SFP Best Practices Report:

Minimizing and managing the impacts of fisheries on bycatch of protected, endangered, and threatened species

By: Megan Westmeyer

Photograph Credit: Braddock Spear

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Sustainable Fisheries Partnership would like to thank ASDA Walmart
for their generous support in the production of this report.

Foreword

ASDA takes its responsibility towards the marine environment extremely seriously and has been a leader in ensuring that the fish we sell come from sustainably managed stocks. But sustainability is not just about the species our customers want to eat; it's also about the other animals in the marine ecosystem that can be affected by fishing activity.

We have done a good job with our sustainable sourcing policies so far but now we want to take that commitment to the next level and develop an approach that protects the whole marine ecosystem rather than just parts of it – an approach known as ecosystem-based fishery management (EBFM).

One of the central components of EBFM is managing bycatch – the accidental catching of non-target species. ASDA wants to see the fisheries it sources from tackling bycatch as effectively as possible and eliminating impacts on animals that might be protected, endangered or threatened. We have commissioned this report to help us understand the problem of bycatch and to learn about best practice from around the world.

ASDA has a commitment to continuous improvement in environmental performance driven by advancing scientific knowledge. This report will equip us and others in the seafood industry to better understand the challenges ahead and we will be looking to our supply chain to take the actions required to deliver sustainable management for the entire marine ecosystem.

Dr Chris Brown,
ASDA,
Sustainable Business Director

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Executive Summary

Ecosystem-based fishery management (EBFM), also referred to as the ecosystem approach to fisheries (EAF), considers all the living and non-living components of a marine community when managing fisheries. Target species and the ecosystems in which they live are inextricably tied, and fishing affects ecosystems in ways beyond just the removal of the targeted species. These effects, along with other anthropogenic effects like coastal development and pollution, may cumulatively have a greater impact than direct fishing pressure alone. Reduction of protected, endangered, and threatened (PET) species bycatch is an important component of ecosystem-based fishery management. It is also an issue that attracts a great deal of attention from consumers and conservationists. Seafood suppliers and buyers should work with their source fisheries to quantify, monitor, and reduce any impacts that occur. There are numerous examples around the world that demonstrate that successful PET bycatch reduction and cooperative actions by the seafood supply chain can ensure productive seafood supplies for the future while protecting important components of the marine ecosystem.

In general, PET species fall into five general classes: marine mammals, seabirds, marine reptiles, fish, and habitat. Marine mammals include whales, dolphins, porpoises, seals, sea lions, and dugongs. Seabirds are defined as those birds that rely on the marine environment for at least part of the year. Marine reptiles include sea turtles and sea snakes. Fish include both bony fish, those species traditionally referred to as "fish," and cartilaginous fish, like sharks and rays. It is important to note that both bony and cartilaginous fish are often targets of fisheries as well as bycatch. Examples of PET species that serve as habitat include coral reefs, sponges, and marine plants. Impact on habitat was addressed in a previous Sustainable Fisheries Partnership report on benthic protected areas and will not be addressed in this report.

Fishery impacts on PET species are dictated by type of fishing gear used. There are three general methods of harvest: "filtering" the water with a net (either by allowing water and fish to move through a stationary net, or by pulling a net through the water); luring the target species in and capturing it (with a baited hook or a trap); or actively hunting for prey (such as spearfishing). Because hunting for specific prey items usually involves visual verification of a target, bycatch is not often an issue. But both the filtering and luring methods can result in bycatch, some more so than others.

With the multitude of anthropogenic threats facing PET species, it is important to minimize bycatch, or the impacts of bycatch, to the greatest extent practicable. It is not always possible to completely eliminate bycatch mortality, and it is not always necessary if the PET population is robust enough to withstand fishing mortality. But the opposite may also be true; if a population is depleted severely, or is naturally small or vulnerable to bycatch mortality because of its biological characteristics, fishing mortality may need to be eliminated completely.

There are three general approaches to bycatch reduction: avoid capture, allow escape, and reduce mortality. These techniques should generally be applied in that order. A fishery should first attempt to reduce the amount of overall bycatch by avoiding capture of PET species through changes in fishing practices, gear types, or fishing closures in certain areas or seasons. If capture does still occur, modification to the gear or fishing technique should be made that will allow the PET species to escape the fishing gear. If escape is not possible, efforts should be made to reduce the amount of mortality caused by the interaction and increase the chance of survival once released from the fishing gear. The fishing industry should always be deeply involved in the development of bycatch reduction methods because the economic consequences of these modifications and regulations can be severe.

Four case studies are presented to illustrate implementation of PET bycatch reduction techniques:

- The **US Atlantic shrimp fishery** is required to use turtle excluder devices (TEDs) to allow sea turtles to escape from trawl nets. While very contentious and difficult to implement, this requirement has greatly reduced mortality of sea turtles and populations are showing signs of rebuilding. In addition, a US law prohibits import into the US of shrimp and shrimp products that were harvested in a manner that may adversely affect sea turtles. Adoption of TEDs was often the simplest method of achieving this goal and TEDs have been implemented in many places around the world, but not everywhere. The EU does not have a comparable law, thus provides a market for shrimp harvested without TEDs.

- A pilot project in the **Swedish Eastern Baltic cod fishery** is experimenting with cod pots as an alternative to gillnets, which have bycatch of a critically endangered sub-population of harbor porpoise. Pots catch fewer though higher-quality fish than gillnets, and pot-caught cod may require a higher price in order for the gear to be profitable. Though still in an experimental phase and not yet adopted by the commercial fishery, the pots were included in a recent Marine Stewardship Council certification along with trawls and longlines, while gillnets failed the certification process.

- On the west coast of the US, the **California groundfish fishery** is prohibited from bottom fishing in 4,300 square miles of Cowcod Conservation Areas to protect and rebuild the severely depleted cowcod stock. Bycatch mortality has decreased drastically and the cowcod stock has stabilized and is showing initial signs of recovery.

- The **Australia eastern tuna and billfish fishery** has had to contend with bycatch of a variety of PET species, including sharks, sea turtles, and seabirds. Thus, this case study illustrates how even a fishery with a multitude of sustainability issues can commit to continuous improvement and move towards sustainability.

In the final section of this report, the lessons learned in these case studies are interpreted to provide a suggested list of best practices in developing PET bycatch avoidance and mitigation techniques. Representatives from the fishing industry must be included from the beginning and all stakeholders should have a clear understanding of why PET bycatch reduction is needed and how it can be achieved. Stakeholders must also ensure that there is a mechanism in place to measure impacts and outcomes. Additionally, monitoring and enforcement of bycatch mitigation measures is crucial. And finally, suppliers should recognize that while voluntary adoption of best practices by the fishing industry is a good start, in many cases legal mandates for mitigation measures are needed. While not a comprehensive lists of suggestions, these practices are a good basis from which to start.

This report concludes with practical actions for seafood suppliers and buyers. It may be necessary to develop procurement policies stating that source fisheries that impact PET species must work to minimize that impact. One such mechanism is participation in a fishery improvement project (FIP), but impacts can also be addressed on an ad hoc basis. The following is a list of practical actions that should be taken to implement PET bycatch mitigation.

1. Identify the source fisheries that are interacting with PET species and prioritize them based on risk – both risk to the PET species (e.g., severely depleted species) and risk to your business (e.g., high-profile PET species or fisheries or high purchase-volume fisheries).

2. Engage with the fishing industry to determine how PET bycatch occurs and enlist their participation in developing mitigation measures.

3. Support the formation of an interdisciplinary work group, including fishermen, scientists, managers, and conservationists. The work group should look to other similar fisheries around the world to obtain ideas of bycatch reduction techniques that have been tested and/or implemented.

4. Encourage the fishing industry to develop and voluntarily adopt changes to fishing practices or gear, potentially including creation of a Code of Good Practice.

5. Encourage the government and/or fishery management authority to implement new regulations mandating PET bycatch mitigation techniques.

6. Support and promote fisheries that successfully adopt PET bycatch techniques. Conversely, if fisheries are unwilling to reduce PET bycatch to the necessary levels, seafood suppliers and buyers may need to place a moratorium on purchases of those fishery products. In this,

hopefully rare, case, suppliers and buyers should be clear to the industry and fishery managers why the moratorium on purchases has been implemented and what steps must be taken by the industry and government to lift that moratorium.

In many countries, impacts on PET species are limited and fisheries may be closed completely if the impacts on PET species become too substantial. In addition, consumers are becoming more aware of the impact of wild seafood harvest on the marine ecosystem and are demanding protection of not only charismatic species, but also those lesser-known species that are important to the health and function of the ecosystem. In order for the global seafood supply chain to secure their resources and markets, consideration must be given to reducing bycatch of PET species to the maximum extent practicable. Countless examples from around the world show that PET bycatch reduction is not only possible, but also practicable.

Introduction

In the late 1990s, a fisheries management paradigm shift occurred. The old paradigm was one of single species management, where the scientific and management focus was solely on the species that were targeted for harvest. The new paradigm was ecosystem-based fishery management (EBFM), also referred to as the ecosystem approach to fisheries (EAF), which considers all the living and non-living components of a marine community when managing fisheries. This new paradigm recognized that target species and the ecosystems in which they live are inextricably tied, and that fishing affects ecosystems in ways beyond just the removal of the targeted species. These effects, along with other anthropogenic effects like coastal development and pollution, cumulatively have a greater impact than direct fishing pressure alone (NRC 1998). In reality, EBFM was not a new type of fishery management, but was the next phase in its evolution (Garcia et al. 2003).

Even before the terms "ecosystem-based fishery management" and the "ecosystem approach to fisheries" were coined, the concepts were being integrated into fisheries management around the world. In 1995, the Food and Agriculture Organization of the United Nations (FAO) included ecosystem concerns in the Code of Conduct for Responsible Fishing. The Code calls for responsible fishing practices that ensured the conservation, management and development of living marine resources, but that also respected the ecosystem and biodiversity (FAO 1995). It stated that not only should fisheries minimize catch and discards of non-target species, but also they should ensure conservation of species belonging to the same ecosystem or associated with the target species, especially endangered species. Fishing gear and methods should be selective, to minimize bycatch (non-target species) and minimize impacts on the associated environment.

In 1998, the US National Research Council defined EBFM as *"an approach that takes major ecosystem components and services—both structural and functional—into account in managing fisheries. It values habitat, embraces a multispecies perspective, and is committed to understanding ecosystem processes. Its goal is to achieve sustainability by appropriate fishery management."* (NRC 1998). While US fisheries law authorized, and in some cases required, the consideration of ecosystem effects when managing fisheries, EBFM was not fully mandated by law until the 2010 National Ocean Policy.

In 2001, the FAO defined EAF as an approach by which *"fisheries strive to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries"* (FAO 2003). FAO participating countries agreed to incorporate ecosystems concerns into fisheries management and set a goal of 2010 for full implementation. Some progress has been made, but in many areas, such as ecosystem research and institutional development, more progress is needed (FAO 2005).

While the terminology may vary by country or organization, the underlying premise is the same: ecosystems are affected by fishing and impacts must be minimized across the entire ecosystem. The complex relationships among all the components of an ecosystem will most likely never be fully comprehended, but fishery managers must strive for greater understanding and take a precautionary approach. While it can be difficult to distinguish between the impacts of fishing and the results of other actions like habitat degradation, pollution, and natural environmental variability, managers cannot use that lack of understanding to allow the continued degradation of ecosystems (Garcia et al. 2003). If the overall health and resiliency of the ecosystem is the goal of fishery management, the likelihood of unknowingly compromising its health and our ability to harvest food from it will be lessened.

Protected, endangered, and threatened (PET) species are one concern within EBFM. There are many definitions for what constitutes a PET species, and no one definition is widely accepted above others. For example, the International Union for the Conservation of Nature (IUCN) assesses the status of species around the world and highlights those threatened with extinction on their Red List of Threatened Species (IUCN 2012). According to their criteria, those listed as Critically Endangered, Endangered, and Vulnerable are facing the highest risk of global extinction and are in need of protection. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement designed to ensure that international trade does not threaten the survival of wild plants and animals. Plants and animals are listed on one of three CITES appendices, according to the degree of protection they require. Participating countries apply a set of biological and trade criteria to determine which species are listed and in which appendix.

Many highly migratory species are given special protection as PET species because fisheries in multiple countries impact the same population, requiring international cooperation to protect them. One intergovernmental treaty, the Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or the Bonn Convention), was formed under the United Nations Environment Program to conserve all sorts of migratory species. Over 100 countries around the world have become members of the CMS and are working to protect endangered and threatened migratory species by conserving or restoring the places where they live, mitigating obstacles to migration, and controlling other factors that might endanger them.

In addition to international organizations and agreements, many individual countries have laws defining PET species, such as the United States' Endangered Species Act and Marine Mammal Protection Act and the Australian Environment Protection and Biodiversity Conservation (EPBC) Act. The FAO has established International Plans of Action (IPOAs) for sharks and seabirds. These IPOAs provide a framework for conservation efforts, but do not mandate participation. Instead individual countries are encouraged to develop their own National Plans of Action (NPOAs). Each country is responsible for developing, implementing, and monitoring their NPOAs, but reports are given to the FAO on a regular basis (FAO 2013a; FAO 2013b).

Regardless of the legislation, agreement, or authority that defines a PET species, they are valuable components of ecosystems and under the principles of EBFM they must be protected. Many PET species show common characteristics such as long life span, low reproductive capability, and late age at maturity, which make them vulnerable to added sources of mortality, and wide-ranging migrations that make them susceptible to multiple fisheries. Some PET species, sharks for example, are predators that exert top-down control that keeps the food web in balance. Others fill a niche in the food web that if vacated would alter the food web dynamics. Other large, charismatic species such as whales and dolphins are often used to inspire conservation of the ocean and are featured in children's stories, advertising, films, and cartoons. And finally, in many people's opinions, PET species simply have inherent value and should be preserved. In many cases it is difficult to obtain reliable information on PET species and fishery interactions, yet there is a range of mitigation measures in effect around the world, and PET species are successfully being protected (Kelleher 2005).

The objective of this report is to describe ways fishing impacts PET species; review the tools and techniques that are used to reduce or avoid impacts on PET species; and finally, to present four case studies demonstrating examples of some of the best practices that have been implemented to reduce PET bycatch in fisheries around the world. The report will conclude with recommendations for best practices in implementing PET bycatch reduction and practical actions for the seafood supply chain.

PET Species-Fishery Interactions

Fishing Gear

Methods of harvesting seafood vary by ecosystem and by target species. There are three general methods of harvest: "filtering" the water with a net (either by allowing water and fish to move through a stationary net, or by pulling a net through the water); luring in the target species and capturing it (with a baited hook or a trap); or actively hunting for prey (such as spearfishing, harpooning, or even digging for shellfish). Because hunting for specific prey items usually involves visual verification of a target, bycatch is not often an issue. But both the filtering and luring methods can result in bycatch, some more so than others. Below is a general review of the fishing methods that most commonly affect PET species, as described by the Food and Agriculture Organization of the United Nations (FAO 2013c), unless otherwise noted. More in-depth descriptions, including illustrations, may be found in Appendix I.

Trawls catch a great number of non-target species, including PET species. This bycatch is often discarded at sea, some of it already dead. Worldwide, bottom trawls account for over 50 percent of bycatch, but only 22 percent of total harvest, and account for the most discarded bycatch by weight; mid-water trawls account for the third highest amount of discarded bycatch by weight (Kelleher 2005).

Dredges have a similar bycatch level to that of bottom trawls, but have higher impact on benthic organisms as they are purposely made to dig into the substrate instead of skimming the surface.

Purse seining can have minimal amounts of bycatch if set around species-specific schools of fish, but often undersized fish or other species are present in the aggregation and are also caught. The use of fish aggregating devices (FADs), man-made floating objects (usually bamboo rafts with old nets hanging underneath) deployed by fishermen to attract fish, typically have higher rates of bycatch than when set around free-swimming schools of fish (Dagorn and Restrepo 2011). Purse seines are often used to target tuna, and these tuna purse seines account for the fourth highest amount of bycatch by weight (Kelleher 2005).

Gillnets have high incidental catch of non-target species, especially PET species. In 1991, the United Nations banned the use of large-scale high seas driftnets greater than 2.5 km due to its high bycatch rate, particularly of PET species.

Longlines are known for having bycatch of seabirds, sea turtles, sharks, and other non-target fish. Tuna and other highly migratory species longline fisheries are responsible for the second highest bycatch by weight worldwide (Kelleher 2005).

While PET species are not usually caught in pots, they can become entangled in the lines that connect to the pots to each other in a string or to a surface buoy marking their location.

Many of these types of fishing gear can be lost at sea and continue to catch marine creatures, called "ghost fishing" (Northridge 1991; Bjørge et al. 2002; FAO 2003; FAO 2013c). This is most common with gillnets and pots. They may ghost fish for weeks, months, or even years. While pots can be designed with biodegradable panels that disable the pot after some time, gillnets or fragments of any kind of net can continue to fish or entangle target and non-target species for a long time.

Marine Mammals

Marine mammals were the first to draw focus to the issue of PET species bycatch, specifically, the impact on dolphins by the Eastern Tropical Pacific Tuna purse seine fishery in the 1960s (Perrin 1968). In this fishery, purse seines were set on schools of dolphins because they are visible surface indicators of the tuna that often school below them. As the purse seines were pulled in, the dolphins became entangled in the net and died.

In addition to purse seines, cetaceans (whales and dolphins) can be caught or entangled by longlines (Garrison 2007) and pelagic trawls (Dans et al. 2003; Zeeberg et al. 2006; Mannocci et al. 2012), but are affected to the greatest extent by gillnets (Read and Gaskin 1988; Cox et al. 1998; Julian and Beeson 1998; Vinther 1999; Baird and Bradford 2000; D'Agrosa 2000). Gillnets have been identified as the primary source of mortality for the endangered cetaceans such as the vaquita porpoise and Hector's dolphin (Rojas-Bracho and Taylor 1999; Slooten and Dawson 2010) and have been implicated in the probable extinction of the Yangtze River dolphin (Turvey et al. 2007), believed to be the first cetacean to be driven to extinction by human activity.

Large whales can also be entangled in ropes that connect pots, traps, or gillnets to each other or to surface buoys (Johnson et al. 2005; Song et al. 2010). Whales come in contact with the gear while feeding on plankton and the ropes wrap around the mouth or tail and become tangled around the animal. Mortality does occur from such entanglements, even if the whale is able to continue swimming with all or part of the gear trailing behind them.

Seals and sea lions, or pinnipeds, forage at sea but spend much of their time on land, thus can be highly affected by coastal fisheries or those targeting the species on which the pinnipeds feed. Again, gillnets are a primary culprit (Zavala-Gonzalez and Mellink 1997; Julian and Beeson 1998; Bjørge et al. 2002; Underwood et al. 2008) and mortality is typically high. Seals and sea lions are also caught in trawl nets, which they often intentionally enter to feed on the entrapped fish, but cannot navigate their way out (Loughlin and Nelson 1986; Hamer and Goldsworthy 2006; Chilvers 2008). Gillnets and trawls have been named as one of the major threats to the critically endangered Mediterranean monk seal. Though commercial sealing ended in the second half of the 20th century, the population has not recovered, in part due to accidental entanglement in fishing gears, especially of sub-adult monk seals (Karamanlidis et al. 2008; González and de Larrinoa 2012). Other gears such as purse seines (Shaughnesy 1982) and salmon trap nets (Wada et al. 1991) also attract foraging pinnipeds but less frequently result in mortality.

Dugongs are herbivorous marine mammals, related to manatees, that tend to be found in shallow coastal waters of the Indo-Pacific. They are the only species in their family that is not extinct, and are generally found in small, isolated populations, making them very vulnerable to incidental fishing mortality (Marsh et al. 2002). Dugongs are caught in traps and gillnets, but the frequency and outcome of these entanglements is largely undocumented and poorly understood (Marsh et al. 2002; Perrin et al. 2005; Read 2008).

Seabirds

Seabirds are defined as those that rely on the marine environment for at least part of the year, and are more threatened than any other class of bird (Croxall et al. 2012). Of seabirds, pelagic seabirds such as albatross, shearwaters, and petrels are the most threatened because they have small clutch sizes, small total breeding populations, restricted number and range of breeding sites, and are often caught as fisheries bycatch (Croxall et al. 2012). Pelagic seabirds are most often caught on longlines (Favero et al. 2003; Petersen et al. 2009a; Barcelona et al. 2010; Trebilco et al. 2010) because they tend to follow boats and prey on baited longline hooks. If the bird takes the bait and gets caught on the hook, they are dragged underwater and drowned.

In addition, diving seabirds, such as auks and murres, can become entangled in fixed or drift gillnets (DeGange and Day 1991; Julian and Beeson 1998). Some of these species are also very vulnerable because of their small populations and limited breeding range, and mortality from fishery bycatch is exerting a substantial amount of mortality (Piatt and Gould 1994).

Reptiles

Sea turtle populations around the world are in decline and at depressed levels. Forced submergence in shrimp trawls was pointed to as the primary cause of anthropogenic mortality in US waters, accounting for more mortality than all other human-induced causes combined (NRC 1990). Sea turtles are caught in mid-water trawls targeting pelagic fish (Casale et al. 2004; Zeeberg et al. 2006) as well as bottom trawls targeting shrimp and ground fish (Epperly et al. 1995; Robins 1995;

Casale et al. 2004; Alió et al. 2010; Haas 2010). They can also be caught in purse seines set on FADs, but are often released alive (Amandè et al. 2010; Gilman 2011).

Other types of fishing gear also cause turtle mortality, but at a rate that is an order of magnitude less than trawl-induced mortality (NRC 1990). Species of sea turtles that spend a great deal of time in the open water environment, such as loggerheads and leatherbacks, can be hooked or entangled in longline gear (MacAlister Elliott and Partners Ltd. 2004; Donoso and Dutton 2010; Kot et al. 2010; Sales et al. 2010; Benhardouze and Tiwari 2012). In addition, gillnets entangle turtles in open water and coastal areas (Echwikhi et al. 2010; Benhardouze and Tiwari 2012; Fiedler et al. 2012; López-Barrera et al. 2012).

Another PET reptile group, though not as high profile as sea turtles, is sea snakes. Found throughout the southwestern Pacific and Indian Oceans, sea snakes have biological characteristics that make them vulnerable to fishing mortality (Milton 2001) and are caught as bycatch in trawl fisheries (Ward 1996; Milton 2001; Milton et al. 2009). Little information is available on the health of sea snake populations (Milton 2001), but they are classified as PET species in some regions (AFMA 2012a).

Fish

Increasingly, many types of fish are being recognized as PET species. Around the world many shark species are in decline. This is of special concern because of sharks' role as apex predators; excess removal of sharks can alter trophic interactions (AFMA 2013). Sharks have very low reproductive rates and have long lives, making them vulnerable to fishing pressure. While sharks are the primary targets of many fisheries, especially those seeking shark fins, they are also caught incidentally in others. Longline fisheries targeting swordfish or tuna have high levels of bycatch, often mainly comprising sharks (Buencuerpo et al. 1998; Francis et al. 2001; Petersen et al. 2009b; Huang and Liu 2010; Afonso et al. 2012). In some cases, sharks are still alive when they are hauled in, but are then finned aboard the boat and the carcasses discarded (Francis et al. 2001; Petersen et al. 2009b). Sharks are also caught in gillnets (Buencuerpo et al. 1998; Perez and Wahrlich 2005), purse seines, especially those set on FADs (Romanov 2002; Amandè et al. 2010; Gilman 2011) and trawls (Zeeberg et al. 2006).

Skates and rays, cartilaginous fish that are closely related to sharks, share the reproductive characteristics that make sharks vulnerable to fishing pressure. They are also targeted by some fisheries, but caught as bycatch in a variety of others including longlines (Francis et al. 2001; Afonso et al. 2012), gillnets (Perez and Wahrlich 2005; White et al. 2006), purse seines (Romanov 2002; Amandè et al. 2010), and trawls (Zeeberg et al. 2006).

Syngnathids (sea horses, sea dragons, and pipefish) are another type of fish that are considered PET species in some areas (AFMA 2012a). Little is known about the population health of most syngnathid species, but there is evidence of large declines for some. Major threats include habit degradation and human disturbance, from activities such as coastal development and fishing gear like as trawls and dredges. Some syngnathids are taken as fisheries bycatch but are retained and sold through the live aquarium trade (IUCN 2012).

Many other types of fish are considered PET species, especially those that have life history characteristics that make them vulnerable to fishing pressure such as long lives, low reproductive capabilities, or dependence upon both ocean and river habitats during different stages of life. In addition, deep-water species have high mortality rates when discarded because of the physiological affects of the pressure change as they are brought up from depth. The US has listed salmon, sawfish, sturgeon, totoaba, and some species of deep-water rockfish as threatened and endangered species (NOAA 2012a). Directed fisheries once targeted these species of fish, resulting in extensive population declines. Now harvest is prohibited, but bycatch remains a threat to their existence.

Habitat

Coral reefs, sponges, and marine plants can also be considered PET species. Around the world, coral reefs, which depend upon a symbiotic relationship between a reef building animal and a photosynthetic algae, are declining in health and can be severely damaged by bottom-tending fishing gear like trawls and dredges (IUCN 2012). Sponges may be damaged or completely removed by bottom-tending gear such as trawl and dredge (Auster et al. 1996; Wassenberg et al. 2002). Sea grasses are the marine plants most threatened by fishing activities such as trawling and dredging, though pollution and increased sedimentation also play a major role in their decline (NOAA 2012a). Generally, impacts on these species may be considered impact on habitat, addressed in a previous Sustainable Fisheries Partnership report on benthic protected areas (Spear and Cannon 2012), and will not be addressed further in this report.

Techniques for PET Species Bycatch Reduction

With the multitude of threats facing PET species, it is important to minimize bycatch, or the impacts of bycatch, to the greatest extent practicable. There are three general approaches to bycatch reduction: avoid capture, allow escape, and reduce mortality (FAO 2011). These techniques should generally be applied in that order. A fishery should first attempt to reduce the amount of bycatch overall by avoiding capture of PET species. If capture does still occur, modification to the gear should be made that will allow the PET species to escape. If escape is not possible, efforts should be made to reduce the amount of mortality caused by the interaction and increase the chance of survival once released from the fishing gear. Tools that reduce bycatch through any of these methods are often generally referred to as bycatch reduction devices (BRDs) (FAO 2003). The fishing industry should always be deeply involved in the development of bycatch reduction techniques and tools because the economic consequences of these modifications and regulations can be severe (Kelleher 2005).

It is not always possible to completely eliminate bycatch mortality, and it is not always necessary either. For example, pinniped (e.g., seals, sea lions) populations can often withstand a more substantial amount of bycatch mortality because they have a relatively high rate of population growth (Read 2008). In the Gulf of California, scientists have estimated the number of fishing days (as a proxy for bycatch mortality) that the regional sea lion population can withstand. In some parts of the Gulf, bycatch mortality is already below the threshold and could increase without compromising the health of the sea lion population (Underwood et al. 2008).

But the opposite may also be true; if a population is depleted severely or is naturally small, or if a species exhibits biological characteristics that make it extremely vulnerable to bycatch mortality (e.g., long life span, late age at reproductive maturity, low reproductive rate), fishing mortality may need to be eliminated completely. This is the case for species such as the vaquita porpoise, right whale, and dugong. Though fishermen may rarely encounter these animals while fishing, making it difficult to convey why stringent rules are needed, a single interaction or mortality event can be very harmful to the population as a whole (Read 2008).

Avoid Capture

One of the tactics used to avoid capture is to scare away the protected species from the fishing gear. Tori, or bird-scaring, lines are used in longline fisheries around the world (e.g., South African and Australian tuna and billfish, South Georgian Patagonian toothfish) to reduce seabird bycatch (Løkkeborg 2011; FAO 2003; Petersen et al. 2009a). A tori line stretches away from the vessel with long streamers attached, which flap in the wind and scare the birds away from the baited hooks.

Another commonly used bycatch avoidance tactic is to make the gear more easily detected by PET species. Acoustic pingers, small battery powered devices that emit a sound, have been highly effective at reducing bycatch of some species of marine mammal (Larsen et al. 2002; FAO 2003; Kelleher 2005; Carretta et al. 2008; Palka et al. 2008; Carretta and Barlow 2011) such as bycatch of beaked whales in the California swordfish and thresher shark drift gillnet fishery and harbor porpoise in the US northeast groundfish gillnet fishery. It is not clear if these pingers scare away marine mammals or merely alert them to the presence of the net. Some studies have suggested that some marine mammals can become accustomed to the sound, and acoustic pingers decline in effectiveness over time (Cox et al. 2001; Carlström et al. 2009). In addition, acoustic pingers may actually attract species, such as harbor seals, which prey upon the fish caught in the net (the "dinner bell effect") (Melvin 1999). There is also concern that heavy use of pingers could drive marine mammals away from valuable habitats (Larsen 1999; Cox et al. 2001). Some species of diving birds, such as murres, also respond to the acoustic pingers, while other species, such as auks, have been shown to be more likely to avoid nets made of highly visible white nylon instead of green monofilament, which is nearly invisible underwater (Melvin 1999). Gillnets can be illuminated with LEDs or lightsticks, or could even be made of photoluminescent materials to help sea turtles see and avoid the net (Wang et al. 2010).

Modifications to the methods used to deploy fishing gear can prevent some species from being exposed to the gear. Many longline fisheries that have seabird bycatch problems, such as the South African and Australian tuna and billfish fisheries, have used the following tactics: set gear at night when fewer seabirds are present; weight the line to carry it underwater faster; use thawed bait (frozen bait floats at the surface); and run the baited line through a chute or funnel until it is underwater (FAO 2003; Kelleher 2005; Petersen et al. 2009a; Trebilco et al. 2010). The Hawaiian longline fishery sets longlines deeper in the water column to reduce the likelihood of catching sea turtles (Bartram et al. 2010). Research on coastal salmon gillnet fisheries has indicated that some seabirds are most likely to interact with fishing gear during dawn and dusk, thus having restrictions on the time of day during which fishing is permitted should lower bycatch (Melvin 1999). In the US Atlantic lobster pot fishery, fishermen are required to use sinking lines (as opposed to the previously favored lines that float) to connect their pots. This reduces the amount of line floating in the water column, reducing the likelihood of a large whale becoming entangled in the gear (Werner et al. 2006; DOC 2007). The previously mentioned practice of setting purse seines on dolphins when targeting tuna in the eastern tropical Pacific is much less common now; it was prohibited by the European Economic Community in Council Regulation No. 3034 in 1992 and products caught in this manner are banned from import into the United States (Gosliner 1999; Kelleher 2005). Many tuna purse seiners use other methods of locating schools of tuna, especially FADs.

Other bycatch avoidance techniques have focused on reducing the attractiveness of fishing gear. Some longline fisheries are prohibited from dumping offal (fish processing waste) while the gear is being deployed which provides less of a foraging opportunity to seabirds (FAO 2003). During hauling in of the line, if offal must be dumped, it is dumped on the opposite side of the vessel, which attracts seabirds away from the hooks and remaining bait (Petersen et al. 2009a). Garrison (2007) found that reducing the overall length of a longline reduces the likelihood that a marine mammal will become hooked or entangled. He theorizes that a shorter main line makes a less attractive and less detectable food source. As such, the US pelagic longline fishery for tuna, swordfish and shark must limit main line length in the Mid-Atlantic Bight to 20 nautical miles (nm) to reduce serious injury and mortality (bycatch) of long-finned and short-finned pilot whales and Risso's dolphins. Additionally Kock et al. (2006) found that marine mammals may be attracted by the sounds accompanying haulback of longlines (possibly another type of "dinner bell effect"), thus shorter haulback times could be present a shorter window of opportunity for marine mammals to locate the fishing gear. Some species of sharks can detect the electrical field given off by metals in the lanthanide series, and research has shown that hooks made of these materials can deter capture of some species of shark (Hutchinson et al. 2012).

Yet another bycatch avoidance tactic is to alter or change bait. Dyeing squid bait blue reduces the number of interactions with seabirds, possibly by making the bait blend in better with water or appear to be deeper underwater (Boggs 2001; Cocking et al. 2008). In addition, birds are less likely to target dead bait because it sinks, whereas live bait will swim and stay at the surface longer (Trebilco et al. 2010). Also, the use of mackerel instead of squid has been shown to reduce sea turtle bycatch (Yokota et al. 2009; Foster et al. 2012).

Fishery management regulations can be designed to incentivize fishermen to avoid PET species, such as the Hawaii shallow-set longline fishery's limit on the number of permissible sea turtle interactions (NOAA PIRO 2013). After 26 interactions with leatherbacks or 34 interactions with loggerheads (verified through 100 percent observer coverage) the fishery closes for the remainder of the year. Theoretically, fishermen will be less likely to fish in areas where sea turtles tend to congregate.

Another method of avoiding capture is to close fishing in areas where PET species are often caught or during seasons when PET bycatch is high. In New Zealand, 240 nautical miles of coastline are encompassed by a protected area where gillnets are prohibited in order to protect the critically endangered Maui dolphin. The population is so depleted that it can withstand only one human-induced mortality every six years, thus fishery bycatch must be eliminated completely (Slooten et al. 2006). Off the coast of northern Chile areas with consistently warmer waters have been identified as loggerhead sea turtle bycatch hotspots, and have been closed to swordfish fishing (Donoso and Dutton 2010). In Australia, areas close to seabird breeding colonies have been closed to longline fishing completely (Trebilco et al. 2010).

Transition to a new type of fishing gear can also be a highly effective method of avoiding capture of PET species. The Mediterranean monk seal at the remote Desertas Islands in the Archipelago of Madeira was so depleted in the 1980s that the Islands were declared a nature reserve and all gill and trammel nets (another type of entangling net) were banned. Local fishermen were financially compensated and provided with more selective alternative fishing gear types such as longlines (Hale et al. 2011). The United Nations General Assembly banned large-scale high seas pelagic driftnets (gillnets fished in international waters) in 1989, because of their immense ability to catch many target and bycatch species even where densities are low (Northridge 1991). In 1992 the European Economic Community banned the use of driftnets longer than 2.5 km to decrease the incidental capture of marine mammals (Kelleher 2005).

Allow Escape

If it is not possible to avoid capture of PET species, the animals should be given an opportunity to escape the fishing gear. One of the mostly widespread bycatch reduction devices that allows escape is the turtle excluder device (TED) used in many shrimp fisheries around the world (Epperly 2003; FAO 2003; Kelleher 2005; Alió et al. 2010) including the United States, Mexico, Australia, Ecuador, Brazil and India (though enforcement is questionable in some areas). A TED is a grate, with bars spaced a few inches apart, sewn into the neck of the net at an angle towards an escape hatch cut in the net. When a turtle, or any other animal too large to pass through the grate, enters the net it is deflected by the angled grate and driven out the escape hatch. Smaller animals are swept through the grate and retained in the back of the net. Similar devices have been implemented in the arrow squid fishery in New Zealand to allow sea lions to escape (Chilvers 2008) and have been experimented with in midwater pelagic trawl fisheries off the northwest coast of Africa to address bycatch of turtles, manta rays, sunfish and dolphins (Zeeberg et al. 2006).

It is also possible to allow marine mammals to escape from purse seines. When a purse seine is set on schools of dolphin and tuna, the dolphin stay at the surface far away from the boat, and the tuna stay deeper in the water and race back and forth. When the tuna are close to the boat, the boat is put in reverse so the far section of the float line is allowed to sink below the surface to allow the dolphins a shallow escape channel. This technique, known as a "back down procedure," is used by many purse seiners in the eastern tropical Pacific tuna fishery and can be enhanced with a Medina panel (developed by tuna boat captain Joe Medina), which is a small mesh panel in the back down area that helps guide the animals out and keeps them from getting tangled in the net (Gosliner 1999).

In addition, fishing gear can be designed and manufactured with inherent weaknesses designed to allow PET species to break away from the gear, increasing their chance of survival. In the northwest Atlantic, the US lobster pot fishery and groundfish gillnet fishery are required to use lines with weak links that allow large whales to break free from fishing gear if the become entangled (DOC 2007).

The use of nylon leaders instead of wire leaders in the Australian tuna and billfish longline fishery has been shown to reduce bycatch of sharks by allowing the sharks to bite through the leader and swim away (Kelleher 2005; Afonso et al. 2012; AFMA 2013). A recent regulation in the US Gulf of Mexico pelagic longline fishery requires the use of weak hooks in the longline fishery. Research suggests that the weak hooks allowed larger tuna, such as the extremely depleted Atlantic bluefin tuna (harvest is prohibited in US Gulf of Mexico, a primary spawning location for this species), to escape from the line (DOC 2011).

Reduce Mortality

If there is no mechanism to allow a PET species to escape from fishing gear, the next step is to minimize the mortality that results from the interaction. One such mechanism is use of a circle hook instead of a "J" hook. A "J" hooks is shaped like the letter "J" – the barb of the hook is very exposed. In contrast, a circle hook is shaped more like a circle, with the barb pointing to the interior of the circle. When a "J" hook is swallowed, the barb is likely to lodge in the stomach or throat of the animal. When a circle hook is swallowed it can be pulled out of the stomach or throat, because the barb is somewhat protected, and typically catches in the animal's jaw – inflicting less damage and increasing the animal's chance of survival. Circle hooks have proven highly effective at reducing bycatch mortality of sea turtles in longline fisheries around the world, including the United States, Australia, and Costa Rica (FAO 2003; Ward et al. 2008; Sales et al. 2010).

Training fishermen to properly handle PET species that are captured in fishing gear can also increase an animal's chance of surviving the fishery encounter. Both Australia and the United States require longline fishermen to carry the equipment needed to safely handle and release sea turtles, and require the fishermen to attend workshops to learn the proper handling techniques (Kelleher 2005; NOAA OSF 2011; AFMA 2013).

Some prohibitions on shark finning are intended to increase their survival rate. If cutting off a shark's fins is prohibited, the fishermen must choose between storing the entire carcass for the duration of the trip, which can take a great deal of valuable space, or discarding the whole animal, possibly still alive (Patterson and Tudman 2009; DAFF 2011).

Many fisheries, including some in the United States and Australia, also have trip limits or prohibitions on landing protected species such as sharks, which eliminate the profit that can be made from retention of protected species (AFMA 2013; Fishwatch 2013). Instead, the PET species will be released and may survive the fishery interaction. Sweden prohibits the fishing and landing of small-spotted catshark, basking shark, porbeagle shark, common skate, and thornback ray in Swedish waters (Zidowitz et al. 2008). Retention and landing of common skate, undulate skate, white skate, and angel shark, among other species, are prohibited in many or all parts of European Union waters (Council Regulation (EC) No. 43/2009).

Case Studies of Best Practices in PET Species Bycatch Reduction

Photograph Credit: Braddock Spear

United States Atlantic Shrimp Fishery

Need

All five species of sea turtle commonly found in the territorial waters of the United States (loggerhead, green, Kemp's ridley, leatherback, and hawksbill) are listed as threatened or endangered under the Endangered Species Act, enabling the federal government to enact protective measures in both federal and state waters. During the 1970s, many loggerhead sea turtles washed up dead on beaches, and many scientists and conservationists believed these turtles had drowned in shrimp trawls. The federal government placed observers on shrimp boats in the Atlantic and Gulf of Mexico, and found that the US shrimp industry's catch of sea turtles was over 45,000 per year, resulting in 12,600 deaths (Henwood and Stunz 1987). Far more turtles were captured in Atlantic waters than in the Gulf at a ratio of 16:1 and most captures were loggerheads. Though the capture rate was higher in the Atlantic, the mortality was lower, at 21 percent, compared to 34 percent in the Gulf where longer tow times were used (Henwood and Stunz 1987). Studies suggested that limiting tow times to less than 60 minutes would reduce sea turtle mortality to less than 1 percent, but tow time limits are extremely difficult to monitor and enforce (Henwood and Stunz 1987).

Development

NOAA Fisheries, the federal regulator of commercial fishing, began to experiment with devices that would allow the turtles to escape from the nets. They initially experimented with a large mesh panel over the mouth of the trawl net. This panel did exclude sea turtles, but also entangled some in the webbing and caused substantial shrimp loss (15–30 percent) (Oravetz and Grant 1986).

The next attempt was modification of a device invented by a Georgia shrimper named Sinkey Boone, which he originally developed to reduce bycatch of cannonball jellyfish. Boone was using this "trawling efficiency device" in all his boats by 1969 and noticed a huge reduction in bycatch, including jellyfish, finfish, horseshoe crabs, sea turtles, and many other species (Boone 2007). The federal government modified this design, tested it with various shrimpers, and found that it released almost all sea turtles without losing as many shrimp as the previous device (Oravetz and Grant 1986).

By 1980, NOAA Fisheries had approved their first TED, based on Boone's jellyfish excluder – the first in the world (Epperly 2003). NOAA initially thought shrimpers might voluntarily use TEDs to reduce bycatch, and distributed many for free. Unfortunately the TED was large, heavy, and unwieldy and many fishermen were resistant to adopting the device. In addition, the shrimpers did not believe that their individual actions could have a substantial impact on the sea turtle populations and were not motivated to reduce turtle bycatch (Henwood and Stuntz, 1987). The TED design went through further modifications to make it lighter and easier to use, but still less than 1 percent of shrimpers were using TEDs voluntarily by the late 1980s (Oravetz and Grant 1986).

Implementation

Conservation organizations and the US Fish and Wildlife Service began to push for mandatory use of TEDs and NOAA Fisheries attempted to phase in regulations requiring TEDs in certain areas during certain seasons. These regulations met great resistance from the fishing industry, and TED opponents lobbied Congress and filed lawsuits in Louisiana, North Carolina, and South Carolina to delay or reverse TED implementation. The state legislatures of South Carolina, Georgia, and Florida passed state laws requiring TEDs in state waters, but some of these laws were also challenged in court. NOAA Fisheries eventually won the lawsuits but politicians intervened and forced suspensions and delays to TED regulations and enforcement (Epperly 2003). In addition, Louisiana passed a state law that prevented their state law enforcement officers from enforcing TED regulations – this law is still in effect today.

By 1990, TED regulations were implemented on a seasonal basis (when turtles were most present) and for ocean trawlers only (offshore federal waters). In some state waters, tow times could be used instead of TEDs (Epperly 2003). That same year, the National Research Council released a report on the decline of sea turtles that identified shrimp trawling as the primary source of human-induced mortality, resulting in as many as 44,000 deaths each year (NRC 1990). The report also indicated this mortality from shrimp trawling accounted for more sea turtle mortality than all other sources of human-induced mortality combined.

In 1992, NOAA Fisheries started to phase in mandatory TED use in state waters and all year round. By the end of 1994, TEDs were required in all otter trawls (essentially the sole gear used to harvest shrimp in federal waters) fished south of Cape Hatteras, inshore and offshore, all year round (Epperly 2003). Tow time limits are still permitted for some other types of trawls fishing in state waters (e.g., skimmer trawls in Louisiana state waters). The mandatory use of TEDs enabled the government to issue an incidental take statement, an exemption to the prohibition of take as required under the Endangered Species Act, allowing the shrimp fishery to continue to operate. TEDs also became required in some other trawl fisheries that interact with sea turtles, such as the winter trawl fishery for summer flounder in North Carolina and Virginia (Epperly 2003).

In 2003, new information suggested that 33–47 percent of stranded loggerheads and 1–7 percent of stranded green turtles were too large to fit through the TED openings and it was already known that leatherbacks were too large to fit through the TEDs (area closures had been used to reduce leatherback mortality). New regulations increasing the size of approved TEDs were soon implemented and were predicted to allow all size classes of loggerhead and leatherback turtles to escape, reducing shrimp trawl-related mortality by 94 percent for loggerheads and 96 percent for leatherbacks (DOC 2003). NOAA requires that certified TED designs release at least 97 percent of sea turtles. Fishermen, such as Boone, continued to develop modifications to TEDs to make them more effective (Boone 2007).

Enforcement

In 2012, NOAA initiated a re-examination of the shrimp fishery's impact on sea turtles because of evidence of non-compliance with TED regulations in 2010 and 2011 (NOAA 2012b). During enforcement inspections, a number of boats were found to be using TEDs that did not conform to the legal specifications. Many of these TEDs were new and the compliance issues were traced back to the net shops that manufactured the TEDS. Some of the issues were minor, such as improper floatation, excessive escape panel flap length, or improper bar spacing, while other issues were major, such as too steep an angle (small turtles will not find their way out) or too small an escape opening (preventing larger turtles from escaping). Compliance inspections and outreach throughout the spring and summer of 2011 improved compliance and lessened the severity of the violations. It is important to note that most of these violations were unintentional – shrimpers were not trying to undermine the TED regulations, they were often unaware that their TEDs were not in compliance.

Before this point, NOAA assumed that compliance with TED regulations was nearly 100 percent and allowed the 97 percent effectiveness rate of TEDs to serve as a proxy for sea turtle capture in the shrimp fishery (estimated 3 percent). Based on this new understanding of non-compliance (complete compliance is not likely to be obtainable, because even in the absence of willful disregard of TED regulations accidental non-compliance will occur), NOAA has proposed a new system to monitor and ensure compliance with sea turtle conservation regulations at a level that would keep sea turtle catch rates in shrimp trawls at or below 12 percent of all interactions (NOAA 2012b). This system became effective in June 2012. NOAA Fisheries is using detailed data on the type and severity of TED violations collected by the NOAA Law Enforcement to estimate sea turtle capture rates every 6 months (NOAA SERO 2013). If the fleet exceeds a threshold of 12 percent, NOAA will identify specific areas where non-compliance is occurring, target training and courtesy inspections in those areas, increase enforcement in those areas, and start monitoring on a monthly basis. If in 6 months NOAA finds that the capture rate has not decreased to below the threshold, area closures will be used in areas where shrimpers are not following the law (NOAA

SERO 2013). The results of the first 6-month review revealed that the average fleet-wide capture rate in shrimp trawls was 13 percent. The violations were not concentrated in any specific area of the Atlantic or Gulf of Mexico, so NOAA began holding informal training and courtesy dockside inspections throughout the region. NOAA will continue monitoring compliance data on a monthly basis to help ensure the shrimp otter trawl fleet achieves the capture rate performance standard in the next 6-month review (NOAA SERO 2013).

Results

According to NOAA Fisheries, the use of TEDs has had a significant beneficial impact on the survival and recovery of sea turtle species (DOC 2003). The Kemp's ridley, listed as endangered, had the lowest population level of any sea turtle species (believed to consist of a nesting population of fewer than 1,000 individuals in the mid-1980s, and at only one beach in Mexico). In 2011, there were over 20,000 nests in Mexico and 199 nests in Texas from a newly emerging nesting population. This increase is attributed to elimination of direct harvest, protection of nesting, use of TEDs, and reduced trawling effort in US and Mexico (NOAA 2012b). The loggerhead sea turtle in the Northwest Atlantic Ocean is listed as threatened. A long-term decline in nesting in southeast US has been interrupted with substantial upticks in 2008 and 2010 (record breaking years). In addition, scientific surveys suggest that juvenile turtle abundance in coastal waters is steady or increasing, with a 100-percent increase in catch per unit of effort from the early 1980s to the early 2000s (NOAA 2012b). Green, leatherback, and hawksbill sea turtles are listed as endangered, but in US waters populations appear to show an increasing trend in nesting (NOAA 2012b).

Many countries around the world have adopted TEDs based on the US design. Indonesia was the first, soon followed by Australia (Oravetz and Grant 1986; Epperly 2003). Some adopted TEDs voluntarily, while others were driven to do so by US Public Law 101-162, Section 609, passed by the US Congress in 1988. This law prohibited import into the US of shrimp and shrimp products that were harvested in a manner that may adversely affect sea turtles. In essence, countries desiring to send shrimp to the US had to adopt fishing methods that would protect sea turtles or only harvest shrimp in areas were turtles are not found. Adoption of TEDs was often the simplest method of achieving this goal and TEDs have been implemented in many places around the world, but not everywhere. The EU does not have a comparable law, and thus provides a market for shrimp harvested without TEDs (Epperly 2003). Clearly, market pressure from one country can affect change around the world, but lack of market pressure from other countries can provide outlets for fisheries that have not reduced bycatch of PET species.

Fishing Industry Perspective

**– Wayne Magwood,
Commercial Shrimper,
South Carolina**

Magwood believes that the use of TEDs in the shrimp industry has directly contributed to rebuilding of sea turtle populations. He has noticed significant increases in the number of sea turtles he sees in the water and has caught more turtles in his try net (a small test net that is fished for a short amount of time to obtain a sample of what is on the sea floor), sometimes even two or three turtles a day, in the last five years than ever before in his shrimping career, which began in the 1970s.

While shrimpers have become accustomed to TEDs and recognize the benefits they offer, such as elimination of heavy organisms such as sharks, rays, and jellyfish, Magwood points out that TED requirements saddle shrimpers with recurring expenses. TEDs can be damaged by large debris such as trees or tires and shrimpers must buy two or three sets of TEDs every year. Some types of debris, such as abandoned crab traps, can not only damage the TED but can also clog it, both preventing turtles from escaping by blocking the escape hatch and causing high loss rates of shrimp by holding the flap open.

In Magwood's opinion, the recent compliance problems are accidental; the penalties (high fines and potential loss of fishing permits) are severe enough to deter intentional non-compliance. But normal fishing behavior can lead to unintentional non-compliance. For example, interactions with large debris can cause bends or breaks of TED bars. Also, nets stretch with time and use, causing changes in the angle of the TED. These issues can also cause increases in shrimp loss, thus shrimpers have an interest in repairing the problems as soon as possible. But sometimes law enforcement boarding happens before the shrimper has an opportunity to fix or replace the TED, and the shrimpers receives a severe penalty for violation. Magwood has personal experience with such problems. In the mid-2000s, a tire hit a TED in one of his nets and broke a bar. On the return from the trip his boat was boarded by law enforcement and he received a violation notice and $8,000 in fines.

Conservation Perspective

– Kelly Thorvalson,
Sea Turtle Rescue Program Manager,
South Carolina Aquarium

According to Thorvalson, the correct use of TEDs dramatically reduces sea turtle mortalities. While many US shrimpers are compliant and remain diligent in using TEDs, some shrimpers still fight the TED requirements and will do what they can to skirt the law. These vessels are a substantial threat to sea turtle populations. In addition, the exemption to TED requirements for skimmer, butterfly, and pusher head trawls is problematic. Tow time limits are harder to regulate than the use of TEDs and a 55-minute tow time limit is pushing the boundaries of what a struggling sea turtle can handle. It would be in the best interest of sea turtles to require some sort of TED in all trawl fisheries that operate in sea turtle population waters, including foreign fisheries that export trawl-caught products to the US.

In Thorvalson's experience, some shrimpers actually like using TEDs because they eliminate all the large organisms and debris that increases drag on the net. The down side of course, is the potential loss of shrimp.

The new federal monitoring and compliance system, with the threshold of a 12-percent catch rate, has a lot of potential for positive impacts. First, it is a systematic approach to monitoring, which is very important. Second, if the fleet as a whole, or even regionally, is "charged" with the percent of captures from a few that are not in compliance, the accountability factor between shrimpers will be much greater.

While the threat to sea turtles from the shrimp industry has decreased, turtles continue to face many human-induced threats. Vessel strikes have become more common among the injuries treated in the South Carolina Aquarium's sea turtle hospital, and they now account for the majority of injuries and deaths of sea turtles off the South Carolina coast.

Swedish Eastern Baltic Cod Fishery

Need

The Baltic Sea is home to a critically endangered sub-population of harbor porpoise, believed to be fewer than 250 mature individuals (IUCN 2012), though assessments of the population size are highly uncertain. Bycatch of harbor porpoise in salmon driftnets and bottom set gillnets played a major role in the decline of this sub-population and continuing bycatch in fishing gear is believed to inhibit its recovery (ASCOBANS 2009). Along the German Baltic coast, as many as 170 harbor porpoise strand each year and many show signs of being caught in nets (ASCOBANS 2011a).

Development

In 2002, an alliance of countries under the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) set forth The Recovery Plan for Baltic Harbor Porpoises, also known as the Jastarnia Plan, with the goal of restoring the Baltic Sea harbor porpoise to at least 80 percent of the carrying capacity. In order to reach that goal, participants in the ASCOBANS Baltic Discussion Group and Jastarnia workshop agreed that bycatch must be moved towards zero (ASCOBANS 2009).

The Jastarnia Plan identified four primary approaches to rebuild the harbor porpoise population including reducing bycatch, supporting research, establishing a network of marine protected areas, and further educating the public. Of these, bycatch reduction is the highest priority. Bycatch reduction methods included: reduce fishing effort in certain fisheries; involve stakeholders in the work of reducing bycatch of harbor porpoises; replace fishing methods known to be associated with high porpoise bycatch; and implement use of pingers immediately (ASCOBANS 2009).

One of the most frequently used fishing gears for targeting Baltic Sea cod is the bottom-set gillnet. Each gillnet is 50–100 m long, and they are linked together in lines of seven to ten or more nets, called a "fleet." Multiple fleets are set during each fishing trip, resulting in thousands of meters of gillnet per fishing boat, and in 2011 there were 206 Swedish vessels using gillnets in the Baltic Sea (Königson et al. 2009; Hervás et al. 2011). Cumulatively, these gillnets represent a substantial threat to the harbor porpoise. But individually, fishermen are unlikely to interact with harbor porpoises because of the small population size, making it difficult for conservationists and fishery managers to convey the need for drastic and costly changes to fishing gear and methods (ASCOBANS 2011a; Hervás et al. 2011). As such, few of the Jastarnia Plan recommendations have been implemented in the Baltic Sea. Sweden offers one exception, with a pilot project that is developing a cod pot as an alternative to gillnets.

Implementation

In actuality, this pilot project was not spurred by the need to reduce harbor porpoise bycatch, it was motivated by a need to reduce predation by seals on gillnetted cod. During the decade preceding the initiation of the project, the number of seals in the Baltic Sea increased while the number of cod decreased, leading to a rise in depredation (removal of fish from fishing gear by a predator) (Königson et al. 2009). (The Eastern Baltic Sea cod population has since rebuilt to above target levels.) Gillnetted cod are damaged or completely removed from the nets by seals, reducing the volume of harvested cod by up to 67 percent and sometimes damaging the fishing gear (Königson et al. 2009). The seals do occasionally become entangled, but this bycatch is not a major concern because most seal populations, especially the grey seal that is the most frequent culprit, are increasing (Königson 2011). Depredation is a serious economic issue for this fishery, and led the Swedish Board of Fisheries to investigate an alternative gear type, the cod pot, that would protect the cod from seals. Since 2011, the Swedish University of Agriculture Science has led this work.

The cod pot was based on a Norwegian two-chambered, floating cod pot (Ovegård et al. 2010; Hervás et al. 2011). The pots are one-cubic-meter cages that are strung together and set about 50 meters apart (The Fisheries Secretariat 2010). This new gear was piloted with three fishermen in Sweden (ASCOBANS 2011a), and found to be species-selective for cod and a viable and promising alternative gear for this fishery (The Fisheries Secretariat 2010; Königson 2010; Ovegård et al. 2010). One study suggested that the total annual harvest with pots could be higher than with longline or gillnet, though they are more effective in some seasons (July–December) than others (February–June) and sometimes catch far fewer cod than longline or gillnet (Königson 2010). The addition of an escape window on one end of the pot made the gear even more effective by reducing the proportion of undersized cod in the pots by more than 90 percent (Ovegård et al. 2010).

Results

The Eastern Baltic cod fishery entered the Marine Stewardship Council certification process in 2010. The application included gillnet, trawl, longline, and the newly developed pots, even though only three vessels were fishing with them at the time and the gear was still in the trial-and-development phase. The trawl, longline, and pot fisheries were awarded MSC certification in 2011, while the gillnet fishery failed the certification process because of the status and management of PET species interactions (Hervás et al. 2011).

Many side benefits have come with this new gear, not the least of which is the reduced threat to harbor porpoises (The Fisheries Secretariat 2010; Hervás et al. 2011). Other benefits include live catch (increasing the quality and value of the target species), reduced ghost-fishing impact, species and size selectivity, no effect on the sea floor, and the ability to leave the pots in the water for a longer amount of time (Königson 2010). Yet some disadvantages remain. Further work on seal exclusion (like a seal exclusion grid or different net materials) is needed and is in progress (The Fisheries Secretariat 2010; Königson 2011). In addition, these pots are not easy to handle in their current design, are not efficient in all seasons, and though the government-funded research has demonstrated profitable catch rates, fishermen do not believe the pots will be profitable in practice (see stakeholder perspectives below). And finally, transition to this gear will also require substantial investments by the fishing fleet and require the continuing purchase of bait (Königson 2010).

Sweden is implementing a program for fishermen to use up to 200 pots commercially (ASCOBANS 2012) and a Swedish fishing gear company is working on a project to develop a full-scale cod pot fishing method (ASCOBANS 2011b). ASCOBANS has encouraged other countries to follow Sweden's example of developing alternative gears and both the Netherlands and Finland are promoting experimentation with and adoption of cod pots (ASCOBANS 2011a).

Fishing Industry Perspective

– Bengt Gunnarsson,
Fiskbranchens Riksförbunds (Federation of Swedish Fish Industries and Trade)

– Tore Johnnson,
Sveriges Fiskares Riksförbund
(Swedish Fishermen's Federation)

According to Gunnarsson and Johnnson, transition from gillnet to cod pot is possible, but few fishermen are experimenting with cod pots and the gear currently does not appear to be profitable. Only the three fishermen who participated in the original pilot project are using the pots, and others are resistant to the idea of gear transition because of the apparent lack of profitability.

There is also some resistance to gear transition because of the substantial capital costs that must be invested up front for a fisherman to transition over to a whole new type of gear, both in the purchase of the gear and in actions needed to alter the fishing boats to be able to safely carry the traps.

In addition, seal depredation is still possible in the current pot design and additional modifications are needed before the fishermen will view the pots as a potential large-scale alternative to gillnets.

One factor that could encourage fishermen to transition to cod pots is an increase in requests for pot-caught cod, or a premium price for pot-caught cod. Yet, it will still be necessary for a fisherman to catch a reasonable amount of cod with this gear type, or even demand and higher price will not motivate transition.

Conservation Perspective

– Charlotta Järnmark
World Wildlife Fund
Sweden

– Inger Näslund,
World Wildlife Fund
Sweden

Järnmark and Näslund believe that transition from gillnet to cod pot is a promising alternative to reduce harbor porpoise bycatch mortality in some areas, as long as the pots are constructed in a way eliminating all possibilities for mammals to enter the trap, but point to the critical need to motivate fishermen to make this transition. Fishermen currently estimate that pot-caught cod would need to receive a higher price than gillnet-caught cod, possibly as much as double, to make it profitable. In mid-2013 there will be further testing of cod pots by a gear manufacturer, including testing of bait and cage design, to increase the amount of cod caught in the pots and seal-proof the cages.

Järnmark also pointed to a report by the Swedish University of Agricultural Sciences that indicates their tests of cod pots have a rate of cod harvest that should be profitable, and have already made modifications to the gear that prevent seals from tearing the netting or compressing the cage to get the fish. This information suggests that research studies are capable of catching cod in pots at a profitable rate, but the industry has yet to see evidence that pots can be scaled up to profitability on their level. Encouragement from the supply chain could motivate the fishermen to experiment with the new gear, as could the recent MSC certification. The MSC has among the highest-rated recognition in sustainable brands among Swedish consumers, and it gives certified products a higher market value, which could help to increase the profitability of the pots.

Gear transition is a tool that World Wildlife Fund (WWF) has used in that past, the Smart Fishing Initiative for example, and species and size selective gear types have been implemented in Sweden and elsewhere in the EU due to WWF work. The salmon fishery in the Baltic Sea once used drift nets, but after that gear was banned fishermen transitioned to longlines in the open sea and traps along the coast. A number of other fish are also targeted with traps, with advantages like size selectivity and live retention.

But bycatch reduction in the cod fishery is not the only factor that must be addressed to rebuild the harbor porpoise population; gillnets are used to target other species as well. But the number of harbor porpoises in the Baltic Sea is so low, that issues beyond bycatch must also be addressed. A new conservation plan for management of harbor porpoise in the Kattegat and Belt Seas will include stakeholders from all the industries that affect harbor porpoise, from fishing to shipping. There is also a need to protect habitat, especially calving and nursery grounds.

California Groundfish Fishery

Need

PET species are not limited to those that are accidentally caught by fisheries. In some cases, target fish species become so depleted that they become PET species. Cowcod in the California groundfish fishery provide one such example. Cowcod is a member of the rockfish family in the northeastern Pacific, ranging from central Oregon (in the United States) to central Baja California (in Mexico), with a center of distribution off the southern coast of the US state of California (NOAA 2009). Cowcod live on high-relief rocky bottoms in 20 to 500 m depths. They have a long life span, approximately 55 years, and reach large sizes of 1 m in length. Cowcod grow slowly and utilize internal fertilization, a rare trait for a marine fish. These characteristics make them very vulnerable to fishing pressure.

Harvest of cowcod peaked in 1976 at 194 mt, then fell to 19 mt in 1998; the estimated population biomass in 1976 was 1665 mt and declined to an estimated 238 mt in 1998. The first stock assessment of cowcod was performed in 1999 and indicated that cowcod was severely overfished, at only 4–7 percent of unfished biomass (NOAA 2009). It was subsequently identified as a Species of Concern under the Endangered Species Act.

Development and Implementation

Traditional fishery management would typically require reduced harvest or a moratorium on harvest until the population is rebuilt. This strategy forces fishermen to discard the fish in question, in hopes that some of the discarded fish live and contribute to rebuilding the population. In the case of cowcod, a deep dwelling fish, such catch and release will not work because of the damage to the fish’s swim bladder caused by the rapid change in depth during capture; discard mortality is very high (NOAA 2009).

Thus, in addition to a complete prohibition on cowcod retention (Dick 2011), the Pacific Fishery Management Council and the State of California jointly implemented depth-based Cowcod Conservation Areas (CCAs) covering 11,000 square kilometers (4,300 square miles) in the Southern California Bight (CDFW 2013). The CCAs were sited in the area where cowcod historically were most abundant and that had generated the greatest amounts of cowcod harvest, and also encompassed the areas where most adult cowcod habitat is found (CDFW 2013). In the CCAs, most bottom fishing is prohibited in areas deeper than 20 fathoms (approximately 36.5 meters) and retention of cowcod by both commercial and recreational fishermen is prohibited. Some exceptions are made for demersal seine nets and hook and line gear that are used to target a few other species of fish and that are unlikely to catch cowcod.

Results

The CCAs have been effective in minimizing fishing mortality over rocky habitat in the Southern California Bight (Dick et al. 2009). Though discard mortality persists outside the CCAs, total mortality has been below the targeted levels every year since 2000 (Dick 2011). The most recent cowcod stock assessment update was completed in 2009 and indicated that spawning biomass was between 4 percent and 21 percent of unfished levels (Dick 2011), reflecting either a stabilized population or a recovering population. A long-lived, slow-growing species like cowcod would be expected to rebuild slowly, especially because it is impossible to completely eliminate bycatch mortality without shutting down all bottom fishing, thus even stabilization of the population size is a good sign. As of 2012, cowcod was in year 12 of a 67-year rebuilding plan and current population size is believed to be 11 percent of the target size (NOAA 2012c).

The California groundfish fishery has demonstrated successful reductions in cowcod bycatch through area closures, but there have been negative effects as well. First, by closing an area to fishing, especially one responsible for the majority of harvest, not only do fishermen lose access to other productive fish species but also fishery scientists and managers lose a substantial data collection tool: the commercial fishery itself (NOAA 2009). Fishery-dependent data such as landings and catch per unit effort are often the backbone of stock assessments. Fishery-independent data, such as scientific surveys, are costly and less plentiful. Beginning in 2011, the portion of the commercial trawl fishery governed by Individual Fishing Quotas is permitted to retain cowcod (still, no trawling is permitted in the CCAs). This fleet maintains 100-percent observer coverage, which records estimates of retained and discarded catch. This fishery is producing important data for stock assessments (Dick 2011).

Fishing Industry Perspective

**– Gerry Richter,
Commercial Fisherman,
California**

According to Richter, the CCAs have been an effective way to protect cowcod, but have come with devastating effects on the groundfish industry.

Richter was part of the team that created the CCAs and used historical catch data from the charter boat industry to identify the traditional cowcod fishery area that produced about 50 percent of the historical catch. This protected area has led to an increase in the cowcod population, which can be seen in fishery observer data from fishing activities outside of the CCAs. There are no monitoring or research surveys inside the CCAs, thus a lack of information about the amount of cowcod inside the closures.

When the CCAs were implemented, groundfish fishermen in Southern California lost most of their traditional fishing grounds for deeper water slope species like sablefish and thornyhead, because the CCAs were a blanket closure that did not allow any bottom fishing in a very large area, even on non-cowcod habitat. Richter pointed out that if these specific area closures had not been implemented, the alternative may have been a complete closure of all fishing grounds deeper than 30 fathoms (approximately 55 meters), and would have produced a more devastating result.

Fishermen were resistant to the CCAs from the start and, even though cowcod stocks appear to be rebuilding, their feelings against such closures have grown even stronger because of the multiple Marine Protected Areas and National Marine Sanctuary closures that have also occurred. The prevailing sentiment is that they are running out of areas to fish.

Conservation Perspective

– Karen Garrison,
Natural Resources Defense Council,
California

While Garrison believes the CCAs have contributed to significant reductions in cowcod mortality and to stabilizing the population, she notes that it is too early to be certain that the cowcod population is rebuilding. For such a long-lived species, recovery is likely to take many decades. She does point to some encouraging signs, though: scientists have found fairly dense aggregations of cowcod in unfished areas, suggesting that protecting cowcod habitat from fishing allows an increase in the population. Additionally, there are anecdotal reports that fishermen are seeing more cowcod in the water. Quantifying and verifying this with data will be difficult, however, because much of the cowcod habitat is closed to fishing and data from the recreational fishery are very limited. Garrison notes that fishery-independent studies are needed, particularly those involving cameras and other non-lethal observation techniques.

Closed areas have been successful in this region for other species. Rockfish Conservation Areas, put in place around 2002, reduced bycatch of several other depleted rockfish significantly and helped put those stocks on the road to recovery. Other best practices include vessel monitoring systems, a robust observer program, improved real-time communication among some fishermen, and the use of barotrauma reduction techniques in the recreational fishery. All of these have helped to enhance the effectiveness of area closures.

Garrison also notes that adverse economic effects on the fishery are not solely from CCAs. For example, over-exploitation of cowcod and other rockfish species has reduced the available biomass. Closed areas like the CCAs can also have ancillary benefits. For example, the CCAs likely have benefited other deep-water populations like blackgill rockfish. Also, marine protected areas in California's state waters are already showing evidence of more mature individuals of several groundfish species and greater numbers of black abalone than in similar fished areas.

Australia Tuna and Billfish Fishery

Need

Some fisheries have the unfortunate distinction of interacting with multiple kinds of PET species, and therefore must adopt a range of mitigation measures to reduce or eliminate problematic bycatch and interactions. The Australian pelagic longline fishery targeting tuna and billfish is one such fishery. It is divided into the Eastern Tuna and Billfish Fishery (ETBF) operating off the eastern portion of the country in the Western Central Pacific Ocean, and the Western Tuna and Billfish Fishery (WTBF) operating off the western portion of the country in the waters of the Indian Ocean. The level of effort in the WTBF is low and there is currently little concern for interactions with protected species (AFMA 2010a), thus this case study will focus on the ETBF. The ETBF targets yellowfin, albacore, and bigeye tuna, as well as broadbill swordfish and striped marlin. While pelagic longline is the primary gear, minor amounts of the target species are also harvested with troll, handline, and rod and reel (AFMA 2013).

Development and Implementation

The ETBF catches a range of non-target species, including sharks, seabirds, marine mammals, and marine turtles – most of which are classified as protected species according to the EPBC Act. The Australian Fisheries Management Authority (AFMA) conducts comprehensive, multi-stage ecological risk assessments (ERAs) to identify vulnerable bycatch species. In the initial phase, the ETBF ERA examined 390 species and found that nearly 10 percent of those (34 species) were potentially at high risk from the fishery. Further analyses were conducted to pinpoint specific species that require extra protective measures, resulting in an ecological risk management (ERM) response to reduce interactions with marine turtles, seabirds, sharks, and whales (Woodhams et al. 2011).

AFMA has implemented a Bycatch and Discarding Workplan containing strategies to minimize bycatch in this fishery and ensure that bycatch impacts on the ecosystem are sustainable. In addition, the ETBF developed an Industry Code of Practice for Responsible Fishing (CoP) in 2003, which specifies voluntary bycatch mitigation measures and handling and release guidelines (AFMA 2013). Federal monitoring includes mandatory reporting of protected species interaction in logbooks, catch disposal records, and mandatory observers. All vessels are given a protected species identification guide to help them identify species with which they interact. There are concerns that logbook data is not reliable, and comparisons between observer data and logbook data suggest that the logbook reporting rate is poor (Baker and Finley 2010). A better audit and enforcement process is needed to ensure compliance with logbooks. In addition, the ETBF is moving towards use of electronic logbooks, which are easier to fill out and submit. This may help to increase compliance.

The current target for observer coverage is 8.5 percent across the fishery, with a minimum of 5 percent in each 5-degree latitudinal band (AFMA 2010b). Actual rates in recent years have been below the target, at 3.6 percent in 2010 and 6.3 percent in 2011 (Patterson and Sahlqvist 2011, Patterson et al. 2012). Data from 2012 were not yet available at the time of publication of this report. While these observer coverage rates may be adequate for frequently encountered species, they are unlikely to generate robust data for rarely encountered species (Bravington et al. 2002, Baker and Finley 2010). In 2013 AFMA is implementing electronic monitoring (EM) systems, using cameras to record harvest and discards, in the ETBF (AFMA 2013). This will result in 100-percent electronic monitoring of the fishery, including protected species monitoring. Generally, only a proportion of EM footage is reviewed on a regular basis, then data are extrapolated to calculate fishery-wide statistics and can be used to audit the accuracy of self-reported data. Footage can be stored and reviewed in its entirety, if need be.

Marine mammals

Marine mammals such as whales and dolphins can be caught on ETBF longlines or tangled in the gear when they prey upon baited hooks and hooked catch. Fishermen are required to report all interactions with marine mammals. The most commonly hooked/tangled marine mammals are short-finned pilot whales and toothed whales, followed by melon-headed, humpback, and beaked whales. Fortunately, most of these whales are released alive, thus no special bycatch mitigation measures are currently required, however, the probability of post-release mortality is not well understood. Fishermen are encouraged to test marine mammal bycatch mitigation tools, and are also equipped with line cutters and de-hookers that enable release with less damage to the animal. From 2006 to 2010, only 20 marine mammal interactions were reported in logbooks and four were documented by fishery observers; these interactions are expected to result in only one to two marine mammal direct mortalities per year (AFMA 2013).

Sea turtles

Green and leatherback are the species of sea turtle most frequently captured on Australian longlines, especially those setting their hooks within 100 m of the surface (referred to as a shallow set). According to the industry logbooks, 75–95 percent of turtles are released alive. Some of this live release may be attributed to the line cutters and de-hookers that each vessel must carry, so that turtles and other PET species can be easily removed from fishing gear should they become hooked or entangled (AFMA 2010b, AFMA 2013). In addition, pelagic longline captains and crew attend educational programs on safe handling and proper resuscitation techniques for turtles that are brought aboard the vessel. The Australian government also has implemented a 10-nautical-mile longline exclusion zone around known nesting beaches during nesting season, when sea turtles are in those areas in high concentrations (AFMA 2010b). All vessels participating in the ETBF must carry a satellite tracking system (called a vessel monitoring system, or VMS) at all times, which helps to enforce closed areas (AFMA 2012c).

The Australian sea turtle bycatch mitigation strategy, approved in 2009, mandates that interaction rates with sea turtles must be maintained below a rate of 0.0040 turtles per thousand hooks (or one turtle per 250,000 hooks set), with the exception of green turtle bycatch, which must be maintained at less than 0.0048 turtles per thousand hooks (approximately one turtle per 200,000 hooks set). (As a point of reference, the pelagic longline sector of the ETBF sets eight to nine million hooks per year; thus the triggers allow for interactions with about 30–45 of each species of turtle per year.) If one of these triggers is exceeded in one year, a Sea Turtle Mitigation Working Group is convened to determine what measures AFMA and/or the industry can implement to reduce turtle bycatch to below the trigger level. If the trigger is exceeded again in the second year, vessels targeting swordfish with shallow set methods must use whole fish for bait and wide circle hooks. If the trigger is exceeded again in the third year, AFMA will implement a trip limit of 20 swordfish unless a fisher applies for exemption under which they can only use whole fish bait and wide circle hooks (AFMA 2010b). The Australian Tuna and Billfish Bycatch and Discarding Workplan considered making circle hooks compulsory in the ETBF to reduce risk to turtles and marlin, but several studies have documented that circle hooks increased shark catch rates in some pelagic longline fisheries (Ward et al. 2008; AFMA 2010a; Gilman et al. 2012,). Other studies have indicated that circle hooks do not have a substantial effect on catch rates of sharks, but do reduce mortality (Godin et al. 2012). More targeted research on the effects of circle hooks on sharks is needed.

Sharks

The catch levels of sharks (including retained and discarded catch) in the ETBF is the highest of all Australian fisheries (DAFF 2011). According to 2012 fishery logbooks, the ETBF primarily interacts with shortfin mako (the vast majority of reported interactions), longfin mako, and porbeagle sharks (AFMA 2012a). These three species are listed as Vulnerable on the IUCN Red List, and were recently added to Appendix II of the Convention on Migratory Species (CMS). This appendix is for species that have an unfavorable conservation status or that would benefit from international cooperation, but are not endangered. According to observer records from 2007 through 2010, the most commonly caught sharks in the ETBF were blue, shortfin mako, and tiger sharks (shortfin mako are often retained, while other species are usually released). Blue and tiger sharks are not listed on a CMS appendix and the IUCN Red List categorizes them as Near Threatened (which is slightly better than Vulnerable).

Many species of sharks are believed to typically survive fishery interactions if they are not intentionally injured or killed. Observers report that most sharks caught and released in the ETBF fishery are alive (57–98 percent), and of those, many are in vigorous condition (40–98 percent). The ETBF is also known to interact with two protected shark species: great white and grey nurse (AFMA 2013). The grey nurse shark was the world’s first protected shark species (protected in New South Wales, Australia, in 1984) because of declines in the population due to heavy exploitation in the 1960s. The east coast population of grey nurse shark is critically endangered (Patterson and Tudman 2009), though not due to longline bycatch, and no grey nurse shark interactions have been reported or observed in the ETBF since 2007 (AFMA 2013). Great white sharks are considered vulnerable under Australia’s EPBC Act and are listed in CITES Appendix II. Illegal trade of fins and jaws are primary drivers in white shark harvest (Patterson and Tudman 2009). Two interactions were reported in logbooks in the ETBF during 2006–2010, both of which resulted in mortality (there were no observed interactions) (AFMA 2013).

Most sharks interacted with are pelagic and highly migratory, thus they are impacted by other countries as well. Australia has an international obligation to manage them under their membership in the Western and Central Pacific Fisheries Commission (WCPFC) (AFMA 2013). As suggested by the FAO's International Plan of Action for Sharks, Australia has developed a National Plan of Action for Sharks (NPOA-Sharks) to assess conservation and management issues concerning sharks and identify needed research and management actions (DAFF 2012).

Mitigation measures in the ETBF are designed to increase the chances of sharks surviving fishery interactions. Harvest of the following sharks is completely prohibited: great white, grey nurse, school, gummy, elephant, sawshark, and a number of deepwater sharks (AFMA 2012b), most of which do not overlap with the fishery. In addition, retention or trading of shortfin mako, longfin mako, or porbeagle sharks that are caught alive is prohibited – they may only be retained if they are retrieved dead. Vessels are also subject to a byproduct retention limit of 20 sharks per trip. Any sharks caught, dead or alive, in excess of that trip limit must be discarded (AFMA 2013).

When sharks are brought to the boat live, the Chondrichthyan guide for fisheries managers recommends that they be kept in the water and cut free from the line as close to the hook as possible, to minimize the length of trailing line attached to the shark after release. If sharks must be brought on deck, fishermen should minimize the amount of time they are out of the water (Patterson and Tudman 2009). All vessels in the ETBF are given line cutters and de-hookers to improve the survival prospects of live-released sharks (AFMA 2013).

Another mitigation measure designed to reduce shark catch rates and possibly to increase the likelihood of shark survival is a ban on the use of wire trace leaders. Sharks are more likely to bite through synthetic materials, such as monofilament nylon, allowing them to quickly escape instead of struggling to free themselves until the vessel hauls in the gear (AFMA 2013). This regulation has proven to reduce shark bycatch rates, but little is known about shark escapee mortality – i.e., what proportion of sharks that escape with terminal tackle attached survive (Patterson and Tudman 2009).

Finally, AFMA has banned the practice of finning sharks at sea (it is illegal to possess or land fins that have been separated from the carcass), preventing fishermen from cutting the high-value fins off of a shark and discarding the low-value body (Patterson and Tudman 2009; DAFF 2011). In addition, shark livers may not be landed without the body in Commonwealth fisheries (Patterson and Tudman 2009).

Seabirds

A wide variety of seabirds are affected by the ETBF, including over 20 species of albatross, seven species of petrel, four species of shearwater, and the southern skua (DEWR 2006). Initially, albatross were the primary species of concern, but a geographic shift in fishing effort has made bycatch of flesh-footed shearwaters more severe (DEWR 2006).

AFMA collects fishery data via logbooks and VMS on the number, species, and life status of seabirds caught; type of bait used; fishing gear and mitigation measures used and stage of operation when the catch occurred; time of day/night of the line setting and haul; date and location of the catch; and external factors (weather conditions, moon phase) that may influence bycatch. In addition, they require that all seabirds killed on pelagic or demersal longlines in Australian waters be brought aboard the vessel; reported to AFMA; reported to Australian Bird and Bat Banding Schemes if banded; and collected for scientific analysis and stored in a way that will preserve it properly, then transported to a storage and analysis facility (DEWR 2006). According to Baker and Finley (2010), seabird bycatch rates from logbook information were underestimated. Robust observer data is imperative and will likely require higher levels of coverage than are currently applied. The new electronic monitoring systems being implemented in 2013 could provide the necessary information.

Seabird bycatch mitigation measures are designed to deter capture. All longline vessels fishing south of 25° S are required to: use at least one tori line; use only thawed bait; use a line weighting system; and not discharge offal while setting (they also are discouraged from doing so while hauling). While fishing north of 25° S, vessels are required to carry an assembled tori line, carry weights for longlines, and obey the same offal discharge restrictions. Tori lines must be at least 100 m long, be deployed such that the line stays above water for 90 m, and have streamers attached every 3.5 m that are maintained as close to the water as possible (AFMA 2012b; AFMA 2013).

In addition, a voluntary seabird Code of Practice suggests that longline fishermen use tori lines even where not required, puncture swim bladder of thawed bait to make it sink faster, use a bait-casting machine, select gear that minimizes bycatch of seabirds, practice safe handling and release, and practice night setting (AFMA 2013).

Seabird bycatch in Australia is managed under the Threat Abatement Plan (TAP), with an objective to significantly reduce bycatch of seabirds at current fishing levels and an ultimate aim of zero bycatch of seabirds, especially threatened species, in longline fisheries (DEWR 2006). Under the TAP, the interaction rate for seabirds must be less than 0.05 seabirds per 1,000 hooks set in all seasons and all areas (based on the previously mentioned estimate of eight million to nine million hooks set per year, this is 400–450 birds total, across the entire fishery). If that threshold is exceeded in any area or any season, AFMA will implement more stringent management, like closures and night setting requirements. According to fishery logbooks (though accuracy of these data is questionable), that level is rarely exceeded (AFMA 2013).

Fishing Industry Perspective

**– Gary Heilmann,
Commercial Eastern Billfish
and Tuna Fisherman,
Queensland, Australia**

Heilmann believes that the bycatch reduction regulations have been effective. In fact, many of these techniques were implemented voluntarily by the fishing industry before they were made mandatory by the government.

According to Heilmann, the shark trip limit works very well because it reinforces the point that the fishery is not targeting sharks. The fishing industry supported the ban on wire traces as a way to further emphasize the fact that they do not target sharks; in fact, many vessels had already transitioned away from wire leaders when the regulation was implemented. A reduction in bycatch of sharks has been very evident to the fishermen, but commercial fishermen are concerned that this could be misconstrued by scientists and conservationists who interpret it as evidence of further depletion of shark populations.

The use of line cutter and de-hookers for sea turtles, as well as proper handling techniques, is another example of successful bycatch mitigation that was initially implemented by the industry on a voluntary basis, and then eventually made mandatory. The fishing industry worked with turtle researchers to implement appropriate devices then conducted port meetings to teach the handling techniques and provided a DVD demonstrating the procedures.

According to Heilmann, the most effective seabird bycatch reduction technique was the compulsory use of tori lines below 25° S and use of weighted lines. The industry is constantly trialing different line weighting designs to maximize effectiveness and is assisting in the design and development of an underwater setting chute to further reduce seabird bycatch.

The bycatch reduction technique with which the industry seems to be displeased is the use of interactions trigger limits. In Heilmann's opinion, this type of approach does not actually address the cause of the bycatch. Instead, he believes that bycatch mitigation should concentrate on reducing mortality instead of just limiting the number of interactions, and should focus on more at-risk species such as leatherback sea turtles and albatross. The fishery could theoretically be closed based purely on the number of interactions that occurred, even if no mortality occurred and even if the interactions were with a less at-risk species. Fortunately, the Management Advisory Committee looks at the details of the interactions to determine if there is a pattern in the bycatch and if there is anything that can be done to improve performance of the fishery as an alternative to closures.

Another example of innovation driven by the fishing industry is the widespread use of circle hooks. Though not required by the government, circle hooks have been proven to reduce bycatch and generally have a higher "live on line" count for tuna catch because the fish are more likely to be hooked in the mouth and not the gut. The same is true for PET species such as sharks and sea turtles, resulting in lower bycatch mortality. The fishermen are considering advocating for mandatory use of circle hooks as another sustainability selling point for their fishery.

In addition, the fishing industry has pushed AFMA to implement EMS instead of onboard observer coverage. EMS will increase the quantity and quality of bycatch data, but will also reduce monitoring costs overall.

Most fishermen initially see these sorts of bycatch mitigation measures as interfering with their right to fish but usually can be persuaded to see the issues from the perspective of other stakeholders as well. At the same time, conservationists must remember harvest of wild seafood comes with side effects, as does all food production. Instead of pushing for absolutely no interaction, which may not be possible, a more realistic desired outcome is minimization of bycatch.

Conservation Perspective

– Peter Trott,
Policy Manager – Fishery Markets,
WWF Australia

According to Trott, the ETBF is highly professional and business savvy. They recognize the conservation benefits of bycatch reduction and have learned to use it to their advantage in marketing their products.

In Trott's opinion, the ban on wire trace has probably been the most effective shark bycatch mitigation measure. Though the shark may swim away with a hook lodged in its mouth, or even its gut, and may eventually die, "at least it was alive in the ocean, not dead on the deck." The survival rate of these sharks is unknown, but at the very least it is higher than the survival rate of sharks that struggle on the line for hours, building up lactic acid, or sharks that are brought up on the deck of the boat to be de-hooked, which is often accomplished after restraining the shark to reduce danger to the crew. Circle hooks are also extremely beneficial in this situation, because they are far more likely to lodge in the mouth than in the gut, increasing the shark's chance of survival. A negative side effect of the wire trace ban on the fishing industry that was brought up by Trott, but not Heilmann, is that some industry members believe that the use of wire leaders can also result in the loss of big tuna and swordfish, leading to negative economic outcomes. Trott also pointed out that this comes with a corollary conservation benefit to the target species, as large female tuna that escape from the fishing gear have a great deal of breeding potential.

The trip limits are moderately effective if there is good compliance and monitoring (as is the case in Australian territorial waters). Trott suggests that some fishermen may actually target their trip limit of sharks, then return to port to offload and sell to markets willing to pay a premium for shark. The impending use of EMS should shed light on the prevalence of this practice. While the trip limits were an initial step in the right direction, in Trott's opinion, they are now outdated and retention of sharks should be completely prohibited.

The most effective bycatch mitigation measure for sea turtles has been the safe handling practices and gear to go with them. Without proper training, the fishing crews would have no idea how to best handle a turtle for its safety. In addition, it is very rare that the ETBF actually catches a sea turtle, possibly due to the widespread voluntary use of circle hooks.

According to Trott, there is no doubt that the seabird mitigation measures have led to a significant reduction in bycatch. Longlines had a devastating effect on seabird populations, but due to the mitigation measures in place, the fishery bycatch rates are nowhere near the level that would have a significant impact on the populations. Some less impacted populations have stabilized or begun to recover. Unfortunately, there have been no signs of rebuilding of the most significantly impacted seabirds such as the wandering albatross and flesh-footed shearwater. This lack of recovery can be attributed to land-based issues in their nesting colonies, such as rodent predation and land clearing, that may not effect a robust population but have substantial impacts on a severely depleted population. There is still some bycatch of seabirds, but potential solutions remain. For example, if scientists determine the location of hotspots where interactions occur at the highest levels, then managers could create an incentive system for fishermen to avoid those areas.

Summary of Best Practices in Developing Bycatch Mitigation Measures

A number of best practices in developing bycatch mitigation measures become clear upon examination of these case studies. While this is not a comprehensive list, these practices are a good basis from which to start.

1. **Representatives from the fishing industry must be included from the beginning.** Fishermen have spent years maintaining and modifying fishing gear and often have the most innovative and practical ideas for how to adjust gear to reduce bycatch. As demonstrated by the US shrimp fishery case study, the TED developed by the government was impractical and eventually was replaced with a similar device that had already been developed by a fisherman. Baltic Sea cod fishermen have participated in the pilot project to test the cod pots, helping to ensure that the designs are viable, yet cooperative work with fishermen must continue to bring these pots to full implementation. ETBF fishermen developed many of the bycatch reduction techniques now mandated in their fishery. But even if fishermen are involved from the beginning they still may not be satisfied with the final results, as seen in the California cowcod case study. Representation from the scientific and conservation communities is also imperative during early stages of development, to ensure the bycatch mitigation techniques meet conservation goals and are scientifically evaluable.

2. **Have a clear understanding of PET bycatch reduction – why it is required and how it can be achieved.** There must be a scientifically proven need for bycatch reduction. Though conservationists often have strong emotional desires to protect PET species, these emotions are not enough justification for fishermen or fishery managers to risk the economic returns to the fishing industry. PET bycatch reduction often comes with costs, sometimes substantial costs (as shown in both the California cowcod and Baltic Sea cod case studies), and all stakeholders must be able to weigh both the costs and benefits. Australia conducts ecological risk assessments, which provide justification for bycatch reduction, and this helps the fishing industry see the issue from other perspectives and accept the need for bycatch reduction. The US government spent a decade trying to convince shrimpers to voluntarily adopt TEDs, but the shrimpers did not see a clear need to do so from their individual perspective. It wasn't until the cumulative impacts were clearly demonstrated in the 1990 National Research Council report on the decline of sea turtles that the government shifted to mandatory implementation of TEDs. Conversely, ASCOBANS has spent over a decade trying to reduce bycatch of harbor porpoise but few changes have been implemented, in part due to the uncertainty in the estimates of the harbor porpoise population, but also because, like US shrimpers in the 1980s, the fishermen struggle to accept that their individual actions could have such a devastating effect on the porpoise population.

3. **Ensure that there is a mechanism in place to measure impacts and outcomes and encourage modifications.** All stakeholders should be committed to continuing research to evaluate the success (or lack thereof) of the bycatch reduction measures. If successful, there may be a point where less severe bycatch mitigation measures are required. For example, the cowcod area closures have closed off a very important fishing area to all bottom fishing. As cowcod recover, it is possible that the closure

could be modified to allow some types of fishing or be reduced in size, alleviating some of the economic stressors on the fishing industry. Unfortunately, the CCAs were not designed with a mechanism, such as a fishery-independent survey inside the CCAs, to measure increases in the cowcod population and stock assessments are based on sparse data and return highly uncertain results. If bycatch mitigation measures are successful, as is the case with TEDs in the US shrimp fishery and seabird mitigation in the Australian ETBF, increases in PET species populations and the efforts made by the fishing industry should be recognized and promoted. Continuing research and evaluation may also highlight possible modifications to mitigation methods, which could make them even more effective. US TED specifications have been altered a number of times, and the fishing industry continues to develop new designs to make TEDs more effective. Fishermen and researchers in the Baltic Sea cod fishery intend to continue to modify the cod pot design to make it more secure from seals and ensure it is an economically viable alternative gear. In the ETBF, fishermen have a long history of proactive modifications to fishing techniques and they continue to investigate new methods of bycatch reduction such as the underwater longline setting chutes to reduce seabird bycatch.

4. **Monitoring and enforcement of bycatch mitigation measures is crucial.** Change is difficult. Mandatory bycatch reduction measures present a challenge to the fishing industry and are often viewed as interference with their right to fish or conduct business in the manner they choose. In the early stages of implementation, it is very important to have both outreach to ensure the required changes are understood, and accountability if the changes are not implemented. But continuing monitoring and enforcement after bycatch mitigation measures are implemented is also important to ensure there is not slippage, either intentional or accidental. One of the primary reasons Australia has been so successful in the ETBF bycatch reduction is the strong accountability, including vessel monitoring systems, mandatory observer coverage, and the impending transition to electronic monitoring systems (though poor compliance with logbooks limits the efficacy of the bycatch triggers). Conversely, TED enforcement in the US shrimp fishery likely was not high enough after the initial implementation in the early 1990s, leading to widespread accidental non-compliance in 2010 and 2011.

5. **Voluntary adoption of best practices is a good start, but eventually, legal mandates for mitigation measures may be needed.** Encouraging fishermen to develop and adopt bycatch mitigation measures, such as through an industry Code of Good Practice is a good starting point. If the bycatch mitigation measures demonstrate side benefits to the fishermen, voluntary adoption may occur. The use of circle hooks in the Australian ETBF is widespread because fishermen recognize the bycatch reduction benefits and that circle hooks have resulted in higher product quality because more target species are alive when retrieved. Additional encouragement from the supply chain may be needed in the Baltic Sea cod fishery to encourage voluntary transition from gillnet to cod pot. Cod pots result in higher-quality product, but fishermen may need to receive a price premium to encourage them to incur the expense of gear transition. But in some cases, voluntary adoption does not occur and mandatory implementation must be required (consider the case of TEDs in the US shrimp fishery), especially if the PET bycatch species stock status is at a critically low level or if the bycatch mitigation measure has a negative economic impact. Mandatory changes are likely going to be necessary in the Baltic Sea cod fishery if the local sub-population of harbor porpoise is to be saved. Yet, voluntary implementation by a portion of the fishing industry can lay the groundwork and build a case for mandatory requirements, and can also ease the transition from voluntary to mandatory (demonstrated multiple times in the Australian ETBF case study).

Practical Actions Recommended to Seafood Suppliers and Buyers

Seafood companies seeking to improve the environmental performance of their source fisheries should consider the impact of those fisheries on PET species. It may be necessary to develop procurement policies stating that source fisheries that impact PET species must work to minimize that impact. One such mechanism is participation in a fishery improvement project (FIP), but impacts can also be addressed on an ad hoc basis. The following is a list of practical actions that should be taken to implement PET bycatch mitigation.

1. Identify the source fisheries that are interacting with PET species and prioritize them based on risk – both risk to the PET species (e.g., severely depleted species) and risk to your business (e.g., high-profile PET species or fisheries or high purchase-volume fisheries).

2. Engage with the fishing industry to determine how PET bycatch occurs and enlist their participation in developing mitigation measures.

3. Support the formation of an interdisciplinary work group, including fishermen, scientists, managers, and conservationists. The work group should look to other similar fisheries around the world to obtain ideas of bycatch reduction techniques that have been tested and/or implemented. Bycatch reduction techniques should be considered in the following order:

   a. Avoid capture of PET species by changes in fishing practices or gear types or by instituting fishing closures in certain areas or seasons.

   b. If avoidance is not possible, seek techniques or gear modifications that will allow the PET species to escape from the fishing gear.

   c. If escapement is not possible, seek techniques or gear modifications that reduce the mortality caused by the interaction with the fishing gear.

4. Encourage the fishing industry to develop and voluntarily adopt changes to fishing practices or gear, potentially including creation of a Code of Good Practice.

5. Encourage the government and/or fishery management authority to implement new regulations mandating PET bycatch mitigation techniques.

6. Support and promote fisheries that successfully adopt PET bycatch techniques. Conversely, if fisheries are unwilling to reduce PET bycatch to the necessary levels, seafood suppliers and buyers may need to place a moratorium on purchases of those fishery products. In this, hopefully rare, case, suppliers and buyers should be clear to the industry and fishery managers why the moratorium on purchases has been implemented and what steps must be taken by the industry and government to lift that moratorium.

Reduction of PET species bycatch is an important component of ecosystem-based fishery management. It is also an issue that attracts a great deal of attention from consumers and conservationists. Seafood suppliers and buyers should work with their source fisheries to quantify, monitor, and reduce any impacts that occur. There are numerous examples around the world that demonstrate successful PET bycatch reduction, and cooperative actions by the seafood supply chain can ensure productive seafood supplies for the future while protecting important components of the marine ecosystem.

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Appendix I

Fishing Gear

Below is a general review of the fishing methods that most commonly affect PET species, including illustrations, as described by the Food and Agriculture Organization of the United Nations (FAO 2013c), unless otherwise noted.

Trawls

Trawls (Figure 1) are cone-shaped nets that are dragged across the sea floor (bottom trawls) or through the water column (mid-water trawls) and filter the water to harvest all species in their path. They can be towed by one or two boats and can vary greatly in size. The mesh size of the net can be used to regulate the species or fish sizes that are trapped in the net, but trawl nets are often used to target small species like shrimp and small fish and thus catch a great number of non-target species, including PET species. This bycatch is often discarded at sea, some of it already dead. Worldwide, bottom trawls account for over 50 percent of bycatch, but only 22 percent of total harvest, and account for the most discarded bycatch by weight; mid-water trawls account for the third highest amount of discarded bycatch by weight (Kelleher 2005).

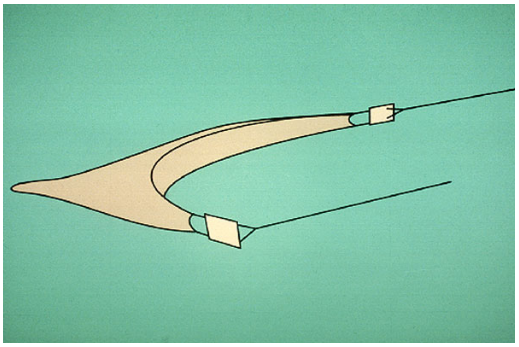

Figure 1: Trawl net.
A cone-shaped net that is dragged through the water. This image shows an otter trawl, with the two "otter boards" at the corners of the net, which help to hold open the mouth of the net as it moves through the water.

Dredges

Dredges (Figure 2) are similar to bottom trawls, but typically have a metal frame holding the mouth open, and have a bag or cone-shaped net made of metal rings or meshes. Dredges are often used in rougher areas or with more abrasive targets such as shellfish and molluscs. Bycatch is similar to that of trawls.

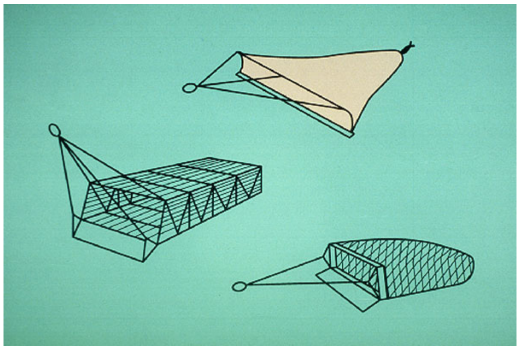

Figure 2: Dredges.
A metal cage or bag that is dragged across the sea floor.

Purse seines

Purse seines (Figure 3) consist of a long, vertical wall of netting with a float line at the top and a lead line (weighted line) at the bottom. This net is used to encircle a school or dense aggregation of fish (possibly aggregated around a floating object or under a light at night). The main vessel drops off a second smaller vessel (or just a buoy if only one vessels is used) with the beginning of the net attached, and then moves away in a circular path, surrounding the school of fish. After the circle of netting is complete the main vessel retrieves the skiff or buoy and secures the ends of the net. Along the lower edge of the gear there are a series of rings, with a line of steel wire or rope running through them. This line is drawn in to "purse" or gather the bottom of the net, until the rings are pulled up and out of the water and are hanging over the side of the boat. Then the net webbing is pulled in until the fish are gathered closely in the net beside the boat, and then they can be brought aboard the vessel with pumps or large baskets (called brailing). Purse seining can have minimal amounts of bycatch if set around species-specific schools of fish, but often undersized fish or other species are present in the aggregation and are also caught. The use of fish aggregating devices (FADs), man-made floating objects (usually bamboo rafts with old nets hanging underneath) deployed by fishermen to attract fish, has been increasing since the 1990s. Purse seines set around FADs typically have higher rates of bycatch than when set around free-swimming schools of fish (Dagorn and Restrepo 2011). Purse seines are often used to target tuna, and these tuna purse seines account for the fourth highest amount of bycatch by weight (Kelleher 2005).

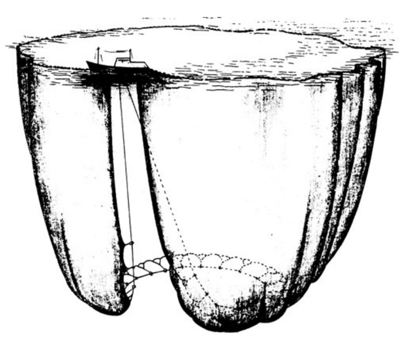

Figure 3: Purse seine.
A wall of netting that is set in a circular fashion, then gathered or "pursed" at the bottom to prevent fish from escaping.

Gillnets

Gillnets (Figure 4) are panels of net that are hung vertically in the water and used to intercept fish that are swimming through the area. Floats on the upper line (head rope) and weights on the bottom line (ground line or foot rope) hold the net in a vertical and spread position. These nets can be single-, double-, or triple-walled. Some are designed to tangle around the whole body of the fish, while others are meant to allow the fish to swim into and partially through the net, then catch on the gill plate of the fish as it tries to back out of the net. Gillnets can be fished at the surface, mid-water, or bottom, and can be set/fixed (anchored to the sea floor) or drifting (free-floating in the water, possibly attached to a boat). Mesh size can be used to regulate the size of fish caught in the net but incidental catch of other species, especially PET species, is a major concern. In 1991, the United Nations banned the use of large-scale high seas driftnets greater than 2.5 km in length because of their immense ability to catch sea creatures.

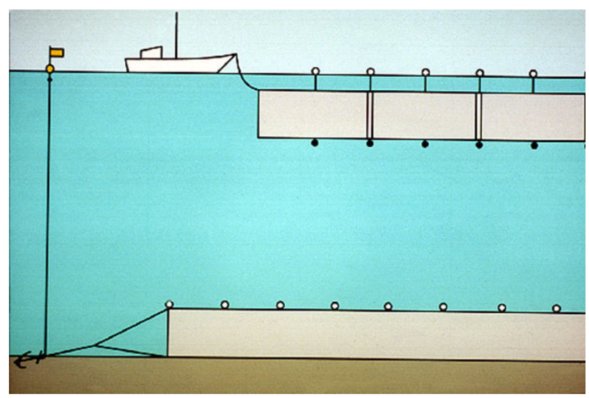

Figure 4: Drift and fixed gillnets.
In this illustration, the drift net is set near the surface and tethered to a vessel (not all drift nets are tethered to a vessel, some are free drifting). The fixed gillnet is anchored to the sea floor and marked with a surface buoy. Fixed gillnets can also be set to fish higher in the water column.

Longlines

Longlines (Figure 5) are a type of hook and line gear consisting of one long main line with branch lines, or snoods, coming off at regular intervals with hooks attached to each. Longlines can be set to drift at a certain depth in the water column, called pelagic longlines, or can be set to fish on or near the bottom, called bottom or set longlines. Pelagic longlines are suspended from surface buoys, while bottom longlines are pulled to the sea floor with weights and small buoys attached to the top line of the net hold it in a vertical position. Longlines have a surface buoy with a flag or lamp attached to each end to be a marker for the beginning and end of the gear. Longlines are usually set from the stern of a vessel and the hooks are baited and branch lines are attached to the main line as it is deployed. After the whole line, sometimes kilometers long, is set out, the gear is left to drift and fish (often all day or over night). Pelagic longlines are often used to target pelagic species of fish like swordfish, tuna, and sharks and bottom longlines are often used to target bottom dwelling fish like cod, halibut, or grouper. Bycatch of seabirds, sea turtles, sharks, and other non-target fish are common. Tuna and other highly migratory species longline fisheries are responsible for the second highest bycatch by weight worldwide (Kelleher 2005).

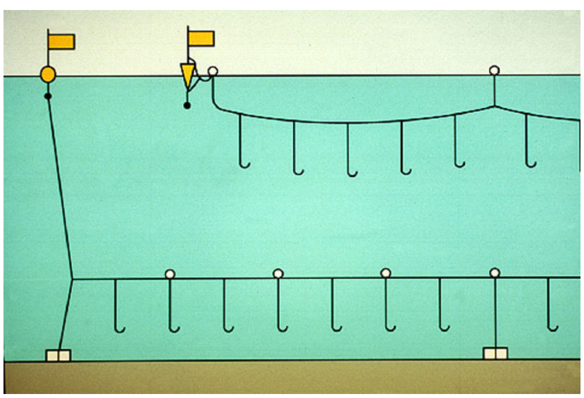

Figure 5: Longlines.
Both pelagic and bottom or set longlines are depicted. Pelagic longlines are suspended in the mid to upper water column by buoys, while bottom longlines are pulled to the bottom with weights while small buoys hold the main line off the sea floor.

Pots

Pots (Figure 6) are cages or baskets that animals enter voluntarily, often lured in by bait or the shelter provided by the pot, but are prevented from escaping by a one-way entrance. They are usually used to catch lobsters, crab, shrimp, octopus, eel, and reef fish. Undersized fish are usually able to escape a via appropriately sized escape holes, if used, or through the mesh of the pot itself. While PET species are not usually caught in the pots themselves, they can become entangled in the lines that connect to the pots to each other in a string or to a surface buoy marking their location.

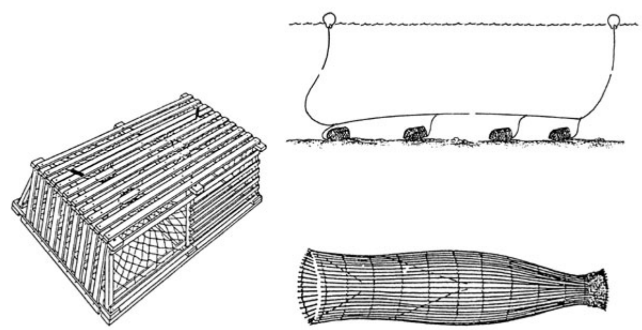

Figure 6: Pots, or traps.
Animals can enter but not escape. They are held in the pot until released by the fisherman. Sometimes pots are held together in a string, attached to each other and to surface buoys with ropes or lines (upper illustration).