclusion grids complemented by escape hatches adapted to the species behaviour[61,92,175]

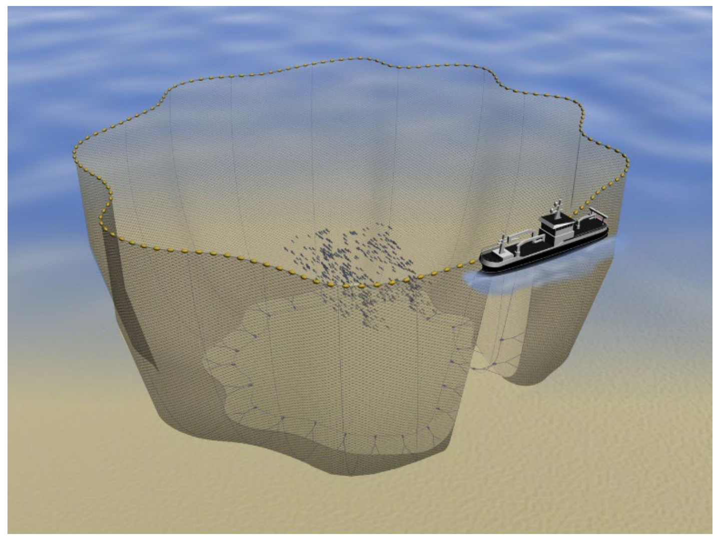
Purse seine: wall of netting that will encircle the fish and slowly close out the bottom, forming an enclosed purse that can then be hauled onboard.  Image ©Seafish	- Purse seiners target exclusively pelagic species, such as tuna, mackerel, herring and others. They can rely on setting on free schools of fish or drifting Fish Aggregating Devices (dFADs), which are small floating wooden or plastic structures with a submerged appendage and a buoy. The submerged appendage can be composed of old netting materials, buoys, ropes and reach up to 50 – 80 meters in depth[95]. dFADs help concentrate fish schools, especially tuna and have therefore become very widespread in tropical tuna fisheries, being the main fishing method used by EU long distance fleet vessels[96.] - The purse seine is in use in a variety of fisheries but is most known for its use in tropical tuna fisheries in non-EU waters. **Example métiers include:** - Yellowfin and skipjack tuna purse seiners in the Indian Ocean, Atlantic, Eastern and Western Central Pacific - Northeast Atlantic mackerel purse seiners” **Appropriate metrics for fishing effort:** - Number of sets : One set is considered to be the full deployment of a purse seine net. Even sets with no target catch can still cause bycatch - Net dimensions : Purse seines can range from “smaller” nets of a few hundred meters and depths of 10-20 meters up to larger tuna seines that can be kilometres in length and up to 250 m in depth. - Number of dFADs deployed per day : dFADs are a massively used tool in tropical tuna fisheries to cause schooling. They are associated with high levels of juvenile bycatch and entangling.	- Extremely high volume of catch - Little to no damage to the seafloor while floating but massive damage to coral reefs and other VME habitats when dFADs are lost or abandoned, which happens on a regular basis	- Low selectivity in terms of size and target species - High levels of bycatch, especially juvenile silky sharks, juvenile oceanic whitetip sharks but devil rays	**Marine mammals** - Some larger marine mammals can be encircled but with low immediate mortality[183,184]. Welfare issues and post-release survival should be considered. - Dolphin pods tend to overlap with tuna schools and their presence might be used to trigger a set by purse seiners. They may then get encircled with low immediate mortality but this can cause long term welfare issues, such calf separation and death or miscarriages due to stress[185–187]	- No purse seining when marine mammals are present in the tuna schools[61,187]. But if they are encircled by accident, the “backdown” procedure and Medina panels can help marine mammals safely escape[98,184,187]. Priority should go not to encircling in the first place. - Pingers generate noise to draw common dolphins away from the purse seine[188] - Restricting FAD use or optimising FAD design to reduce entanglement[98,184,189]
				Seabirds - Seabirds can get entangled and trapped in the net. Problematic for vulnerable species, notably the Balearic Shearwater[41,187,190,191]	- Avoid setting under whale sharks[61] - Bird scaring kite[192] - Using a modified purse seine (MPS)[147]
				Marine turtles - Turtles can get entangled in the FADs. If encircled in the net, they are usually found and released alive[98,184,187]	- Restricting FAD use or optimising FAD design to reduce entanglement[98,187] - Deploying boats to spot and release entangled turtles[98,184,187] - Night fishing[98]
				Elasmobranchs - Sharks, especially juvenile silky sharks and oceanic whitetip sharks, are often present in tuna schools and FAD associated sets[92,98,184] - Whale sharks might be presents in “free schools” that are not associated with dFADs and might be encircled if they were not spotted. -	- Banning setting purse seines around tuna school associated with whale sharks[98] - Restricting FAD use or optimising FAD design to prevent entanglement[92,98,184] - Releasing before hauling onboard, proper handling technique onboard and optimising release through separate conveyor belts and ramps[193,194] - Closures of high-density areas, such as nurseries[184]

Photo: ©Georg Wietschorke

Bycatch mitigation measures

Bycatch mitigation measures can be distinguished in two main categories:

- Technical mitigation measures: They tend to focus on the actual gear itself and how it operates. These can include pingers, setting times, mesh sizes. Changing gear can also be considered a type of technical measure.
- Fishing effort measures: They tend to focus on the intensity of the fishing activity and where it is taking place. Measures include fishing closures, reduction of fishing opportunities for vessels with high bycatch or support for diversification to encourage effort reduction.

This guide does not go into detail for all possible mitigation measures of these two categories but multiple publications and reports have extensively described bycatch mitigation, focusing on certain fishing grounds, methods or species groups[60,61,140,195,196]. The following publications provide a more extensive overview of bycatch mitigation measures applicable and are worth reading due to their different angles and of focus, which complement this guide:

- The 2021 GFCM book provides an overview of bycatch mitigation measures for all sensitive species and major fishing gears[61].
- The 2024 study by Fauconnet was commissioned by the PECH committee of the European parliament and touches upon bycatch in fisheries through the angle of selectivity in fisheries[195]
- The 2021 report by Read for ASCOBANS focuses more on the cost-benefit analysis of bycatch mitigation measures, as well as their advantages and disadvantages[196].
- The 2025 report by WWF UK with a similar pedagogic approach to this guide on bycatch mitigation but including specific mechanisms linked to UK supply chains[197].

This guide focuses instead on the major mitigation measures considered in the bycatch debate, namely acoustic deterrent devices, fishing closures and use of alternative gears. It focuses on these measures because as useful as they can be, they do come with important sets of considerations that should be fully understood. The guide touches on these mitigation measures through the aspect of marine mammal bycatch, which currently receives the most public and political attention. The takeaways are however also applicable to other species groups and are quickly summarised in Table 4. Additionally, there are two overarching mitigation measures that are not underlined in the Table 3 and 4 for redundancy as they are beneficial to all métiers and gears at all times with no considerations:

- Guidelines for good handling and release practices f**or all species groups as this minimises on board mortality, addresses animal welfare impacts and can minimise post-release mortality.** Multiple guides have been produced to train fishers and are valuable resources that should be used.[22,32]
- Reductions in fishing effort, meaning overall reduction and not just geographical displacement, lead to reductions in bycatch. **Less fishing effort means less bycatch.**

Table 4: Main bycatch mitigation measures discussed in this report, with their associated benefits and considerations

	Benefits	Considerations
Pingers	- Little to no impact on target catch - Very effective for certain species, such as harbour porpoise - No change to fishing method	- Not appropriate for all species - Source of noise pollution and should not be used without fisheries closures to protect key habitats - Malfunction, wrong frequencies or poor coverage can make bycatch worse
Fixed closures	- Strongly reduce bycatch for all species - Umbrella benefit for the ecosystem	- Fishing effort should not be displaced to an area with equal or superior bycatch risk - Closures without enforcements and monitoring are ineffective
Dynamic closures	- If appropriate, can strongly reduce bycatch during key periods or once bycatch mortalities are becoming problematic - Can incentivise fishers to improve their bycatch mitigation practices or risk losing access to fishing grounds	- Dynamic closures are not appropriate for all species or population, especially if they're endangered - Conditional dynamic closures only are recommended with proper enforcement and monitoring
Alternative gears	- Can help drastically reduce bycatch risk if moved to the appropriate alternative gears with lower bycatch risk	- The fishing effort of the new gear should be carefully distributed to prevent excessive pressure on fish stocks - Fishers should be incentivised to go through this gear transition, but enforcement may become necessary

Acoustic Deterrent Devices - Pingers

Acoustic Deterrent Devices, also known as ADDs or pingers, are small devices that can be attached to fishing gear and produce sounds within the hearing range of cetaceans. This sound then causes cetaceans to avoid or distance themselves from fishing gear equipped with pingers, reducing their bycatch[117,119]. They are currently required under the Technical Measures Regulations (TMR) for vessels over 12 meters using bottom gillnets in certain areas of the Baltic and a small number of ICES divisions[198.] Their technical characteristics and spacing are currently regulated by EU Regulation (2020/967), which adds onto the TMR[199]. Pingers can be an efficient measure to mitigate bycatch without fundamentally changing the associated fishing gear and without reducing yield of target catch[200]. They do however come with a set of considerations that are important for them to be effective[60,113,140]. Otherwise, they can be ineffective or at worse detrimental to the sensitive species if used inappropriately. Indeed, pingers are an important source of noise pollution and wide-scale use of pingers can cause cetaceans to be displaced from key habitats[117,118]. As such, widespread use of pingers should only be considered in complementarity with static fishing closure areas, shielding key habitats from the pinger-induced noise pollution. Widespread use of pingers may also be impossible due to conflicts of interests with military sonars, with security policy overtaking conservation policy[201]. This is particularly important in the case of the critically endangered Baltic proper harbour porpoise.

This is particularly important in the case of the critically endangered Baltic proper harbour porpoise, which needs widespread fixed fishing closures[201].

It is essential to keep in mind that pingers have been demonstrated to reduce bycatch for a few cetacean species, but not all species are sensitive to them[60,113]. The main species where pingers have been found to be effective in reducing bycatch is the harbour porpoise and common dolphin. They have mixed effects to no effect on bottlenose dolphins and can even have an attractive effect for seals with the so-called "dinner bell" effect[140,202]. The use of pingers must be appropriate in terms of sound frequency and volume, distance between pingers and overall fleet coverage. Indeed, studies have indicated that limited use of pingers in gillnets could lead to increased bycatch rates of harbour porpoises compared to the scenario where no pingers are used[113,118]. This will occur if a few pinger-equipped gillnets drive harbour porpoises into non-pinger equipped gillnets, which they have much more difficulties detecting. For the use of pingers to be beneficial for reducing harbour porpoise in a gillnet fishery, one study suggested that pinger coverage needs to be superior to at least 30% and lower pinger coverage could lead to increased bycatch[118]. Pinger models must also be reliable as malfunctioning pingers can lead cetaceans to believe passage is safe and increase entanglement rates[203].

The pingers must be the appropriate frequency and mechanisms to avoid causing detrimental effects, as low frequencies can cause "a dinner bell" effects for pinnipeds (seals and sea lions), which increases depredation and bycatch in fishing gear. Pingers should therefore operate at a frequency of 40 kHz or more, above the usual 0.5 to 40 kHz hearing ranges of pinnipeds, if pingers are used to mitigate bycatch without attracting pinnipeds and increasing depredation[202,204]. Additionally, dolphins and porpoises are reactive to different frequencies of pingers and using inappropriate frequencies/pingers may have no effect at all. **In short, pingers can be quite an efficient mitigation tool for certain species but multiple very important factors need to be considered**. An overview of these factors is provided in the following studies and FAO guidelines[60,113,140]. The Joint Nature Conservation Committee (JNCC) updates a very extensive report on pingers for marine mammal mitigation, including a database on available pingers[119]. The report and database do focus on the wider maritime industry rather than only fishing but provide a very useful tool to consider available pingers, their technical considerations and associated marine mammal species.

Longterm widespread pinger coverage for over a decade led to an estimated 50% decrease in common dolphin bycatch in a California gillnet fishery and 50-70% decrease in harbour porpoise bycatch in a Gulf of Maine gillnet fishery[203,205]. Smaller pinger trials conducted in the gillnet fisheries in the North Sea and the Atlantic reduced the bycatch of harbour porpoise upwards of 90%, without impacting catch and with minimal added labour[114,200]. Pingers do not fully eliminate bycatch on their own, but they can strongly reduce it when used appropriately. Combining pingers with other measures, such as a spatial closures, can enhance their effectiveness for bycatch mitigation and buffers their detrimental effects[118,120]. Indeed, spatial closures shield key habitats from the noise pollution caused by pingers[117,118,120]. Without the complementary closures, widespread pinger use could actually do more harm than good.

In order for pingers to be most effective and not detrimental, test studies considering multiple factors (fishing gears, model, bycatch species, distancing, overall pinger coverage etc...) are essential before deployment at the fisheries level. However, **this argument should not be used to delay their testing, use and implementation for bycatch mitigation.** Pingers, along with effective complementary measures such as spatial closures are needed urgently for the Baltic proper harbour porpoise, with a single mortality a year threatening the viability of the population[36].

Spatial closures – Fixed and dynamic

Spatial or temporal closures, also known as time-area fishing closures, are used to strongly reduce or fully restrict the fishing effort in an area using gear that poses a high risk to species sensitive to bycatch. The closures can be implemented according to different factors[60]:

- Time of the year, as fishing grounds might be used more intensely by sensitive species for seasonal breeding or feeding.
- Fishing gears, with specific gears or métiers being restricted due to their bycatch risk
- Presence of critical habitats or migration corridors

Spatial closure can also be static/fixed or dynamic, each method having its advantages and challenges:
A static closure means the spatio-temporal range of the closure area stays fixed over time. Static closures are not easy to integrate into law, implement and monitor due the potential strong pushback from the impacted fishing community or fisheries management authority, as it leads to a displacement or reduction of effort, which can impact fishers. However, the fixed geographical bounds of the closure do make it easier to push through government processes and agreements in comparison to dynamic closures. The challenges are that the sensitive species for which the static closure was implemented, might be displaced and render the closure inappropriate, especially if it was designed based exclusively on historical data[206]. This displacement might be caused by climate change and environmental variability, which lead to a gradual distribution shift out the closure area[126,207]. The sensitive species might also be displaced by human activities taking place at the borders of the closure area, especially if the closure area is not large enough to buffer for diffusive impacts, such as underwater noise or light pollution.

- The original closure of the Bay of Biscay from January to February 2024 to gillnetters is an example of seasonal closure. It was effective in addressing the bycatch mortality of common dolphins by 76% when compared to previous years over the same period[208,209]. The evaluation report of the closure does state that indirect environmental effects might have been slightly beneficial but the closure was still the major factor for bycatch reduction, making it a relative success[209]. The closure was renewed for January – February 2025 and expanded by the EU Commission to additional gears (trawlers, seines) and restrictions (only vessels under 8 meters were allowed to keep fishing) but its associated evaluation report hasn't been released at the time of publication of this guide. The closure is again foreseen for 2026.

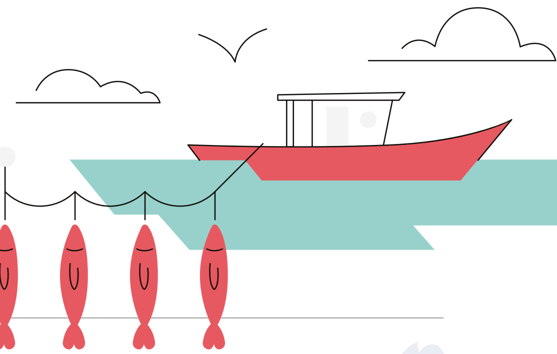
The closure of the Bay of Biscay was however not an easy process, as it happened after years of pressure and recommendations from ICES and IWC, culminating in a court case in France. The closure was also associated with a large economic compensation package, which is not feasible or appropriate for all scenarios. It also was actually too short for fulfil ICES advice, which recommended a closure over multiple months. Evaluations are still pending whether the closure was effective enough or whether it should be extended.

- A dynamic closure is a spatio-temporal closure that is not constant and only comes into force when certain conditions are met and for a given period of time. Conditions can include the presence of the sensitive species in the fishing area, triggering the closure around the detected area or a certain bycatch threshold being reached, causing the associated area to be closed off.

Dynamic closures are not applicable in all scenarios, as certain animals might be too hard to detect or populations are too low, which would cause the dynamic closures to effectively never kick in. For example, the Baltic Proper harbour porpoise is critically endangered with a small population and shy behaviour, making its detection practically impossible. If it is not detected, the dynamic closure never kicks in and the bycatch mitigation is effectively void. Under such a scenario, ICES and experts argue that dynamic closures are not applicable that the effort should instead be on implementing of static closures[201,210]

- For the condition of presence, detection of one or multiple individuals can lead to a closure of the area for a given period, in an effort to strongly reduce fishing effort. The conditions (number of individuals present and density) and consequences (type of gears prohibited, duration and surface area of the dynamic closure) are adapted to the local context. To illustrate, the visual or acoustic detection of North Atlantic right whale in the Gulf of St Lawrence triggers a closure of a defined area around the detection position. Pot gear is then prohibited in the dynamic closed area for a period of 15 days and the prohibition can be extended for another 15 days if the right whale is detected in the last week of the closure[159]. These models are now evolving and include probabilistic presence of the sensitive species based on water and weather conditions[131].
- When it comes to a threshold for bycatch, a dynamic closure can be triggered once the bycatch rate or bycatch mortalities reach a given value. The Australian Fisheries Management Authority (AFMA) has such a system in place for dolphin bycatch in its gillnet and trawl fisheries, with a review period of 6 months and most vessels equipped with electronic monitoring[115,211]. If an individual operator reaches a given number of dolphin interactions across 6 months (3 for gillnets and 1 dolphin interaction for every 50 trawls), they are mandated to cease fishing with said gear and submit an individual mitigation plan[212]. Once the monitoring footage is reviewed and the mitigation plan is implemented and accepted, the operator may resume fishing with said gear. If the operator exceeds the interaction rate over multiple periods, he is then prohibited of using the problematic gear in the area or the whole fishery for a period of 6 months. This dynamic closure based around individual responsibility incentivises fishers to actively reduce their interactions without penalising fishers who already do. The AFMA had also implemented dynamic closures based on sea lion bycatch mortalities, which could lead to the closure of a management area for 18 months[116,213]. This example is discussed further in the alternative gear section.

Static and dynamic closures are actually complementary, since they offer different benefits and drawbacks. Static closures tend to cover large areas, which can provide conservation benefits to the ecosystem by protecting key habitats on top of the bycatch reduction. They also tend to amplify the beneficial impacts and mitigate negative impacts of associated mitigation measures, notably the use of pingers or changes to alternative fishing gears[116,118]. Static closures can however be difficult to enforce, as they might lead to missed fishing opportunities and a reduction of fishing yield, causing pushback[131,214]. On the other hand, dynamic closures may have lower opportunity costs since they are not constant, and fishing may take place when they are not active. They also allow for geographical flexibility, which is important to bycatch mitigation during migration or longer-term displacements caused by climate change. **They are however not applicable for all species or populations, especially if they are endangered or difficult to detect.**



Fishing closures can be effective in reducing bycatch and amplifying conservation efforts, but they do come with a set of important considerations:

- The reduction or elimination of fishing effort in one area should not lead to a displacement of the same effort to another area, with equivalent or increased bycatch risk. Otherwise, the bycatch might not be reduced at all, simply displaced geographically or at worse, increased[60,215].
- Even if displaced to a lower bycatch risk area, fishing effort can still cause enough bycatch to be problematic. It is therefore important to complement closures with other bycatch mitigation measures for the closure to be strictly beneficial. A potential example is to examine a combination of widespread pinger coverage and spatial closures for harbour porpoises, with both measures amplifying their individual benefits[118,120].
- **Closures, especially static closures can be costly as the displacement of efforts is not always homogenous, and fishers might be forced to reduce their effort**. While reductions in fishing effort are beneficial in the longer term, the short-term loss should be addressed, especially for small and medium-scale fishers that might not have the necessary capital to withstand a sudden revenue loss. Ideally, the fishers would have been involved in the co-management of the closures and could have been able to plan for this reduction in fishing effort. Regardless, relevant fishers should be supported in developing diversification pathways, including but not limited to pesca-tourism, rangers of Marine Protected Areas, algae farming, scientific trials or retrieval of ghost gear. This support is important to promote acceptance and compliance of the local fishing community, especially for small-scale. On the contrary, direct payments and financial support have been found to be ineffective in achieving their long-term objectives of bycatch mitigation as they do not address the root causes of the issue and do not lead to a durable reduction in fishing pressure[216,217]. Instead, fishers could be supported to build their own tie-up fund, a financial reserve set aside by the fishing business itself to manage periods of reduced fishing activity. Other government social schemes may be used as well, as necessary, to support incomes during fishing closures.
- Enforcing fishing closures in areas where the sensitive species are not present or at times during which they are absent can lead to ineffective measures with strong pushback from the fishing community[60,131]. Closures should be based on robust spatial data regarding the abundance and spatio-temporal presence of bycatch sensitive species**. In case of endangered populations, such as the Baltic Proper harbour porpoise, the precautionary principle is prioritised, and closures should be enforced as temporary measures while assessments are completed.**

Alternative low-impact fishing gears

Different fishing gear can have varied impacts on sensitive species groups, as mentioned in the introduction and illustrated in the overview Table 3. In the main fishing gears, gillnets are problematic because they exhibit high bycatch risk for all sensitive species groups. A mix of mitigation measures can be implemented to reduce the by-catch risk of gillnets in some circumstances, but if the gillnets are replaced with alternative fishing gears with lower bycatch risk, the bycatch will be further decreased or even eliminated in a few cases. The gear changing process can be easy if fishers are already using multiple gears on a regular basis. But it can also be a long one for fishers who used a single gear, particularly since the fishers should be trained and used to the new gear, while a study must assess the economic viability of the new métier.

Although it is a challenging strategy, there are success stories. Due to high levels of sea lion mortality in gillnets, the Australian Fisheries Management Authority (AFMA) implemented in 2010 a series of static and dynamic closures for gillnets, along with a requirement for 100% observer coverage (in-person or through REM)[213]. The AFMA in-centivised the gear change to longlines, as longliners were allowed to fish in static and dynamic closure areas and with a reduction of observer coverage from 100% to 10%[116]. A decade later, there was a 98% reduction in sea lion bycatch mortality, along with 95% of gillnet fishing effort being replaced by longline fishing effort[116]. Despite this gear change, the 2020/2021 total yield was extremely close to the 2009/2010 yield, before the new management measures were implemented. The 2022 review study did state that although management measures were successful, gear switching created challenges to fishers due to modification and increased operational costs[116]. Those increased costs were likely one amongst several factors for 27% of fishers who sold their vessel in a government buyback scheme between 2005 and 2015[116,218]. When applied to EU waters, the Mediterranean provides good opportunities for testing and implementing change of fishing gears for small-scale fishers at the EU level.

Important considerations:

- Before changing to a new gear, there must be an impact study that evaluates the economic viability of the alternative gear in the targeted area and stock.
- It is important to make sure that changing gears does not displace previous fishing effort onto another stock or target species and threaten its viability. If a fleet of gillnetters change to pots and start targeting lobsters, their added fishing effort on top of the effort of the historical pot fishers might cause the lobster stock to collapse.
- Due to gear changes, the fishing area or target stock might change for certain fishers and conflicts of interest with previous historical users might arise.
- Changing gear is expensive and small-scale fishers that do not have the necessary capital should be assisted in doing so[196].

Interactions between mitigation measures

When considering bycatch, it is essential to keep in mind that there is no magical solution for mitigation and elimination. It is by nature a complicated issue, since a mitigation measure that might be effective for one species in a particular métier might be inefficient or detrimental for another species in the same métier[219]. To illustrate, the implementation of a wider type of hook, called circle hooks, in pelagic longlines reduces the bycatch rate of leatherback turtles by up to 63% and reduces the severity by hooking turtles in the mouth rather than in the gut or oesophagus[219]. However, it can also increase the bycatch of sharks up to 20% when compared to the standard J hooks, while still decreasing the mortality[220]. The use of circle hooks in pelagic longlines is a great example for bycatch mitigation because while it is still beneficial overall, it has a trade-off by causing increased shark bycatch that should be accounted for[86]. **As such, bycatch mitigation measures cannot be focused around one single measure, species group or métier and should be instead considered as a matrix**. As Gilman put it, “bycatch mitigation should not be about robbing Peter to pay Paul and should instead be a wider integrated process”[219]

While certain measures might be antagonistic or neutral, some are also able to have synergies. Spatial closures, either dynamic or static, tend to enhance the benefits of other bycatch mitigation measures. For example, the combination of spatial closures and the use of pingers proved much more effective in mitigating bycatch of harbour porpoises and increasing their abundance than pingers alone[118,120]. Indeed, the added sound pollution due to pingers can displace dolphins or porpoises of key habitats if the pinger coverage is quite high[118,120]. However, protecting this key habitat through a static closure can shield it from the pinger noise pollution, making both measures complementary[118,120]. Fishing closures in Australia not only protected key habitats and spawning grounds but did also help support a transition from gillnets to longliners, reducing sea lion mortality by 98% over a decade[116,218]. On the contrary, poorly informed fishery closures in another Australian gillnet fishery with no additional mitigation measures are not preventing the further decline of the local sea lion population[116]. **The main takeaway from this section should be that not one measure is perfect and there is no silver bullet. Measures must be taken in complementarity to tackle bycatch efficiently.** They must be adjusted in combination with other technical solutions or reduction in fishing effort, while being adapted to reality of the sensitive species, métiers and socio-economic context of the area.

Process to address a bycatch issue

This section describes a non-exhaustive process on how to address a bycatch issue, from start to finish, using general concepts that can be tailored to their local and temporal context. **This process is a lengthy one and the multiple steps should not be used as a reason to delay a bycatch mitigation strategy, especially in the case of major bycatch mortalities or if the strategy is focused on endangered populations.** They simply offer a sample of all the decisions and mechanisms that should be included in an effective bycatch mitigation strategy. Co-management is described in more details in its own section.

Identification and characterisation of the bycatch issue

The first step of addressing a specific bycatch issue is realising that there is an issue in the first place. The initial identification that there is a potential bycatch issue can be prompted by one or multiple sources amongst the following:

- **Existing monitoring programs:** Existing monitoring programs, which include deployment of at-sea observers and/or Remote Electronic Monitoring (REM) systems, will feed bycatch data to the relevant national authorities, which are usually the fisheries management and the environmental protection authorities. This data should then be communicated to the EU through existing regular reports, such as in the framework of the MSFD, the Marine Action Plan or the Habitats Directive. Research organisms such as ICES can also put out calls for evidence, asking states to share their bycatch records.
- **Direct interviews with fishers:** These interviews, also called rapid assessment surveys, are short interviews with fishers that are designed to estimate bycatch numbers for certain species and as well as the context associated with bycatch events. Fishers are first promised by consultants or researchers that the data is anonymised and then ran through a questionnaire that estimates the scale of their bycatch interaction, and the conditions linked to those encounters.
- **Self-reporting by the fishers:** Fishers can be affected by causing or witnessing bycatch and may decide to come forward, as long as there is a relation of trust with management authorities. It is also in the fishers' interest to address a bycatch issue, and they will likely be willing to do so if there are no consequences to self-reporting, such as fines or reduction in fishing opportunities. Self-reporting numbers are not robust enough for management decisions, but they can be useful to identify a bycatch issue and kickstart proper monitoring.
- **Analysis of stranding records:** When analysing stranded mortalities of sensitive species, it can be possible to detect physical signs of bycatch wounds on the animal, at first sight or through necropsy. The estimated time and cause of death can then be crossed with environmental conditions (ocean currents, winds, wave height) to extrapolate mortalities.

This preliminary identification of a bycatch issue should be crossed with existing bycatch assessments or bycatch mortality thresholds for the concerned species or populations. If there are none available, there should be an assessment and development of mortality threshold, urgently in case of a threatened population or a large-scale bycatch issue. Research bodies such as ICES, the STECF or the JRC can be contracted to conduct this in-depth assessment. It is necessary to properly characterise the local context and its relation to the bycatch dynamics, an essential step to develop an effective mitigation strategy. **If the situation has been assessed as urgent, as is the case with the Baltic proper harbour porpoise, action should be prioritised over further monitoring**. Due to the population being critically endangered, monitoring programs are unlikely to be effective and will only delay the implementation of necessary mitigation measures.

Development of a mitigation strategy

Once a bycatch issue has been identified and its dynamics are understood, at least partly, the next step is to develop a mitigation strategy to efficiently deal with said issue. The strategy should include a combination of different mitigations measures, as no single measure can address a bycatch issue on its own. Ideally, the strategy should combine technical measures focused on the actual use of the gear, with measures touching on the fishing effort and its spatiotemporal distribution. Mitigation measures should also be tailored to the local context in terms of:

- **Target species**: the mitigation measures should be considered to minimise the impact on yield of the target species while eliminating bycatch or reducing it to the greatest extent possible.
- **Bycatch species and their dynamics**: mitigation measures should be chosen to reduce bycatch for all sensitive species involved and if not possible, reducing the harm caused to other species to the maximum while still mitigating bycatch for the species most impacted. Not all mitigation measures are effective for every species and an effective bycatch mitigation strategy should reflect this. Bycatch species may also have dynamics which should be considered, such as season presence in breeding or feeding grounds and migration routes.
- **Métier(s) and compatibility with fishers:** One or multiple metiers can be involved in a bycatch issue at similar or different levels depending on the species or the season. Different métiers have widely different technical measures, which should be adapted to the specificities of the métiers considered. If possible, fishers should be included in the decision-making process through co-management and should be able to give advice on their preferred mitigation measures, provided they are proven to be efficient at reducing bycatch.
- **Synergies and complementarity of mitigation measures:** Measures should be taken in complementarity, as no single measure can be a silver bullet. A good example is that the use of pingers in a wider area, paired with a fishing closure area in which pingers are not allowed, enhances the conservation and mitigation benefits of both measures.
- **Local marine ecosystem(s) and ocean dynamics:** The local marine ecosystem can have physical properties, such as depth, composition of seafloor, ocean currents and temperature, which should be taken into account when choosing mitigation measures.

Assessment of implementation pathways

Once a mitigation strategy is tailored to the local context, the step is to assess the different pathways to maximise its effectiveness and widespread implementation. The implementation should take into account several local factors:

- **Structure of the fishing industry:** building on the analysis of the métiers involved in a bycatch issue, it is important to consider the organisational structure of local fishers and the composition of said structures. Fishers are usually regrouped under local guilds or cooperatives, which can then be part of bigger organisations at the regional or national level. These structures can be powerful vessels for widespread implementation or to the contrary, widespread opposition to bycatch mitigation strategies.
- **Socio-economic context:** Fishers throughout the EU can have widely different socio-economic realities depending on their métiers, state of their target fish stocks, national economies and individual opportunities. Implementation pathways must take these differences into account for the mitigation strategy to be properly implemented.
- **Cost of the mitigation strategy and associated funding mechanisms:** Bycatch mitigation measures will have a price, which will usually include the initial implementation, maintenance and enforcement costs. While mitigation measures must not be decided on cost efficiency and must instead be based on welfare and conservation considerations instead, cost for fishers and other stakeholders should be reflected implementation pathways, especially for small-scale low impact fishers with little to no capital. Funding should be easily accessible, related to binding bycatch mitigation obligations and could come from regional, national or European funding schemes. The EMFAF is an example of a European fund, which could cover costs related to technical bycatch mitigation measures as well as bycatch monitoring schemes. EU funded projects focused on bycatch might also have earmarked funds for bycatch mitigation research or implementation that could be used.
- **Stakeholder dynamics:** Bycatch issues are famously complicated when it comes to dynamics with stakeholders, as well as between them. There should be careful consideration when balancing the interests of all stakeholders involved, including between stakeholders of the same type. Different government branches or fishers' guilds might also have conflicting interests on bycatch mitigation measures and their implementation pathways.
- **Existing national and international regulations:** While Member States are subject to the different regulations at the EU level, they do have some flexibility in how they implement those regulations at the national level. Implementation pathways for a bycatch mitigation strategy should be coherent with the national regulations and bureaucratic process.

Actual implementation of the bycatch mitigation strategy

The implementation itself can take multiple paths, which can include some or all of the following steps:

- **Inclusion of the strategy of the regulation framework and adapting of regulations if necessary**: Existing frameworks, either at EU level (CFP, Technical Measures Regulation, the Habitats Directive) or at the member state level should be used to implement and enforce the binding requirements set out in terms of bycatch monitoring and mitigation. If the existing framework is not an appropriate lever for implementation (e.g regulation not including a certain area, species or species group, métier or vessel length), it should be adapted in order to reflect that and provide legal and institutional tools for implementation and enforcement.
- **Utilisation of EU funded projects:** Certain EU projects are focused on bycatch monitoring and mitigation (CIBBRiNA, REDUCE, Marine Beacon) and provide multiple useful deliverables such as ID guides, bycatch mitigation toolkit, reference points, and socio-economic analysis. An added benefit is that these projects tend to include EU stakeholders and respect EU regulations, making them easily applicable.
- **Co-management with local fishing communities:** Integrating fishers in the implementation dialogue will increase the likelihood of compliance and collaboration, as opposed to an unexplained top-

down approach. Fishers will also be a valuable resource into the advantages and shortcomings of the implementation process, which could jeopardize the whole strategy if done improperly.

- **Creation of enforcement mechanisms and penalties:** Regardless of the situation, any implementation strategy should include enforcement and penalties, which are necessary for all actors to act in good faith. This can include routine control operations by enforcement authorities as well as fines or reductions in fishing opportunities for actors who actively not cooperating. The intensity of these measure will depend on the degree of compliance by all parties involved.

Evaluation and adaptation

Once a bycatch mitigation strategy is implemented, real-time monitoring and feedback are important to quickly detect any major issues and assess efficacy. This is particularly important in situations with major bycatch mortalities and when the strategy is focused on an endangered or critically endangered populations. Short-term evaluations can include :

- **Yearly analysis of bycatch monitoring data** : Time-series of bycatch data after the implementation of the strategy could be crossed with pre-implementation numbers.
- **Direct contact with fishers :** Discussions with primary actors can provide on insight on the efficiency of the strategy and where it might be lacking. For example, a technical adaptation of the gear might be malfunctioning or causing loss of target catch, leading fishers to avoid adopting them. Issues can arise in terms of funding, acceptance by fishers, assistance by the local or national fisheries management authority, etc...
- **Assessing the funds distributed :** If a strategy included funding mechanisms for multiple mechanisms (research trials, diversification support for small-scale fishers,), the distribution funds can be a useful proxy to assess its implementation. If the allocated funds quickly run out or if on the contrary, target actors struggle gaining access to the allocated funding, there is an issue which needs to be solved.

Once immediate issues have been identified through real-time evaluation and addressed, the mitigation strategy should be allowed to run over months or years (duration dependent on the strategy) without constant modifications. Once a sufficient amount of time has passed, a formal policy evaluation process can be completed through:

- **Scientific evaluations:** Evaluations by the relevant scientific bodies (ICES, STECF, JRC) can evaluate in detail the whole process of the bycatch mitigation strategy, focusing on its results and identifying weaknesses. These shortcomings, especially if they are major, should be included in the adaptation of the mitigation strategy.
- **Public consultation:** This process, which can be run at a local, national or EU level, is an important tool to understand the different perspectives of all stakeholders on the implemented bycatch mitigation strategy, as well as their recommendations.

Photo: ©Lena Hohls

Co-management and the inclusion of fishers in the dialogue

Bycatch mitigation is at heart a complex issue because fishers do not want to cause bycatch and mortalities of sensitive species. Bycatch tends to happen because it might not be enough of an issue for individual fishers to cause a change in their behaviour. Indeed, an individual fisher or vessel might be very rarely involved in bycatch episodes[105,195]. Therefore, bycatch mitigation measures that are not designed with the involvement of fishers can be viewed as unfair collective punishment by the local fishing community. Certain mitigation measures, although effective at reducing bycatch, can be inappropriate to the local context. As fish stocks have been declining, the low yields of small-scale fishers have led to lower revenues. This low income, considering that most small-scale fishers own their vessel and are their own source of capital and income, does not allow for strong reductions in yield or self-funded bycatch mitigation measures. As such, co-management schemes should involve mechanisms for fishers most in need in order to support diversification in cases of yield reduction and to provide financial support earmarked for implementation of technical mitigation measures.

Without the understanding and acceptance from the fishers, mitigation measures would need to be complemented by strong enforcement and penalties, which can be expensive and difficult to enforce. Enforcement and penalties should always be integrated into a mitigation strategy regardless, but their scale will be dependent on the degree of compliance of the affected fishers. With these considerations in mind, co-management is an important solution to integrate fishers into the designing and implementation process of a bycatch mitigation strategy. Early integration into the decision-making process allows fishers to feel acknowledged and considered, making them allies rather than antagonists, in addition to greatly increasing the probability that any measures brought forward are practical and appropriate. Through allyship, the local fishing community can champion bycatch mitigation and conservations efforts, drastically reducing the scale of oversight and enforcement needed. **The underlying condition of a successful co-management scheme is that**

the bycatch mitigation strategy is a binding obligation rather than an option. It has to happen, and fishers are given the opportunity to be involved in the co-management of how it should happen. Despite all the advantages that co-management can offer, enforcement and control are still important to ensure that mitigation measures are implemented and that regulations are respected over time.

The 2022 publication of BirdLife Europe & Asia, in the framework of the MedBycatch project, brings insights from co-management with fishers throughout the Mediterranean and European waters[221]. It provides an overview of the different approaches and levels of co-management, as well as a description of processes, which are then illustrated using existing examples.

Gear libraries

Gear libraries are an innovative approach when it comes to co-management for bycatch mitigation. Currently in place in the United States and Canada, research organisms or state administrations allow fishers to rent out innovative fishing gears free of charge[157,158,222,223]. As the existing gear libraries are focused on reducing whale entanglement in pots, they currently offer "on demand" systems that eliminate the buoy line in which whales can get tangled. Fishers are encouraged to apply and if successful, they can rent out the gear for a period up to three months free of charge under the condition that they provide scientific data and user feedback[223]. The Maine Department of Marine Resources even compensates fishers for the lost fishing time due to gear testing, training or research day[157]. Using this data, scientists, gear manufacturers and decision makers can then implement mitigation measures that have been trialled and approved by fishers, backed up with extensive trial data[224]

Fishers affected by fishing closures due to whale entanglements are prioritised, as fishers equipped with on-demand systems on their pots have derogations to maintain their activities in the closure areas[158,224]. Indeed, on-demand systems have the potential to strongly reduce or fully eliminate entanglements in pots and therefore are allowed keep fishing[224]. The system has been accepted by part of the fishers, as the CanFISH library has trailed a dozen different systems with 16 crews, totalling a 1000 deployments at sea[225]. The NOAA gear library offers more than 500 on-demand systems, working with around 60 fishers across 5 states and three fisheries[224,226]. The gear library approach allows fishers to try out innovative bycatch mitigation measures at no-cost, while providing their input and feedback before said measures or gears are implemented through regulation[227]. They also have the benefit of being cheaper than purchasing gears for individual fishers, since the loaning system allows for widespread use. While this system is currently only in place for on-demand system for pot fisheries, it could be applied to general fishing gears. This could allow a gillnetter to get familiar with another gear causing less bycatch, such as pots or longlines, without having to make an economic commitment. It would however be important that fishers are consulted on the types of gears and materials available before purchase, as this makes gear libraries a co-management process rather than a purely consultative process.

Case study: Collaboration and future co-management with Scottish creel fishers to reduce whale and basking shark entanglements

In Scottish waters, small-scale fishers target *Nephrops norvegicus* (prawn) crab, (brown and velvet) and lobster with creels, which is a local name for pots. Creels are joined together in a string (a fleet), with the number of creels in a fleet generally ranging from 10 to 60 connected by a groundline. This groundline between creels is usually floating rope, which creates loops in the water column between creels that can be several metres high and entangle whales and basking sharks. Entanglements in groundline comprise around 80% of basking shark and minke whale entanglements in Scottish creel gear, and 50% of humpback entanglements (an estimated annual entanglement rate of 6 humpback, 30 minke whales and 29 basking sharks[104,105]). The Scottish Entanglement Alliance (SEA), a partnership of governmental, NGO, research and industry groups, has been addressing this issue. One suggestion from fishers interviewed by SEA was to trial sinking groundline as an alternative to floating groundline to remove the loops of rope and therefore reduce the entanglement risk. (S. Calderan, interview, April 2nd 2025). Through co-management with the fishers, the practicality of sinking groundline was trialled. The trials involved 15 prawn and crab fishers around the northwest of Scotland and Isle of Skye, testing whether sinking groundline was functional and efficient for them. Trial rope was purchased with dedicated national funding and fishers were given a small payment for each fleet re-rigged with sinking groundline, of which 60% was given at the beginning of the trial and 40% at the end of it. Overall, 61 fleets were re-rigged with sinking groundline and the official trial lasted for 15 months in 2023-2024, for a total of 1545 data-backed hauls[105], although all the gear is still currently in use at the time of this report. The gear trials were complemented with the deployment of depth/movement sensors and observations with a Remotely Operated Vehicle (ROV) to gather more qualitative and quantitative data on the behaviour of creels and rope, both floating and sinking, when on the seabed. Sinking groundline was shown to have negligible impact on the seafloor, which might even lower when compared to floating groundline, as the creels can move around less on the seabed.

Overall, the trials were a success, and fishers were satisfied with the sinking groundline, in that it was not very different to using floating rope and it could even be beneficial in some cases since the creels moved less on the seabed. An essential aspect of those trials is that fishers were motivated to engage with the entanglement issue, and it was their mitigation suggestions which were trialled. They were also consulted throughout the process, testing whether this mitigation measure would be practical for them. The trials are effectively still ongoing as the fleets rerigged with sinking groundline are still used on the 15 vessels. Following this trial (which was limited in its temporal and spatial scale), workshops have been run around the Scottish coast to present the results of the trials to other fishers, with at least one original trial fisher present at each workshop to engage with local fishers and answer technical questions. The workshops provided a forum for fishermen to discuss their experiences and concerns and input into the ongoing engagement process. Workshop attendees were also offered a fleets-worth of sinking groundline to trial for themselves free of charge and there are now a total of 60 vessels trialling sinking groundline throughout Scotland, in different conditions and setups than the original trial (S. Calderan, interview, April 2nd 2025). The next step for the project is conducting a socio-economic analysis focusing implementation options and funding. Fishers will then be consulted through a series of workshops on their preferred implementation and funding pathways (S. Calderan, interview, April 2nd 2025). This will result in recommendations on implementation to the Scottish government, which is legally obliged to take measures to reduce entanglement[228]. The outputs of the project will be non-binding but the government has included co-management in its 2030 fisheries management strategy[229]. Extensive information about this research and co-management process can be found in journal articles and published reports[104,105,107,230].

Guidelines for successful co-management[p]

Do's

- Engagement must be genuine. Ask fishers what they advise rather than telling them what is going to happen. If fishers can only choose between options, you have already restricted the potential for collaboration, and they will be less motivated to be involved. Use a local facilitator or consultant who is familiar to the fishers and can introduce the project informally. This soft introduction will make it likelier that fishers participate in a more formal workshop.
- Be respectful of fishers' time and work around fishers' schedules and time constraints. Meet fishers when it is most convenient for them and travel to them, instead of the opposite. One afternoon where they're not fishing is one afternoon where they're not earning.
- Identify "champions" within the local fishing community, who can discuss participation with other fishers. An informal leader and expert can help break inertia and put the co-management process on track.
- If possible, provide a gear library system for fishers to get used to gear modifications or alternative gears. Ask fishers the gears they would like to test instead of providing an existing selection.
- Include an enforcement or penalty system, which is designed to keep all actors acting in good faith. Effective and long-term collaboration can only work if actors are penalised for not respecting the agreed rules.

Don'ts

- Mitigating bycatch should be framed in terms of solutions rather than problems. Do not use strong wording that condemns fishers as people responsible for bycatch. Co-management is about collaborating with fishers against a bycatch issue, not against fishers.
- Do not use one way communication when engaging fishers. Talk with fishers rather than talking at them and make their input is acknowledged.
- Do not consider fishers as foes or as a challenge to deal with. Fishers are important sources of local ecological knowledge and can provide very valuable inputs.

Consultation during one single step is not co-management. Fishers should be included in designing practical and appropriate solutions but this inclusion should not hinder the implementation of a bycatch mitigation strategy.

p The following advice was gathered through interviews with Biancia Cisternino and Susannah Calderan from Whale and Dolphin Conservation (WDC), which were involved in the present case study for co-management and have extensive practical experience on co-management with fishers.

Regulations, implementation tools and funding

Published reports have focused extensively on evaluating EU regulations in regard to bycatch, their performance and how they could be improved:

- The 2025 Environmental Investigation Agency report provides an overview of cetacean bycatch in European waters and associated recommendations[231]
- The 2022 BirdLife report provided an evaluation on the progress of bycatch mitigation for sensitive species in the EU. It also gave recommendations to Member States and to the Commission on improvements and paths forward[232]

Additionally, the EU has funded and continues to fund multiple projects on bycatch monitoring and mitigation. They are similar in their objectives and structure, as they aim to improve the knowledge about bycatch monitoring and mitigation, integrating various stakeholders and make policy appropriate recommendations. Their differences are mainly in their geographical focus, the fishing métiers and fleets as well as the stakeholder constellation. Outputs from these projects can be valuable to inform management decisions about bycatch mitigation and should therefore be regularly monitored for deliverables.

Photo: ©Henning Kunze

The projects are namely:

CIBBRiNA is a LIFE-funded project running from 2023 – 2029, which integrates fisheries, management authorities, scientists and civil society (with Seas At Risk being a CIBBRiNA partner). It is currently in its early phases but should publish interesting deliverables, including reference points for bycatch mortalities of sensitive species and bycatch mitigation toolkits applicable to EU waters and regulations. It is divided in 6 work themes that each touch on a different aspect of the bycatch issue.

- Budget: 12 million € total, with 8 million € from LIFE funding (LIFE22-NAT-NL-LIFE-CIBBRiNA/101114301)
- Geographical area: North Atlantic, Mediterranean and Baltic
- Métiers included: Gillnets, deep-water longlines, pelagic longlines, pelagic trawls and bottom trawls
- Covered species groups: Marine mammals, seabirds, turtles and elasmobranchs

Marine Beacon is a Horizon-funded project (Project ID 101135237) running from 2024-2028, with a similar approach to CIBBRiNA, with the difference is that it focuses exclusively in the North Atlantic and is less diverse in its stakeholder range, with a focus on research institutions and selected industry partners. It also works on a case study basis, covering 7 regions (including the Bay of Biscay) and focusing on one or multiple bycatch-sensitive species.

- Budget: 9 million € from Horizon (Project ID 101135237)
- Geographical area: North Atlantic, including the high seas and covers EU and non-EU waters. On top of North Atlantic EU waters, it includes Greenlandic, Icelandic waters as well the Areas beyond National Jurisdiction.
- Covered species: The species coverage is dependent on the case studies, but the range covers marine mammals, seabirds, sea turtles, elasmobranchs and cold waters corals, with the last not being covered in the other projects.
- Métiers included: Bottom trawlers, demersal and pelagic longliners, gillnetters, handlines and purse seines

REDUCE is an 8 million € Horizon-funded (Project ID 101135583) project running from 2024 – 2027, with a majority of stakeholders being research institutions, along with a few NGOs and private company, focusing on the Eastern Central Atlantic Ocean. It focuses on the bycatch impact of the EU fishing fleet in this ocean basin and the appropriate bycatch mitigation pathways.

- Budget: 9 million € from Horizon (Project ID 101135237)
- Geographical area: Eastern Central Atlantic Ocean, including tropical waters and the Gulf of Guinea
- Métiers included: Pelagic trawlers, purse seiners, drifting pelagic longlines and bottom trawlers, all vessels having flags from EU countries.
- Covered species: It depends on the métier studied but the range covers marine mammals, seabirds, sea turtles and elasmobranchs.

Improving the Technical Measures Regulation

The objective of the 2019 TMR was to harmonise all existing bycatch mitigation measures (including for fish) across different regulations and pooling them together in one overarching regulation. As such, it integrated multiple components of the Council Regulation 812/2004 on the incidental catch of cetaceans in fisheries, namely monitoring requirements, the implementation of gillnet closures and the technical specificities for pingers. That does however pose a problem, as existing criticism of the 2004 regulation by ICES, ASCOBANS, STECF and others was not integrated during this overhaul[233–236]"

As advised on several occasions, the requirements for bycatch monitoring and mitigation should be centred on the gear specific fishing effort (length of gear in use, number of hooks or pots, soaking time) and the areas it takes place in, instead of solely on the length of the fishing vessel[19,234,237] The STECF advises instead that the pinger requirements not be based on fishing effort or area, which are arbitrary requirements that might be inappropriate but rather on bycatch risk[236]. The specific advice and solutions differ based on the source (ICES, STECF or Rogan et al) but the sources agree that monitoring and mitigation measure requirements based on vessel length are inefficient [19,236,238]. Indeed, the TMR currently requires gillnetters in the certain area of the Baltic and ICES divisions to use pingers, but only if they are above 12 meters. This is inconsistent with the reality as 94% of gillnetters in the EU are under 12 meters and therefore not covered by the regulation[238].

When it comes to monitoring, cetacean bycatch monitoring under the TMR is only required for certain vessels above 15 meters, which is inconsistent with 76% of the EU fishing fleet being under 12 meters in 2022[21]. Under current EU regulations, vessels under 15 meters are not required to carry electronic reporting systems, such as electronic logbook or VMS. This will however change with the newer Control regulation (EU/2023/2842) and by 2028, vessels under 12 meters will be required to have VMS installed and report electronically. At the time of writing, there is however no clarity about the possible evolution of bycatch monitoring and reporting requirements once the electronic reporting requirements for smaller vessels are rolled out. The TMR also does not provide any explicit threshold for bycatch mortalities, which could be important lever for the Commission and Member States to implement mitigation measures.

Exclusively on mitigation measures, the enforcement rules of closures and pingers have been transferred over without any changes from the regulation 812/2004 to the TMR and its associated regulations such as EU 2020/967. This is problematic as the requirements and enforcements for pingers and closures were found to be improvable or at worse, inappropriate[196,236]. The STECF states that the requirements for pingers in terms of gears and areas was inappropriate, with high pingers use in métiers with low bycatch and low pinger use for métiers with high bycatch. There is one pinger enforcement rule based on gear length in the North Sea, with pingers being only required for bottom gillnets and entangling nets with a length lesser than 400 m. This creates a loophole where gillnets can just be extended past 400 metres in length and avoid being subjected to the pinger requirement[117,236]. The same pinger requirement is also only seasonal despite evidence of the harbour porpoise being present year round in the encompassed area[117,236].

As for the technical specifications of the pingers set out by TMR, they were brought over from the regulation 812/2004 despite previous issues. The spacing between each pinger required by the TMR is 100 or 200 meters, which is best for bycatch mitigation but can lead to increased costs and malfunction probability[239]. Spacing of 400 to 500 meters was found to still be proficient at mitigating bycatch if the noise level is increased by 10 dB, reducing by half or more the numbers of pingers that should be purchased[110]. Additionally, the required sound specifications for pingers (frequency, tone, pulse interval) makes them mostly efficient for harbour porpoise mitigation but not particularly for other species[236]. The Commission did however integrate part of the STECF advice on technical specifications for pingers. Under the TMR associated EU regulation 2020/967, Member states now have the possibility to have a derogation for pingers that do not fit TMR requirements but have been proven to be at least as effective, which allows better research and development compared to regulation 812/2004. The previous regulation had a similar derogation mechanism but the derogation was only applicable for a period of two years and required continued renewal, which limited funding and research opportunities[236].

In short, the Technical Measures Regulation goes in the right direction but has multiple caveats and loopholes that prevent it from being truly effective at reducing bycatch. By incorporating the multiple improvements suggested by ICES, the STECF, ASCOBANS/ACCOBAMS and independent scientists, the TMR can really become a powerful tool to drive bycatch reduction and elimination in EU fisheries.

Incentives for implementation

While bycatch is a pressing environmental issue, it can be episodic or rare for the individual fishers and bycatch mitigation can be considered much lower priority for small-scale fishers compared to other elements (Camille Richer, interview March 19, 2025). In some case, certain fishers might be motivated to find solutions but as mentioned in the section on co-management, bycatch mitigation is a binding requirement, and non-compliance should result in penalties. The binding requirements should be complemented by incentives in order to have effective widespread participation and implementation. Once a set of bycatch mitigation measures has been through a test phase and been proven to be applicable and effective in the associated context, the next step should be a socio-economic analysis. This type of analysis should be conducted through consultation with the affected fishers and should focus on the economic issues associated with the mitigation measures, as well as the appropriate incentive mechanisms. It should however be made clear that the bycatch mitigation strategy is a binding obligation rather than an option. It has to happen, and fishers are then given the opportunity to be involved in helping design the implementation process and its associated incentives.

Incentives should be supportive, as acceptance and collaboration from fishers leads to better implementation but these should still be complemented by penalties for non-compliance[195]. A research report for the PECH Committee of the EU Parliament provides an overview of incentives applicable for bycatch mitigation in the EU, which may take different forms depending on their methods, objectives and local context[195] :

- Using groups dynamics by supporting and uplifting sustainable fishing practices amongst fishers. This can take the shape of communication campaigns, which aims to foster pride amongst fishers or through investments in increased transparency and traceability schemes. Traceability allows fishers to better market their catch and increase their revenue without a price subsidy, while fostering soft competition to encourage more reticent fishers.
- With regulatory trade-offs, restrictive measures can be designed to be complemented by an alternative incentive. In the case of the fishing closures for gillnets, fishers can still be allowed to fish in the restricted area if they switch to another fishing gear with less bycatch risk.
- Conditional incentives for fisheries that value best practices and bottom-up approaches.

One existing solution not included in the research report by Fauconnet is the inclusion of bycatch mitigation measures in funding applications made by fishers for other elements they have more interest in. Fishers could be in search for funding for elements that diversify their livelihoods, such as improved inclusion in the value chain or for quality of life refitting of existing vessels (e.g improvements that do not increase fishing capacity, such as guard rails for security, coverage from the sun or an on-board toilet). Bycatch mitigation measures should be a section of the process where fishers can make their application more favourable when include bycatch mitigation. In the spirit of co-management, fishers can choose amongst offered options or suggest alternatives that have been proved to be efficient and are appropriate to their métier and socio-economic context. This would also allow national fisheries authorities of Member States to support their fisheries while simultaneously addressing the bycatch issue and working towards their Good Environmental Status MSFD targets.

Additionally, the report only brushes on the possibilities offered by the Article 17 of the EU Common Fisheries Policy. This article states that fishing opportunities (quotas or fishing days) should be allocated by Member States to their fishers based on environmental, social and economic criteria. It also states that “Member States shall endeavour to provide incentives to fishing vessels deploying selective fishing gear or using fishing techniques with reduced environmental impact". Article 17 can therefore be a powerful tool for the implementation as a higher proportion fishing opportunities can be allocated to the fishers who proactively implement bycatch mitigation measures. Article 17 has however been rarely, if at all, been used to address bycatch in EU fisheries. There is however an existing example of fishing opportunities allocated under similar conditions than article 17, discussed in the following case study.

Case study: Quota allocation in the Patagonian toothfish fishery based on bycatch mitigation effort

Fisheries covered by French Southern and Antarctic Lands, more commonly known as TAAF, are subject to a strict management plan developed by French national authorities. Although TAAF waters are national waters and belong in the French EEZ, France has voluntarily submitted to the regulations of the RFMO covering Antarctica and its surrounding waters, the Convention on Conservation of Atlantic Marine Living Resources (CCAMLR). As an effort to reach conservation targets set by CCAMLR, the TAAF authorities have implemented a strict management plan for its fisheries, namely for the longline fishery targeting Patagonian toothfish *Dissostichus eleginoides*. The TAAF have two different quotas pools, with one quota pool for the EEZ of the Kerguelen archipelago and another quota pool for the Crozet archipelagos. The quota amounts are different, as the populations are considered separate, but the majority of the management plan rules apply to the two EEZ.

The 2019-2025 management plan for the Patagonian toothfish included 20% of Total Allowable Catches (TACs) to be allocated based on bycatch criteria for rays and seabirds. Bird bycatch had to be kept under 5 birds for a million hooks in order to access 4.5% of the quota. This TAC proportion might seem small but the 2019-2020 TAC for both EEZ was 7000 tons, with 270 tons being allocated according to the bird bycatch criteria. Considering that the export of Patagonian toothfish from the TAAF had a value of 115 million € in 2022, the economic benefit of accessing this seabird bycatch related quota is a very effective incentive to implement mitigation measures[240]. The previous management plan from 2015-2019 was greatly successful in reducing bird bycatch thanks to a similar quota allocation system and these reductions were maintained but not further encouraged. On the contrary, the 2019-2025 management plan intended to actively reduce ray bycatch and therefore had a much higher pool of 990 tons for allocation. In order to access this quota, the criterium was that ray bycatch had to be consistently reduced (5% yearly reduction in Crozet, with a target of 25% reduction over 6 years; 20% reduction every 2 years in Kerguelen, with target of 50 % over 6 years). The draft for the 2025 – 2029 management plan does still include the same bird and rays bycatch criteria, but these are now weighed on a point-based system rather than through specific TACs. Although a 2019 evaluation of 2015 – 2019 management plan argued that the bycatch criteria should also include a negative quota system if bycatch goes over certain threshold, it stated the improvements were there and should be maintained[241].

Funding mitigation measures

Effective bycatch mitigation measures can face challenges if implementation did not consider appropriate funding pathways. Small-scale fishing vessels are usually owned by small families or one physical person, usually with limited profit margins. Their income, considering that most small-scale fishers own their vessel and are their own source of capital and income, does not tend to allow self-funded bycatch mitigation measures. In the GFCM area, which encompasses other non-EU countries around the Mediterranean, the remuneration of small-scale fishers is half what industrial fishers earn[48]. Fishers, especially small-scale, may have little capital to invest.

The low capital available for fishers is an issue since it is mismatched with the functioning of EU and national funding schemes. To illustrate, the European Marine Fisheries and Aquaculture Fund (EMFAF) is the main funding mechanism associated with fisheries in the EU covering the period 2021 – 2027. Grants from the EMFAF are reimbursements, meaning fishers receiving EMFAF grants must first spend the initial money and wait for reimbursements, which can take up to 1 year (Camille Richer, interview March 19, 2025). But since certain fishers might not have that initial capital to spend and might be unable to wait for the EMFAF reimbursement, they are in effect unable to access EMFAF funding.

This mismatch in funds and timing was the reason behind the creation of certain initiatives, such as the BlueMove[q] fund from BlueSeeds and WWF in 2022. BlueMove[r], with an operational grant from the MAVA foundation, was able to support small-scale fishers in Croatia, Cyprus, Greece and Portugal in accessing EMFAF funding[242]. The assistance was:

- Technical: Hiring one or multiple local consultants that were familiar with fisheries, national administration and application processes for EU grants. These consultants were then tasked with assisting fishers to navigate national processes for grants applications and facilitate general coordination.
- Financial: Using money from the grant, BlueMove was able to act as collateral for local banks, which could then provide low interest loans to the fishers once the EMFAF application had been accepted. Fishers could then invest the bank loan in their activity and reimburse the original loan once they receive the EMFAF grant.

As part of the assistance, bycatch mitigation measures were included in the application for the funding. They were part of the funding package and a requirement. This project, which still runs at time of writing, bridges a big implementation gap which should be the responsibility of other actors, including the Member States. Portugal, as part of its Mar 2030 strategy, is offering a 10% direct payment for the total value of the EMFAF grant allocated to an individual or project[243]. While this is a step in the right direction and should be celebrated, the issues about the financing gap remain. Any project aiming to reduce it should consider the following:

- EMFAF money is distributed through Member States, with each having their applications processes, requirements and funding cycles. The first element is tracking down the organism or people in charge of EMFAF funding at the national level, which might prove to be time consuming. The list of national authorities in charge of EMFAF funding can be found here, despite some information already being outdated. Not all countries offer continuous EMFAF funding and might do so according to cycles, which should be considered before developing an application.
- Local consultants that can be involved in the process should be knowledgeable in fisheries, since they should understand the underlying business models and regulations. This is important to gain trust with fishers, which may already feel discouraged by previous approaches not being tailored enough to their needs and contexts.
- Banks that have previously worked with fisheries might be keener to provide loans to fishers, especially if they are more familiar with EMFAF funding. In certain cases where quota can be traded, banks might accept to use quota allocated to the recipient of the loan as a collateral and loan out the money to fishers, despite their little capital.

Additionally, the multiple EU-funded projects (CIBBRiNA, Marine Beacon and REDUCE) have a combined budget of about 30 million €, with those projects having work packages dedicated to bycatch mitigation research or implementation. As such, they could also be an interesting source of funding for trialling innovative mitigation measure or testing out implementation for existing ones.

q The information gathered in this section was consolidated through an interview with Camille Richer, Environmental Fund Manager for BlueMove.

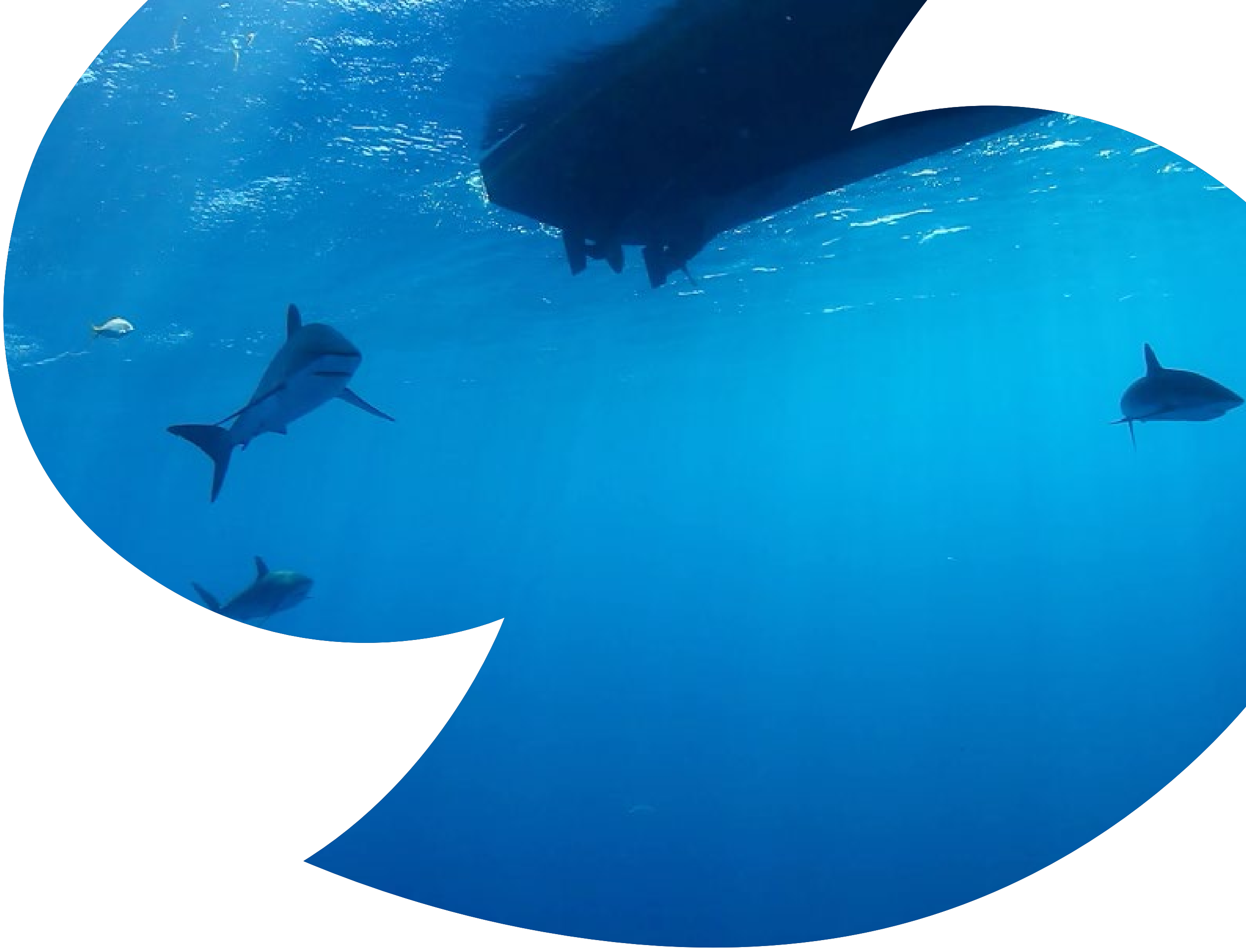


Photo: @Christine Gstöttner

Conclusion

As a main player of fisheries in its own waters and worldwide, the EU has the responsibility and the potential to drastically reduce or fully eliminate bycatch in many of its fisheries. Now is the time to act as many EU bycatch-focused projects have recently started and will be able to provide many useful inputs. As a last reminder of the leitmotiv throughout this document: bycatch monitoring and mitigation is a long and arduous process, as no one single solution is ever magical. It is a matrix of measures that always come with a set of considerations and trade-offs, which must be adapted to the local context. Solutions should include all stakeholders in the spirit of co-management and work mainly through incentives, but enforcement, penalties and monitoring remain essential. Bycatch mitigation and elimination is an essential process, not only to protect sensitive species and populations as a whole but also to reduce welfare impacts to the maximum extent. The best bycatch is no bycatch at all.

Annex 1 Vulnerability of species groups to bycatch

Fisheries bycatch is the main global direct human threat in terms of impact when it comes to seabirds, with an estimated 146 000 seabirds killed by bycatch annually in EU waters[1,2]. These high mortalities threaten seabird population as certain species, such as albatrosses, shearwaters and petrels, are long-lived and reproduce slowly[3]. Seabirds can mature at a minimum of 2 years (a minimum of 5 years for albatrosses or frigatebirds) and produce small clutch sizes of 1 to 3 chicks 4. Of these small clutch sizes, seabirds can experience high mortalities in their first year of life, up to 60%[5,6.] These high mortalities of juvenile seabirds could be even more exacerbated by fisheries and bycatch, as juvenile seabirds have less experience and could rely more on fisheries for feeding, increasing their bycatch rates[7]. Bycatch is an issue not only for juvenile seabirds but also for adults, which have normally very high survival rates, with 70-90% of the adult population surviving into the next year[4,8.] As such, seabird populations are very sensitive to any increases in adult mortality[3,8]. Additionally, prey depletion caused by overfishing is another major threat for seabirds, particularly as their foraging range can be limited during breeding season[3]. Seabirds are also under many land-based threats, including light pollution, energy infrastructure habitat degradation and the intrusion of invasive species such as rats and cats. **In short, seabirds can be very sensitive to bycatch through their life stage and increases in mortality could have strong impacts on the populations.**

As for sea turtles, bycatch is estimated to be the greatest threat in both the Mediterranean and OSPAR[s] waters[9–11]. It is specified in "waters" due to the land-based pressures faced by sea turtles, namely the destruction of their nesting habitats caused by coastal developments and erosion, light pollution and predation[11–13]. Additionally, sea turtles are particularly sensitive to climate change, as the sex ratio of each clutch is dependent on nest temperature, on top of increased flooding risk threatening the nests[13,14]. As such, it is established that sea turtles are facing a variety of threats, both on land and in the water. Regardless, bycatch is still considered to be one of the major threats, land or sea-based[11,13,15]. This pairs poorly with the long sexual development of sea turtles, as all three species mature relatively late and have long nesting intervals[16,17]. Indeed, the loggerhead, green and leatherback turtles all have a minimum maturity age of around 15-20 years and may take up to 2-3 years before nesting again[16–18]. This is however a minimum and some turtles can take up to 50 years to mature[17,18]. As such, marine turtles are very sensitive to any human impacts, including bycatch.

Marine mammals, which includes whales, dolphins, porpoises and seals, are highly sensitive to bycatch, namely due to their life cycle[19–22]. Indeed, they reach sexual maturity after a minimum of 3 – 5 years (up to 18 – 21 years for sperm whales!), with an average gestation period of 11 months for one single calf or pup[20,23,24].
The birth of that offspring is then followed by a period of nursing, lasting a few weeks or months for seals and up to years for certain whales and dolphins, including up to 8 years for bottlenose dolphins[23,25–27]

Marine mammals are therefore very vulnerable to any increased mortality and endangered populations may take years or decade of extensive conservations efforts before any visible recovery if any at all, especially in the case of cetaceans[28,29]. They face less land-based threats than seabirds and sea turtles do, but are vulnerable to direct mortality from collisions with vessels and can be impacted by marine litter, PFAS and coastal ecosystem degradation, amongst others[30–32]. Due to their reliance on sound for communication and hunting, marine mammals are especially sensitive to human-induced underwater noise[33]. Sources include military sonars (which can cause episodes of mass strandings), installation of offshore windfarms, shipping, seismic surveys looking for fossil fuels[34–39]. Bycatch itself is already a severe issue for marine mammals, but these adjacent threats and the slow life cycle of marine mammals only underline the necessity to drastically reduce the severity of bycatch.

The world's oceans are undergoing profound changes as a result of human activities. However, the consequences of escalating human impacts on marine mammal biodiversity remain poorly understood. The International Union for the Conservation of Nature (IUCN. The birth of that offspring is then followed by a period of nursing, lasting a few weeks or months for seals and up to years for certain whales and dolphins, including up to 8 years for bottlenose dolphins[23,25–27]. Odontocetes are characterized by slow life histories and extensive maternal care, where offspring nurse for years in some species. Among some of the largest toothed whales, the mother and offspring of one or both sexes stay together for a lifetime, forming the basis of strong matrilineal social units and transmission of culture along maternal lines. Mother and calf face a series of challenges from the moment of birth.

s The OSPAR convention, named after the Oslo and Paris conventions of 1974 and 1978 on marine pollutants, covers the waters of the North Atlantic

The newborn must quickly learn to follow and breathe alongside the mother—and wait for her while she dives for food. Within months the calf transitions to infant position for much of the time, although their swimming ability allows them to associate with others in the mother's network. Because calves can easily become separated from their mothers, an effective communication system is necessary, and signature whistles and pod-specific dialects appear to serve this function. The mother plays a central role in the development of calf social and foraging tactics. Where this has been studied, calves adopt maternal behaviors, including foraging specializations, and share the mother's network post-weaning. Although difficult to demonstrate "teaching" per se, dolphins are particularly good candidates given their exquisite learning ability and social tolerance. The role of non-mothers is clearly important in calf development, but whether calf interactions with non-mothers constitute "allomothering" remains unclear for most species. What is clear is that group living by cetaceans affords the calf protection from predators and possibly from infanticidal males. The causes of calf mortality are generally not known, as carcasses are rarely retrieved, but disease, predation, poor maternal condition, and anthropogenic causes (pollutants, provisioning, bycatch, boat strikes. Marine mammals are therefore very vulnerable to any increased mortality and endangered populations may take years or decade of extensive conservations efforts before any visible recovery if any at all, especially in the case of cetaceans[28,29]. They face less land-based threats than seabirds and sea turtles do, but are vulnerable to direct mortality from collisions with vessels and can be impacted by marine litter, PFAS and coastal ecosystem degradation, amongst others[30–32]. Due to their reliance on sound for communication and hunting, marine mammals are especially sensitive to human-induced underwater noise[33]. Sources include military sonars (which can cause episodes of mass strandings), installation of offshore windfarms, shipping, seismic surveys looking for fossil fuel [34–39]. Bycatch itself is already a severe issue for marine mammals, but these adjacent threats and the slow life cycle of marine mammals only underline the necessity to drastically reduce the severity of bycatch.

Annex 2 Vulnerable and endangered species and populations

The IUCN Red List of Ecosystems includes eight categories: Collapsed (CO), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE).

	Example species	Assessments in EU waters and non-EU waters fished by EU vessels	IUCN Status	Trends
Marine mammals	**Dolphins and porpoises**			
	Harbour porpoise - *Phocoena phocoena*	Global - Atlantic, Pacific and Arctic oceans	LC	Unknown
		Europe - Northeast Atlantic, Black Sea and Baltic	LC	Stable
		Baltic subpopulation	CR	Decreasing
		Black Sea	EN	Decreasing
		Iberian peninsula - in the process of assesment by IUCN	Portugal - CR	Decreasing
	Bottlenose dolphin - *Tursiops truncatus*	Global - Atlantic, Pacific, Indian oceans and Mediterranean	LC	Unknown
		Europe - Northeast Atlantic, Black Sea and Mediterranean	LC	Unknown
		Mediterranean	LC	Unknown
		Gulf of Ambracia	CR	Decreasing
	Common dolphin - *Delphinus delphis*	Global - Atlantic, Pacific, Indian oceans and Mediterranean	LC	Unknown
		Europe - Northeast Atlantic, Black Sea and Mediterranean	LC	Unknown
		Mediterranean	EN	Decreasing
		Gulf of Corinth	CR	Unkown
	Whales			
	Minke *whale* - *Balaenoptera acutorostrata*	Global - Atlantic, Arctic, Pacific, Indian and Southern oceans	LC	Unkown
		Europe - Northeast Atlantic	LC	Stable
	Sei whale - *Balaenoptera borealis*	Global - Atlantic, Arctic, Pacific, Indian and Southern oceans	EN	Increasing
		Europe - Northeast Atlantic	LC	Increasing
	Blue whale - *Balaenoptera musculus*	Global - Atlantic, Arctic, Pacific, Indian and Southern oceans	EN	Increasing
		Europe - Northeast Atlantic	NT	Increasing
	Fin whale - *Balaenoptera physalus*	Global - Atlantic, Arctic, Pacific, Indian and Southern oceans, along with the Mediterranean	VU	Increasing
		Europe - Northeast Atlantic and Mediterranean	LC	Unknown
		Mediterranean Sea	EN	Decreasing
	Orca - *Orcinus orca*	Global - Atlantic, Arctic, Pacific, Indian and Southern oceans	DD	Unknown
		Europe - Northeast Atlantic and western Baltic	LC	Unknown
		Straight of Gibraltar	CR	Stable
	Sperm whale - *Physeter macrocephalus*	Global - Atlantic, Arctic, Pacific, Indian and Southern oceans, along with the Mediterranean	VU	Unknown
		Europe - Northeast Atlantic and Mediterranean	VU	Decreasing
		Mediterranean Sea	EN	Decreasing

Marine mammals	**Seals**			
	*Mediterranean Monk Seal -*Monachus monachus*	Europe - Mediterranean and Northeast Atlantic	VU	Increasing
		Eastern Mediterranean	EN	Unknown
	* Grey Seal -*Halichoerus grypus*	Global - North Atlantic and Baltic	LC	Increasing
		Europe - Northeast Atlantic and Baltic	LC	Increasing
		Iceland	National - VU	Unknown
	* Harbour Seal -*Phoca vitulina*	Global - North Atlantic and north Pacific	LC	Unknown
		Europe - Northeast Atlantic and Baltic	LC	Unknown
		Iceland	National - EN	Unknown
		Greenland	National - CR	Unknown
	Ringed Seal – Pusa hispida	Global - North Atlantic and North Pacific	LC	Unknown
		Europe - Northeast Atlantic, Baltic and Lake Saimaa	EN	Decreasing
		Baltic	Norwegian - VU	Unknown
		Saimaa ringed seal	CR/EN	Increasing
Seabirds	**Seabirds**			
	Scopoli's shearwater - *Calonectris diomedea*	Global - Atlantic and Mediterranean	LC	Decreasing
		Europe - North Atlantic and Mediterranean	LC	Unknown
	Black guillemot - *Cepphus grylle*	Global - Northeast Atlantic, Arctic and Baltic	LC	Unknown
		Europe - Northeast Atlantic and Baltic	LC	Unknown
	Northern fulmar - *Fulmarus glacialis*	Global- North Atlantic, North Pacific, Arctic and Baltic	LC	Unknown
		Europe - North Atlantic and Baltic	VU	Decreasing
	Great cormorant - *Phalacrocorax carbo*	Global - North Atlantic, Mediterranean, Baltic and central Asia	LC	Increasing
		Europe - North Atlantic, Mediterranean and Baltic	LC	Increasing
	Balearic shearwater - *Puffinus mauretanicus*	Global/Europe - Mediterranean and Eastern Atlantic	CR	Decreasing
	Albatrosses and petrels			
	Wandering Albatross – *Diomedea exulans*	Global - Atlantic, Pacific, Indian and Southern Ocean	VU	Decreasing
	Northern Royal Albatross – *Diomedea sanfordi*	Global - Atlantic, Pacific, Indian and Southern Ocean	EN	Decreasing
	Black Browed Albatross - *Thalassarche melanophris*	Global - Atlantic, Pacific, Indian and Southern Ocean	LC	Increasing
	Southern Giant Petrel – *Macronectes giganteus*	Global - Southern Ocean	LC	Increasing
	White Chinned Petrel - *Procellaria aequinoctialis*	Global - Atlantic, Pacific, Indian and Southern Ocean	VU	Decreasing
	Grey Petrel - Procellaria cinerea	Global - Atlantic, Pacific, Indian and Southern Ocean	NT	Decreasing

Sea turtles	Sea turtles			
	Loggerhead turtle -*Caretta caretta*	Global - Atlantic, Pacific, Indian and Mediterranean	VU	Decreasing
		Northeast Atlantic	EN	Unknown
		Mediterranean	LC	Increasing
		South Pacific Ocean	CR	Decreasing
	Leatherback turtle -*Dermochelys coriacea*	Global - Atlantic, Pacific, Indian and Mediterranean	VU	Decreasing
		South West Altantic Ocean	CR	Increasing
		East Pacific Ocean	CR	Decreasing
	Green turtle -*Chelonia mydas*	Global - Atlantic, Pacific, Indian and Mediterranean	EN	Decreasing
		Mediterranean	NT	Increasing
		Central South Pacific	EN	Decreasing
Elasmobranchs	**Pelagic sharks**			
	Great white shark (Carcharodon carcharias)	Global - Atlantic, Pacific, Indian and Mediterranean	VU	Increasing
		Europe - North Altantic and Mediterranean	CR	Decreasing
		Mediterranean	CR	Decreasing
	Sandtiger shark (Carcharhinus taurus)	Global - Atlantic, Pacific, Indian and Mediterranean	CR	Decreasing
		Europe - North Altantic and Mediterranean	CR	Decreasing
		Mediterranean	CR	Decreasing
	Smalltooth Sand tiger shark (Odontaspis ferox)	Global - Atlantic, Pacific, Indian and Mediterranean	EN	Decreasing
		Europe - North Altantic and Mediterranean	CR	Decreasing
		Mediterranean	CR	Decreasing
	Blue shark - *Prionace glauca*	Global - Atlantic, Pacific, Indian and Mediterranean	NT	Decreasing
		Europe - North Atlantic and Mediterranean	NT	Decreasing
		Mediterranean	CR	Decreasing
	Oceanic whitetip shark - *Carcharhinus longimanus*	Global - Atlantic, Pacific and Indian	CR	Decreasing
		Europe - North Atlantic	EN	Decreasing
	Silky shark - *Carcharhinus falciformis*	Global - Atlantic, Pacific and Indian	VU	Decreasing
		Europe - North Atlantic and Mediterranean	DD	Unknown
	Scalloped hammerhead shark - *Sphyrna lewini*	Global - Atlantic, Pacific, Indian and Mediterranean	CR	Decreasing
		Europe - North Atlantic and Mediterranean	DD	Decreasing
	Basking shark - *Cetorhinus maximus*	Global - Atlantic, Pacific and Mediterranean	EN	Decreasing
		Europe - North Atlantic and Mediterranean	EN	Stable
		Mediterranean	EN	Decreasing
	Short fin mako - *Isurus oxyrinchus*	Global - Atlantic, Pacific, Indian and Mediterranean	EN	Decreasing
		Europe - North Atlantic and Mediterranean	DD	Unkown
		Mediterranean	CR	Decreasing
	Longfin mako - *Isurus paucus*	Global - Atlantic, Pacific, Indian and Mediterranean	EN	Decreasing
		Europe - North Atlantic and Mediterranean	DD	Unkown
		Mediterranean	DD	Unkown
	Porbeagle- *Lamna nasus*	Global - Atlantic, Pacific, Indian and Mediterranean	VU	Decreasing

		Europe - North Atlantic and Mediterranean	CR	Decreasing
		Mediterranean	CR	Decreasing
	Thresher sharks- *Alopias spp.*	Global - Atlantic, Pacific, Indian and Mediterranean	VU	Decreasing
		Europe - North Atlantic and Mediterranean	EN	Decreasing
		Mediterranean	EN	Decreasing
	Demersal sharks			
	Common, smoothback and sawback angelsharks- *Squatina* spp.	Global & Europe : Atlantic and Mediterranean	CR	Decreasing
		Mediterranean	CR	Decreasing
	Kitefin shark - *Dalatias licha*	Global - Atlantic, Pacific, Indian and Mediterranean	VU	Decreasing
		Europe - North Atlantic and Mediterranean	EN	Decreasing
		Mediterranean	VU	Decreasing
	Tope shark - Galeorhinus galeus	Global - Atlantic, Pacific, Indian and Mediterranean	CR	Decreasing
		Europe - North Altantic and Mediterranean	VU	Decreasing
		Mediterranean	EN	Decreasing
	Black-spotted and common smoothhounds - *Mustelus* spp.	Global & Europe : Atlantic and Mediterranean	VU	Decreasing
		Mediterranean	VU	Decreasing
	Common, longnose and shortnose spurdogs - Squalus *spp.*	Global - Atlantic, Pacific, Indian and Mediterranean	VU	Decreasing
		Europe - North Altantic and Mediterranean	EN	Decreasing
		Mediterranean	EN	Decreasing
	Rays and skates			
	Common skate - *Dipturus batis*	Global & Europe - North Atlantic	CR	Decreasing
	Maltese Skate - *Leucoraja melitensis*	Global & Europe - Mediterranean	CR	Decreasing
	Spiny butterfly ray - *Gymnura altavela*	Global : Atlantic and Mediterranean	EN	Decreasing
		Europe : North Atlantic and Mediterranean	CR	Decreasing
		Mediterranean	CR	Decreasing

Annex 3 Overview of existing regulations and initiatives at EU level

Bycatch of sensitive species at the European level is regulated directly or indirectly through multiple regulations and directives, namely:

- **Habitat Directive**: The 92/43/EEC Directive on the conservation of natural habitat and of wild fauna and flora names the species and habitat that are strictly protected in the European Union and should be protected from anthropogenic impacts

- **Marine Strategy Framework Directive**: The 2008/56/EC Directive establishing a framework for community action in the field of marine environmental policy, more commonly referred to as the MSFD for Marine Strategy Framework Directive. The MSFD established what conditions and values are considered for a species and habitat to be in Good Environmental Status (GES). The MSFD is particularly critical in setting legally binding targets for bycatch reduction, which EU Member States must follow. Should they not reach their GES objectives, the EU Commission can launch infringement procedures against Member States to force them to take appropriate measures.

- **Birds Directive**: The 2009/147/EC Directive on the conservation of wild birds lists the protected bird species and urges that conservation measures must reduce anthropogenic impacts.

- **Common Fisheries Policy**: The 2013/1380 Regulation on the Common Fisheries Policy (CFP), which sets out the rules to manage EU fisheries. In Article 2.5, objectives (a) and (j) state that the CFP should reduce unwanted catches as far as possible and strive to achieves GES as stated in the MSFD.

- **Technical Measures Regulation**: The 2019/1241 Regulation on the conservation of fisheries resources and the protection of marine ecosystems through technical measures, more commonly known as the Technical Measures Regulation (TMR) states that "Member States should put in place mitigation measures to minimise and where possible eliminate the catching of such species by fishing gear" for species protected under the 92/43/EEC and 2009/147 EC regulations, mentioned above. Member States should therefore submit joint recommendations to the Commission on how they plan to reduce bycatch. It also introduces need for certain bycatch mitigation measures, such as mesh sizes, fishing closures and pinger use as well as monitoring requirements. However, most of the mitigation measures apply only to vessels over 12 metres.

- The 2022/303 Commission Delegated Regulation consider that the Baltic proper harbour porpoise should be considered a separate population and implements closures of certain areas to gillnet
- Binding conservations measures in RFMOs that the EU is a contracting party of. One example is the 2023/2124 regulations on certain provisions for fishing in the General Fisheries Commission for the Mediterranean (GFCM) Agreement area, making GFCM recommendations legally binding at EU level. The GFCM itself has binding recommendations on bycatch mitigation for each taxa of sensitive species[40–43]

Annex 4 Infringement procedures

Under EU law, the European Commission has the right and duty to trigger infringement procedures against the Member States if they do not comply with regulations that have binding requirements[44]. In other words, the EU Commission can take countries to court if they are not meeting their obligations and this can result in fines for the member states, which can amount to millions of euros. The whole process spans multiple years and is composed of 5 steps, which all include a waiting period[44]:

1. Letter of formal notice: The Commission requests further information through a letter of formal notice to the country concerned, which must send a detailed reply within a specified period, usually 2 months.
2. Reasoned opinion: If the Commission concludes that the country is failing to fulfil its obligations under EU law, it may send a reasoned opinion: a formal request to comply with EU law. It explains why the Commission considers that the country is breaching EU law. It also requests that the country inform the Commission of the measures taken, within a specified period, usually 2 months.
3. If the country still doesn't comply, the Commission may decide to refer the matter to the Court of Justice. Most cases are settled before being referred to the court.
4. If an EU country fails to communicate measures that implement the provisions of a directive in time, the Commission may ask the court to impose penalties.
5. If the court finds that a country has breached EU law, the national authorities must take action to comply with the Court judgment.

In the case of bycatch, these infringements procedures fall mostly under the Habitats Directive (Directive 92/43/EEC), which requires Member States "to monitor and prevent bycatch of cetaceans, turtles and seabirds by fishing vessels"[45]. Infringement procedures can also fall under the EU Common Fisheries Policy, which requires Member States to reduce unwanted catches as much as possible[46]. At the time of writing, the EU Commission has ongoing infringement procedures regarding bycatch against the following 8 Member States:

- France – INFR(2020)4036
  - 02/07/2020 – Formal notice
  - 15/07/2022 – Reasoned opinion
- Sweden – INFR(2020)4037
  - 02/07/2020 – Formal notice
  - 07/02/2024 – Reasoned opinion
- Portugal - INFR(2020)4038
  - 16/11/2023 – Formal notice
- Spain – INFR(2020)4039
  - 02/07/2020 – Formal notice
  - 15/07/2022 – Reasoned opinion
- The Netherlands - INFR(2021)4062
  - 09/02/2022 – Formal notice
- Bulgaria - INFR(2022)2052
  - 15/07/2022 – Formal notice
- Italy – INFR(2023)2181
  - 07/02/2024 – Formal notice
- Croatia – INFR(2024)2223
  - 12/02/2025 – Formal notice

They each have an associated infringement case number, which includes the year in which the infringement procedure started. Using that number, public information about each ongoing infringement procedure can be accessed on the Commission website[47.] While it can be argued that the process is a lengthy one, it can nonetheless lead to good results. The infringement procedure against France has contributed to the implementation of the fishing closure on the Bay of Biscay in 2024, which has been expanded and renewed in 2025 and 2026. This closure has been successful in strongly reducing the bycatch of common dolphins and the infringement procedure was likely a contributing factor to its implementation.

Despite their advantages, infringements procedures can have certain caveats which need to be kept in mind. Indeed, they are very long processes and can span years, during which the cause of the infringement might not be addressed by the targeted Member States. Journalists from Investigate Europe have also stated environmental infringement procedures take longer than other infringement procedures. It is estimated that the whole process takes 12 years to address environmental cases, instead of 9 for others[48]. There also has been evidence of Member States being convicted on environmental issues in the European Court of Justice, without any fines being imposed or measures taken[48]. While this is likely due to workload rather than blockage, it is important to follow and address the 8 open infringement cases for bycatch, as the EU has currently 1525 open infringement cases[47]. Pressure from policymakers or civil society prompt the Commission to initiate infringement procedures, that same pressure should be maintained for the procedures to be effective and have consequences.

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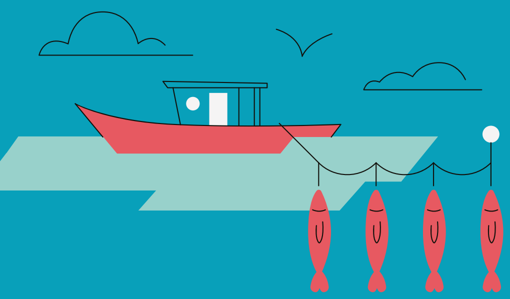

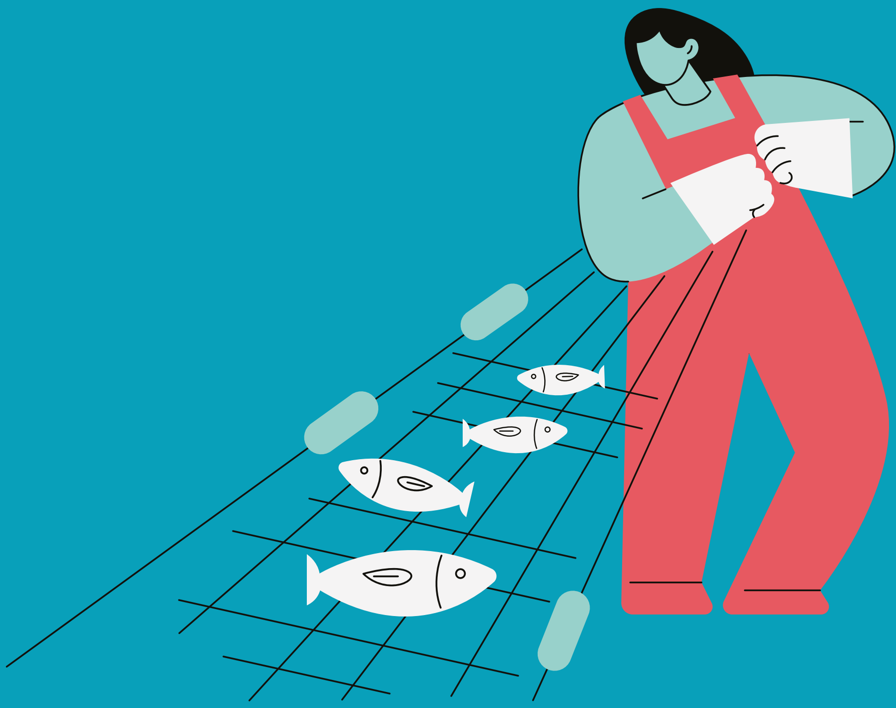

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