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Bycatch: Causes, Impacts, and Reduction of Incidental Captures

Paulo de Tarso Chaves
Department of Zoology, Federal University of Parana, Curitiba, Brazil

Definitions

Catch, from a fishery perspective, includes all living biological material, such as corals, jellyfish, tunicates, sponges, and other noncommercial organisms, retained or captured using fishing gear. **Target catch** is the catch of a species or species assemblage that is primarily sought in a particular fishery, such as shrimp, flounders, or cods. **Incidental catch** is the retained catch of non-targeted species, for example, aquatic mammals, turtles, and seabirds. Conversely, **discards** is that portion of the catch returned to the sea as a result of economic, legal, or personal considerations.

Bycatch is the total catch of non-target animals. It can be explained assuming *animals* in a "species" sense; in this case, bycatch excludes the target species. In contrast, when considering *animals* in an "individual" sense, all individuals discarded after being caught, including juveniles and undersized organisms of target species, constitute bycatch, with no distintion between target and non-target species. Bycatch is usally thrown back to water, dead or dying, or likely to die. However, a fraction of the bycatch is commonly retained to be sold.

Therefore, bycatch is the discarded catch plus incidental catch. Discarded catches frequently include non-marketable individuals of target species; hence, this proposal does not exclude the bycatch of the target species. Hereafter, bycatch is considered in such a broad sense: the total catch of non-target individuals, which implies discarding of target and non-target species, and retention of non-target species (incidental catch).

Introduction

During fishing, many animals are retained by nets, traps, and baited lines. In addition to fish, crustaceans and mollusks, also mammals, birds, reptiles, as well as echinoderms and other invertebrates, are caught. Captures different from those targeted by fishers are known as bycatch (Kelleher 2005), an occurrence that can overcome the target resources (Costa et al. 2008). National Marine Fisheries Service (2011) does not distinguish between target and non-target species, and adds to bycatch any unobserved mortality due to a direct encounter with fishing gear. The retained catch of non-targeted species is considered a particular type of bycatch, the incidental catch (Alverson et al. 1994; Kelleher 2005). Conversely, discards is that portion of the catch returned to water as a result of economic, legal,

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or personal considerations (Alverson et al. op. cit.).

Bycatch is common in marine fisheries. Raby et al. (2011) reviewed a total of 1,152 papers on bycatch and discarding and stated that 96% bycatch were from marine fisheries. However, bycatch also occurs in inland waters, where crocodiles, turtles, otter, and platypus are often killed by fishing (Raby et al. 2011; Serena et al. 2016). Bycatch is more commonly reported in commercial fisheries; as a result, research on bycatch and mitigation efforts have focused on large-scale industrial fisheries. But bycatch from recreational fishing can also have a significant effect on some non-target species Bell and Lyle 2016; Fisheries New Zealand 2020; and Serena et al. (2016) reported that, between 1980 and 2009, 56% of platypus deaths with an identifiable cause in Victoria, Australia, were due to drowning in traps or nets set by recreational fishers.

Bycatch is accumulated because target and non-target species share a common habitat and are both vulnerable to the same fishing gear. For example, shrimp and fish occupy the benthic zone exposed to trawling (Broadhurst 2000; He 2007; Pina and Chaves 2009) (Fig. 1); crabs and octopods cohabit with lobsters in benthic zones exposed to gillnets and traps (Groeneveld et al. 2006; Giraldes et al. 2015); fish, turtles, penguins, and mammals use pelagic waters exposed to setnets during migratory movements (Cheng and Tien-Hsi 1997; Cardoso et al. 2011; FAO 2020).

Low selectivity is the main cause of bycatch. Trawl nets go through a reduction in mesh size when used; consequently, several unintentional materials are captured, mainly small-sized benthic organisms. In contrast, traps and pots are less restrictive to individual size, but are strongly selective by habits; further, carnivorous mammals, reptiles, and cephalopods are attracted by baits destined for lobsters and crabs (Groeneveld et al. 2006; Serena et al. 2016).

Bycatch and incidental captures are also accumulated when the fishing gear is deployed. Such gear commonly affects seabirds and pinnipeds, which are attracted by available food. Another incidental capture is that of dugongs, dolphins, and whales in control nets deployed to avoid sharks in coastal waters, common in Australia. Such captures are not linked to commercial or recreational fisheries, but are also classified as bycatch (Erbe and McPherson 2012). Similarly, the capture of non-target specimens in fisheries with a scientific purpose also constitutes a bycatch; for example, crustaceans caught in samplings for fish inventories, and vice versa. Thus far, the impact of scientific fishing efforts on the aquatic fauna has been neglected; further, the

Bycatch: Causes, Impacts, and Reduction of Incidental Captures, Fig. 1 Shrimp trawling is a common source of bycatch, and fishers have to segregate the marketable and non-marketable products species and biomass that are affected by such fishing efforts remain unknown.

Fishing grounds generally overlap with foraging areas, as in the case of wintering and breeding marine birds in southern Brazil (Bugoni et al. 2008). This cohabitation is stressed when aquatic predators such as sharks, dolphins, albatrosses, and petrels get caught on baited hooks or fish get entangled in the longlines and gillnets (Cardoso et al. 2011), or when platypus enters a trap after detecting the target resource, a crayfish (Serena et al. 2016). In fact, the gut contents of fish caught during shrimp trawling is commonly filled with shrimps and other invertebrates, demonstrating that the non-target capture was feeding on the target (Gomes and Chaves 2006).

Quantifying Bycatch

The complete knowledge and quantification of bycatch effects on natural populations requires knowledge of life history, demographics, population connectivity, and trophic interactions as well as ecological relationships between target and non-target species (Komoroske and Lewison 2015). The total volume of bycatch accumulated worldwide is unknown, in part because of the discards before landing. Most bycatch is discarded aboard for two reasons: low economic interest, depending on species, individual size, and sanitary conditions; and landing interdiction, varying among species, legal size, and period of the year. Estimated levels of discards from shrimp fisheries could reach at least 85% of the total bycatch (world estimates for 1983: 11.2 million t bycatch, 9.5 million t discards – Alverson et al. 1994). In Tasmania, gillnet fisheries discard over half of the commercial catch, with discard rates of 80% for non-target species (Bell and Lyle 2016). Physiological stress and injury by entanglement accelerate animal death. Indeed, high losses occur by predation on fish during the retention time, from a few minutes in recreational fisheries to several hours in commercial ones. Opportunistic carnivores, such as puffers and crabs, bite fish in gillnets and hooks, killing them and contributing to catch losses.

Globally, total bycatch is estimated to represent 40.4% of global marine catches (Davies et al. 2009); however, a great part of bycatch capture is neglected by official statistics. Considering marine capture data, in 2014 (81.5 Mt) bycatch had summed 32.9 Mt (FAO 2016), a volume superior to that estimated in 1990 of 28 Mt (FAO 1996). Juvenile catches in industrial fisheries, especially those of small pelagics (e.g., sardines and anchovies), have not been adequately reflected in the estimates of most countries, while large-scale bycatch of turtles, cetaceans, pinnipeds, and seabirds are not generally quantified by any existing system or research (Davies et al. 2009).

Information on incidental capture can be documented in the fishers' logbooks or by independent observer programs. However, these tools are not available for most fisheries and regions, particularly for artisanal and small-scale fisheries, a particularly data-poor sector. Research and other vessels conducting fishery-independent surveys can provide useful information on the identity and quantity of incidental captures (Kennelly 1995). For example, studies have recognized oceanographic conditions and habitat features associated with the distribution of loggerhead and leatherback turtles off Hawaii (Komoroske and Lewison 2015). The study promoted the NOAA-led program *Turtlewatch*, which created weekly maps depicting ocean areas where bycatch of both species was more likely to occur. Even so, by the known "observer effect," observed fishers tend to follow best practice fishing principles, producing not 100% reliable data, which are subject to be underestimated (Davies et al. 2009).

Impacts

Scientists agree that bycatch represents a risk for conservation. Many threatened, endangered, or protected species are exposed to non-target fishing that has affected their natural populations. Pelagic longlines used by industrial fleets, for example, are a primary source of mortality to seabirds and marine turtles. Some marine turtles are protected because they exhibit special life history characteristics, such as slow maturation, low fecundity, and high adult survivorship. Data compiled by Lenta and Squires (2017) indicate that incidental capture is the greatest direct threat to marine mammals, and in this group, the annual mortality reaches globally 665,000 individuals. The lobster gillnet fisheries constitute a major source of mortality that likely has seriously negative impacts on the depleted eastern Pacific hawksbill population (Liles et al. 2017).

Sharks and rays are strongly vulnerable to baited hooks in pelagic and bottom longlines. They are also entangled by trammel nets and gillnets while trying to catch other fish (Costa and Chaves 2006) (Fig. 2). Hooks, gillnets, and traps also affect air-breathing species, such as reptiles, birds, and mammals, that will drown within a few minutes after retention (Bugoni et al. 2008; FAO 2009; Serena et al. 2016; Fisheries New Zealand 2020). In the case of turtles, juveniles (Cheng and Tien-Hsi 1997) and nesting females (Silva et al. 2010) are also a cause for concern.

Low size selectivity of fishing gears such as trawl nets for shrimps has an impact on juvenile finfish and on adult crustaceans particularly crabs, on mollusks such as bivalves and gastropods, and on echinoderms, such as sand dollars and sea stars. Frequently, adults are caught during the spawning season.

Unfortunately, laws implemented to protect breeding season of a target resource can neglect the life cycle of cohabitant species (Souza and Chaves 2007; Pina and Chaves 2009). Ecological disturbances can occur from bycatch. In northeastern Brazil, Giraldes et al. (2015) reported that decapod species caught in lobster fisheries play a role as detritivores, herbivores, and first consumers within the reef ecosystem. They are also natural prey items for reef fish species. Therefore, the removal of benthic organisms affects the abundance and fish species that occupy these

Bycatch: Causes, Impacts, and Reduction of Incidental Captures, Fig. 2 Fishers throwing to the birds the invertebrates that landed with the main catch habitats, generating cascading effects throughout the food web (Kennelly 1995).

The quantification of the biological effects of bycatch is a multidisciplinary challenge. Komoroske and Lewison (2015) stated that bycatch affects all ecological levels, causing population decline, sinks populations of species, and changes food web interactions. Alverson et al. (1994) pointed out that the bycatch of species having life history strategies – with or without parental care – and reproductive and natural mortality rates similar to that of target species, may have less impact than the capture, in which the life history features differ between bycatch species and target species.

The impacts from bycatch are considerable not only for conservation, but also on economic indicators. Discards frequently include non-marketable individuals of target species, for example, fish entangled in gillnets for a long time, resulting in unsatisfactory *sanitary conditions*. These catches are omitted in fishery assessments. Indeed, as a large proportion of bycatch takes as juvenile fish, the average weight of which is much lighter than the weight of the larger fish recorded in the statistics of landings. The ecological importance of these juveniles to the marine environment is therefore not adequately conveyed when expressed in weight; thus, the ecological impact of bycatch is potentially far greater than can be reflected in this current estimate (Davies et al. 2009).

Lenta and Squires (2017) argue that the costs of catching endangered species have to be internalized in fisheries costs. Discarded fish generally include small individuals of commercially valued species (Souza and Chaves 2007), having a significant impact on adult stocks and fisheries yield. Kennelly (1995) suggests that this may not have any detectable effect on subsequent stocks of fisheries if most juveniles would have died of natural causes. Normally, fishery interaction problems exist, in which, for example, discards from demersal trawling conflicts with other fisheries that target the bycatch species that are discarded by trawlers.

Other economic implications from bycatch result from predation by non-target organisms on target organisms. In lobster trap-fishery, Groeneveld et al. (2006) observed that octopuses can enter traps, feed, and escape before lines are hauled. Gut contents showed that 80% of them had a preference for the bait. In these fisheries, bycatch benefits from lengthening the available time for escape.

Currently, the costs of bycatch are not factored into the costs of fishing. For example, concerning the impacts of bycatch on marine mammals, seafood from fisheries with marine mammal bycatch seems to be overproduced and underpriced, with a negative public perception (Lenta and Squires 2017; FAO 2020). As commented by the FAO (2016), excessive bycatch is often a problem for fishers as it slows their catch sorting operations considerably, causing inferior catch quality, and in trawling fisheries, particularly, it increases fuel consumption.

Economic losses are also registered in fishing gear. Non-target animals like pinnipeds and dolphins cut cables and nets. Destruction, accidental movements, and loss of fishing gears are currently attributed to entangled large fish and reptiles, too. Penguins and dolphins are generally avoided by professional gillnet fishers (Cardoso et al. 2011).

Ethical implications must also be considered. Kennelly (1995) demonstrated that when hundreds of thousands of juvenile fish were bycatch, protests against commercial and recreational fisheries were recorded. At the consumer level, the capture of non-target species may disqualify a fish product from a specific label even when the bycatch species is not depleted (FAO 2016).

In contrast, seabirds are simultaneously “beneficiaries” and victims. Coastal birds benefit from bycatch because a large part of small fish and invertebrates, those with no economic value, are discarded before landing. Studies cited by Tsukamoto et al. (2008) indicate that over 80% by weight of discards sink and that 14% of them are available to seabirds. These fish are generally benthic and are normally not accessible to pelagic predators, and thus, are exposed to scavenging by petrels, albatrosses, sharks, mammals, and other carnivores. Behavior of birds and dolphins suggests that they have learned to follow trawlers (Kennelly 1995). This unnatural food availability is responsible for the increased bird densities in certain coastal areas subjected to intense fishing efforts (Wagner and Boersma 2011) (Fig. 2). Simultaneously, in coastal and oceanic waters, penguins and other birds that forage underwater are caught by fishing gears when feeding on baited hooks, or on fish kept by gillnets and hooks (Cardoso et al. 2011; Fisheries New Zealand 2020).

Human Use of Bycatch

The Nordic Council of Ministers NCM (2003) refers to bycatch as "the proportion of the catch that is taken on board, or brought to the surface by the vessel, which is subsequently thrown back to sea, dead or dying, or likely to die". It assumes that all bycatch is discarded, which is not true. Although a bycatch definition could be "catch that is either unused or unmanaged" (Davies et al. 2009), these captures are frequently welcome by fishers. During benthic trawling, for example, several fish with economic value are caught, being an interesting byproduct of shrimp fisheries. Bluefish, mackerel, weakfish, and sharks feed on benthic invertebrates; thus, they occur together with seabob shrimp. Depending on their individual size, this byproduct is sometimes sold at a higher price than that of shrimps. In southern Brazil, Gomes and Chaves (2006) found that 35% of trawling bycatch species is locally marketed. However, the size of marketed individuals is larger than that of the samples of bycatch in shrimp fisheries. Conversely, gillnets for demersal fish, such as croaker and flatfish, can retain large shrimps, which are easily marketable. This commercial bycatch (Costa et al. 2008) includes cephalopods, crabs, and cartilaginous fish, varying according to the fishing gear employed. Octopus bycatch is currently an additional product of lobster-fishery that can be sold to increase earnings (Groeneveld et al. 2006). In contrast, in many fisheries, non-target organisms are poorly used. This is the case with lobster fisheries performed in northeastern Brazil, where the large crab *Damithrax hispidus is* even more abundant than the target spiny lobster, *Panulirus echinatus*; however, only the chelipeds from larger crabs are used, while the rest of the body is discarded on the beach (Giraldes et al. 2015).

The use of bycatch extrapolates commercial purposes and can include cultural components, as is the case for cetaceans. In Gambia, Senegal, and Guinea-Bissau, Leeney et al. (2015) reported that dolphin bycatch is generally distributed among the community as food as well as for medicinal purposes and for traditional ceremonies.

The landing of all bycatch, instead of discarding them, is controversial. The FAO (1996) assumes that the landing of bycatch is a fundamental solution to the bycatch and discard issue. In fact, the production of food to satisfy human and animal requirements is a global challenge. Martin (2017) suggests that a possible solution for the food crisis resides in making more with less, by using the enormous amount of protein discarded as bycatch. For this, Kennelly (1995) states that more diverse markets for such products need to be developed. In contrast, today, discards represent a traditional food for marine birds (Fig. 3). Consequently, Soriano-Redondo et al. (2016) warn that the recent reform of the European Common Fisheries Policy, which intends to ban discards through the landing obligation of all catches, may force seabirds to seek alternative food sources. These authors found that the probability of bird interactions with longliners increases as the number of trawlers (many discards) decreases. Thus, the landing obligation of trawlers bycatch should be carefully monitored and counterbalanced with bycatch mitigation measures in the longline fleet.

Reducing Bycatch

Supporting a better use of bycatch is welcome; however, this does not mean to support bycatch. Prize initiatives for the development of practical, innovative fishing gear (www.wwf.panda.org) designed to avoid unwished captures should be encouraged. Lenta and Squires (2017) cite an example of reward for reducing bycatch of marine mammals, the SmartGear prize. Policies on this matter are available in several countries, and new designs for gears are being developed to increase

Bycatch: Causes, Impacts, and Reduction of Incidental Captures, Fig. 3 Selling of bycatch: small pickled fish sold in Southeastern Brazil

the survival of animals after release. In the tuna fishing industry, for example, Bugoni et al. (2008) found that mortality is particularly high when longline uses small hooks, as they are easier to be swallowed by birds. In addition, gear-based and non-gear adaptations are recommended by Willems et al. (2016) to further reduce the bycatch of small individuals.

Incidental captures and bycatch are expected in all fisheries; further, adaptations in fishing gear as well as regulations created for their operation and overall bycatch quotas have been developed to avoid unwished catches. Technological adaptations explore differences between target and non-target animals according to their behavior or size (Broadhurst 2000; He 2007; Serena et al. 2016; FAO 2018). Traps for crabs can add an extra opening to the roof of traps, improving the platypus's and freshwater turtles' ability to escape in a timely manner. In longline fishing, circle hooks are more effective for avoiding turtles than the conventional J-hook design. Circle hooks and traps designed to reduce bycatch and damage to traps are also being developed in shark sanctuaries. A decrease in bird apprehension by hooks can also be obtained by deploying weights, weighted lines, and longer secondary lines (Bugoni et al. 2008). Bycatch reduction devices (BRDs) in shrimp trawl nets consist of a particular mesh design on the top of the net, allowing fish to escape during trawling. In Suriname's seabob shrimp fisheries, a reduction in the overall catch rate of rays was estimated at 36.1% using the alternate mesh design (Willems et al. 2016). In 1987 the US government passed a federal bycatch regulation that required all shrimp trawlers to use turtle excluder devices (TEDs) while fishing in US waters. TEDs are grids of bars with an opening either at the top or at the bottom of the trawl net; fish and turtles are excluded by behavior movements (FAO 2012).

The use of a top-opening excluder device in trawling nets can also prevent the bycatch of mammals by promoting the escape of pinnipeds (FAO 2020). In terms of cetaceans, acoustic alarms (*pingers*) are efficient in gillnets. On the Australian coast, they are also used on shark control nets, preventing entanglement of humpback whales, dugongs, and dolphins. Erbe and McPherson (2012) state that the received sound level should be measured in the field at the time, rather than relying on the manufacturer specifications in combination with a simple sound propagation model.

Juveniles cannot escape from traps as easily as adults can, as is the case with crab traps that catch platypus (Serena et al. 2016); thus, escaping from fishing gear can be harmful to these animals. In spite of this, Raby et al. (2011) consider mechanical adaptations to fishing gear a preferable solution to the requirement of pulling the gear and release the bycatch, a process that can exacerbate stress and injury among the fish. Bell and Lyle (2016) investigated how capture conditions, immediate mortality, and delayed mortality are affected by gillnet soak duration. The authors state that the maximum gillnet soak duration regulations implemented as a strategy to improve fishing practices appear to be effective for most species in facilitating high post-capture survival.

Legal measures remain a subject of discussion and are still missing adequate data for support. In January 2018 the European Parliament voted to ban pulse trawling, which potentially reduces bycatch in flatfish fisheries. Stokstad (2018) explains that irrespective of the lack of clear effects of electric pulses, this type of trawling, although more selective than a typical trawling net, is harmful to non-target marine life. In fact, many sharks and rays, for example, are particularly sensitive to these electrical fields. In contrast, ICES (2018) argues that there is insufficient information available on the detection threshold of organisms to the electric pulse, or on adverse response thresholds, to quantitatively assess the potential effect of electrical exposure at the population level. A long-term experiment of the small spotted catshark *Scyliorhinus canicula*, one of the more common species in the southern North Sea, demonstrates that the feeding and reproductive behavior of this species was not altered by pulse exposure.

Attention is also required for scientific studies to focus on fisheries. The use of electric fishing as a sampling method suffers from restrictions on water conductivity, flow rate, and depth (Bolin et al. 1989); it is not recommended as a unique sampling method in inventory studies (Oliveira et al. 2014). However, as individuals respond differently to the characteristics of electrical current, depending on species and body size, most of the capture is harvested alive. Hence, despite the stress imposed on the fish, electrofishing is a satisfactory method to reduce post-capture mortality (Bolin et al. op. cit.).

In addition to technological adaptations, fishing routines can help reduce bycatch. Spatial measures may include zones reserved for traditional fishing activities or for specific gear types (FAO 2016). Longline fishing is restricted to operate after sunset as stipulated by Brazilian laws, in view of the low activity of seabirds in this period. Colored flags are expected to repel albatrosses and petrels during longline fishing, but still require legislation. Gillnetting closures of key areas in Tasmania, implemented in 2015, are cited by Bell and Lyle (2016) as a tool to reduce the probability of skate bycatch in its habitat. These authors argue that implementation of maximum soak duration regulations represents an effective step toward reducing bycatch mortality.

Time/area closures can avoid bycatch in sensitive areas, reducing interactions between marine mammals and fishing gear. Although unpopular with fishers, this measure is highly recommended, particularly where marine mammals aggregate, such as breeding grounds (FAO 2020). Paradoxically, anthropogenic pressures on coastal environments can disturb fishing activities and indirectly contribute to conservation. This is observed in northeastern Brazil, where irresponsible tourism on a reef environment as a result of the tourism trade has been a strong driver of reduction in use of gillnets, benefiting the lobster population and accompanying bycatch decapods (Giraldes et al. 2015).

Partnering with the fishing community has proven positive. As observed by Liles et al. (2017), spatiotemporal patterns in fishing effort and turtle bycatch in set nets at shallow depths with longer soak times during the peak lobster fishing season offer guidance for potential community-based mitigation strategies in lobster gillnet fisheries in El Salvador and Nicaragua. Surveys with anglers in general show that discards in noncommercial fisheries, and educational campaigns, such as the distribution of guides (FAO 2009) and line cutters and dehookers (Bugoni et al. 2008), are useful in guiding fishers on handling procedures for sea turtles and birds in general, improving survival after release. These campaigns as well as the implementation of monitoring programs and participation in local forums have proven effective (Silva et al. 2010). Social media hits for seabird-related outreach campaigns, and material and mitigation guidance toward amateur charter vessel operators are policies in New Zealand, which present an exceptional number of seabird species Fisheries New Zealand 2020.

Incentives to decrease bycatch (e.g., for mammals) are also possible from consumer markets and firms in the supply chain through eco-labeling, certification, and standards (Lenta and Squires 2017). Tax landings based on the observed level of bycatch on each fishing trip, or on representative trips in this time and area, are proposed. However, while the initial direct costs of bycatch reduction may be low, relatively high and largely fixed regulatory costs risk will need to request subsequent adjustments. The institutional and infrastructure costs to implement, monitor, and enforce mammal bycatch programs, for example, may be comparatively high. In Brazil, despite Brazilian legislation, a large proportion of the trawling fleet is unable to implement normative regulations on TEDs because their use is not economically and operationally viable (Silva et al. 2010).

Top–down approaches to fishery management adopted for reducing bycatch, thereby reducing wastage and the ecosystem impacts of fisheries, can lead to significant yield losses for the fishing industry. As stated by Tsukamoto et al. (2008), any technology or policy aiming at a bycatch and discards reduction must consider fishers to compensate for the landing losses. For TEDs, Mukherjee and Segerson (2011) found that, over the period 1989–2003, the estimated harvest loss for the fishing industry was approximately 2% lower than that claimed by the industry. Small-scale fisheries, in particular, provide important livelihood support and poverty alleviation for coastal residents. Better multidisciplinary management would bring all sectors together to avoid reduced fishing efforts (FAO 2016).

Conclusions and the Way Forward

The uncertainty in rate estimation impedes the development of effective mitigation strategies. There is ample opportunity for research on freshwater bycatch in developed countries as well as on commercial bycatch of freshwater fishing of developing countries. Techniques to reduce interactions between fishing gears and corals, sponges, and other structure-forming invertebrates are particularly strategic. Improving the understanding of post-release mortality is also necessary.

Fishers' behavior will determine the success or failure of bycatch management measures; therefore, the involvement of the fishing sector is necessary to obtain full cooperation. It includes recreational fisheries, by way of social media campaigns. Area closures aiming to avoid bycatch of threatened, endangered, or protected species in critical sites have to be subjects of research, considering social and economic communities concerned with fishing. Payments for ecosystem services can provide a form of reward for reducing and directly pricing bycatch. Subsidies that finance innovation, diffusion, and adoption of bycatch reducing technology can ultimately increase economic and ecological welfare.

Bycatch is expected to link biology, oceanography, and ecology to engineering, sociology, and economics. It is a byproduct inherent to extractive activities that offer challenges in all environments and communities where fishing takes place. All fisheries worldwide are a cause for concern, with different human comprehension and management practices. They can be included as illegal, unreported, and/or unregulated fishing, directly linked with the Sustainable Development Goal 14, *Conserve and sustainably use the oceans, seas, and marine resources for sustainable development*, which, according to the United Nations (2019), remains one of the greatest threats to sustainable fisheries, the livelihoods of those who depend on them and marine ecosystems. Undoubtedly, ethical questions as well as conservational and economical questions, requesting multidisciplinary approaches to mitigate their effects, should be addressed.

Cross-References

- ▶ Artisanal Fisheries: Management and Sustainability
- ▶ Destructive Fisheries
- ▶ Fisheries Management

▶ Fisheries Management: An Overview
▶ Marine Biodiversity-sustainable Fisheries Nexus with Special Reference to the Coral Triangle
▶ Transboundary Fisheries Management

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