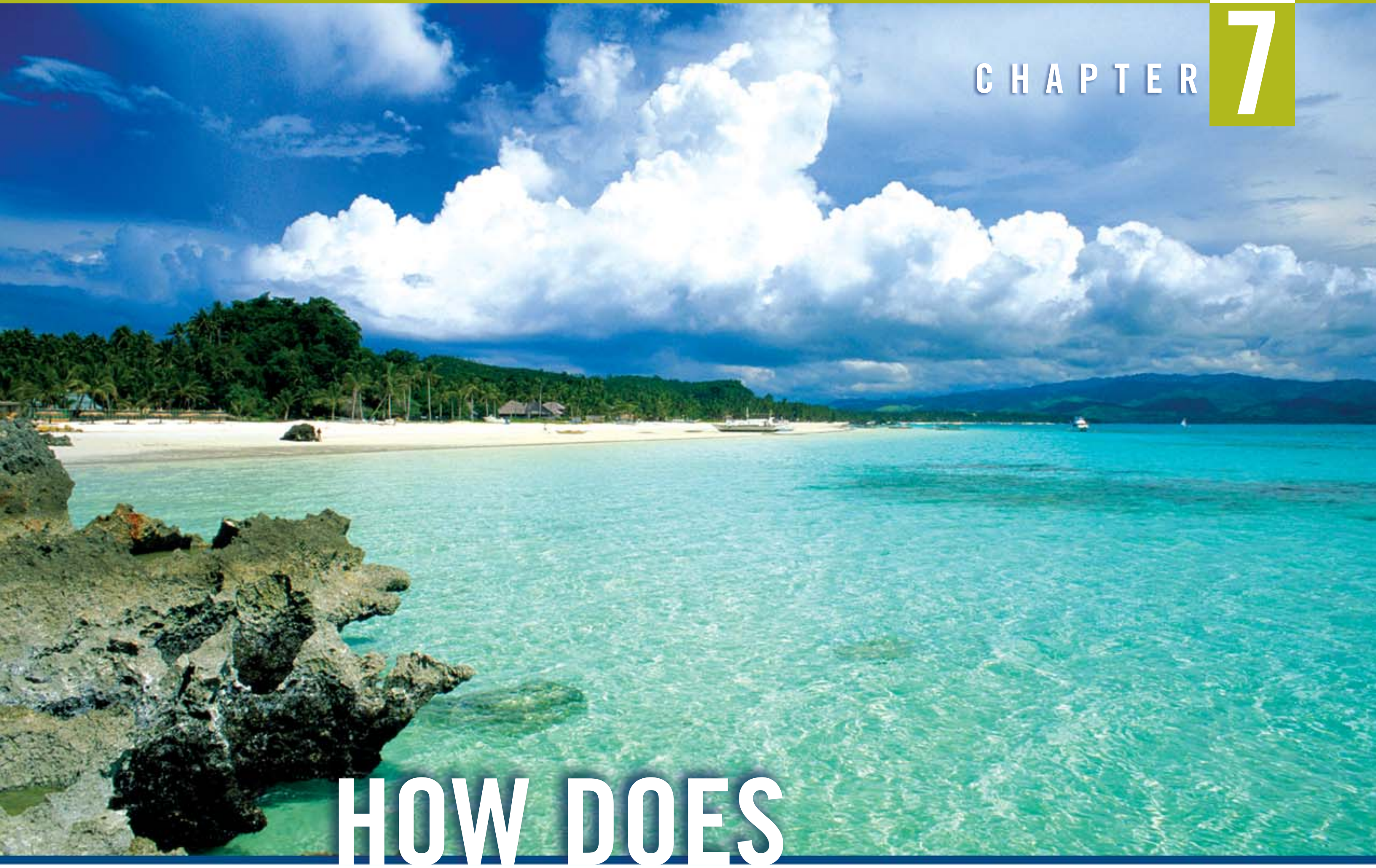
CHAPTER 7



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HOW DOES FISHING AFFECT ECOSYSTEMS?

Both the quantity of fish we catch and the manner and frequency with which we harvest them affect marine and freshwater ecosystems. Overfishing a particular stock, for instance, affects not just the population of that particular species, but can also change the composition—the population balance among the various species—of a given habitat. Thus, the potential impacts from fishing go well beyond the targeted fish and often include substantial collateral damage to non-target animals as well as freshwater and marine habitats, such as coral reefs and seagrass beds. The cumulative effect of these impacts is, according to some scientists, the leading cause of current changes in the structure and functioning of coastal and marine ecosystems—more influential than climate change or water pollution (Jackson et al. 2001). To mitigate these harmful effects we not only have to *fish less*, we also have to *change the way we fish* by using alternative fishing methods and modified gear that lessens the impacts on habitats and non-target species.

The impacts of capture fisheries on ecosystems can be broadly categorized into four types:

(1) overfishing of target animals;

(2) mortality of non-target species (bycatch, discards, and "high-grading");

(3) alteration of community structure; and

(4) habitat degradation from fishing gear and fishing practices.

Overfishing is discussed in detail in Chapter 3, so this chapter will focus on the three other negative impacts listed above. In Chapter 6 we look at the environmental impacts of aquaculture, a related issue.

BYCATCH, DISCARDS, AND HIGH-GRADING

What is Bycatch?

The world's fishing fleets harvest a large number of fish and other animals besides the particular fish species they are targeting. These non-target fish and animals, accidentally caught in fishing gear along with the intended species, are called *bycatch* or *incidental catch*. Some of this bycatch is retained for sale, but a portion of it—often a large portion—is returned to the sea, usually dead or dying. The animals and fish returned to the sea are known as *discards*. At times, even some of the target species are discarded if they are damaged, do not meet the minimum legal size for landing, or fall short of other legal and economic yardsticks.

Bycatch or the incidental catch of non-target species is a key contributor to the depletion of fish stocks, and can have a significant impact on endangered species of fish, mammals, and seabirds.

One particular profit-driven practice that involves commercially valuable fish is called *high-grading*—discarding smaller fish of the target species to make room for larger, more valuable fish caught later in the day. Imposition of strict catch quotas may create incentives for high-grading as fishers struggle to maximize the value of each kilogram of the quota (Gills et al. 1995). The result of high-grading for the fisher is a higher return on the day's fishing effort, but the ecological price is high, since the discarded fish are often juveniles of the target species that will not reach maturity. Discarded species tend to have very low survival rates by the time they are returned to sea, so juveniles that are discarded will not go on to reproduce, thus harming the development of future stocks of the species. Discarding commercially viable undersized fish is therefore not only wasteful but biologically and economically unsustainable. Scientists believe that the present level of bycatch is a key contributor to the biological depletion of fish stocks and changes in the species composition of the marine environment (Alverson et al. 1994). It can also have a significant impact on endangered species of fish, mammals, and seabirds.

How Much Bycatch and Discarded Catch is there?

Bycatch and discards, and the associated high mortality of non-target species, such as marine turtles, is one of the major challenges facing sustainable fisheries. The latest FAO estimate of total discarded catch is considerable, but reflects quite an improvement over previous numbers (Kelleher 2004). World marine fisheries today discard less than 10 million metric tons of animals (Kelleher 2004), whereas previous estimates, although not directly comparable because of different methodology used, placed this figure at around 20 million metric tons (FAO 1999c). This estimate does not include discards from inland fisheries (lakes and rivers), marine mollusc fisheries, or releases and discards from marine recreational fishing. Lower discard rates reflect better utilization of the catch, adoption of more selective gear (particularly in Europe, North America, and New Zealand), reduced effort in some major trawl fisheries, and application of policies to reduce bycatch (Kelleher 2004). Yet, to some extent, these figures still underestimates the discard of marine mammals, turtles, and seabirds which can be substantial in certain fisheries. Hundreds of thousands of marine mammals are estimated to be caught worldwide each year (Read et al. 2003). Unfortunately, discard estimates are highly uncertain. Lack of uniform data on discard quantities and species composition acts as a barrier to the development of more selective fishing gear, improved estimates of species mortality, and better fisheries policies.

To many people the terms bycatch and discards are synonymous with "waste." However, this is only partially true, since much bycatch is commercially exploited, particularly in Asia where all species are considered to be targets and the entire catch is utilized. Bycatch that is retained is often sold for human consumption or, particularly in Southeast Asia, used as aquaculture feed (Alverson 1998). And as the new estimates for discarded catch show, utilization of the retained bycatch has improved considerably (Kelleher 2004). The Northwest Pacific, Northeast Atlantic, and the Western Central Atlantic continue to be the areas with the highest discard rates (Alverson et al. 1994, Kelleher 2004). Incentives for fishers to implement measures to avoid unwanted bycatch, or to create markets for currently discarded species, can reduce wastage. However, simply making better use of bycatch does not necessarily address some key issues, such as the impact of fishing on endangered marine mammals, birds, and other marine species, or changes in fish population structures that may impact future stocks.

Which Fisheries Have the Largest Bycatch?

In some fisheries, the bycatch rates are so high that there are more non-target animals than target species in each net. The catch, and therefore the bycatch, depends on many factors including the type of gear used, as well as how and where it is used. All fishing gears are to a certain degree selective; however, fishing gear that is towed along the ocean floor, such as trawls tend to be less selective than lines or purse seines. Such less selective gears tend to have higher discard rates. The top highest

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Some fishing gear catch more non-target species in each net: shrimp bycatch, eastern Florida, USA.

discard rates (the proportion of the total catch discarded) are dominated by shrimp trawl fisheries; bottom-trawl fisheries for finfish such as cod, flounder, halibut, and sole; and the tuna and other highly migratory species longline fisheries that have a considerable discard rate for sharks (Alverson et al. 1994, Kelleher 2004). Crustacean and other bottom-trawl fisheries jointly account for approximately 50 percent of estimated global discards, while representing about 25 percent of global landings (Kelleher 2004). A recent review of the fishing gears used in the United States and their impact on ecosystems confirms that bottom-trawls, bottom gillnets, and dredges have substantial ecological impacts on marine biodiversity (Morgan and Chuenpagdee 2003).

Shrimp trawling continues to be the major source of discards worldwide, accounting for close to 35 percent of discards from commercial fisheries in the 1980s and early 1990s (Alverson et al. 1994). However, there has been some improvement in certain regions of the world due to stricter enforcement of gear-use regulations and better catch utilization (Alverson 1998; Kelleher 2004). U.S. shrimp fishers in the Gulf of Mexico, for instance, used to discard more than 5 kilogram of fish, such as red snapper, and other animals for each kilogram of shrimp they caught (Alverson 1998). Since 1998, the use of certified Bycatch Reduction Devices (BRDs)—a device installed in shrimp nets that provides a small opening to allow red snapper and other finfish to escape—has been required for most offshore shrimp trawlers in the Gulf of Mexico in order to reduce the severe bycatch of juvenile red snappers (NMFS 1998). It is estimated that BRD usage has reduced bycatch of red snapper in the Gulf by 40 percent (NMFS 2004).

The United States example shows, that in some cases, discard rates can be significantly reduced by modifying gear and fishing methods, if that is accompanied by incentives for, and enforcement of, gear regulations. However, there is still considerable debate on the effectiveness of many of these devices and gear modifications, especially as it relates to the loss or potential loss of target catch. If gear regulations have a high impact on fishery profits, the implementation of their use becomes very challenging. In the case of the Gulf of Mexico, the financial losses incurred by shrimp fishers in an effort to restore snapper stocks far outweigh the commercial value of the snapper fishery, making the use of BRDs unpopular. Therefore, while the use of BRDs have helped to mitigate the problem, they are not as effective as is necessary for recovery of the red snapper stock (Gallaway and Cole 1999).

The fisheries with the lowest discard rates tend to be pelagic trawls, mid-water trawls, some high seas driftnet fisheries, and purse seines targeting menhaden, sardine, and anchoveta. In these cases, the placement of the net in the water column and the schooling behavior of the targeted fish combine to reduce bycatch. Small-scale and subsistence fisheries also have practically no discarded catch, since most of these fishers sell or consume everything they catch (FAO 1999a; Jennings et al. 2001).

BYCATCH OF DOLPHINS, SEABIRDS, TURTLES, AND SHARKS

The current debate, research, and regulations concerning bycatch tend to focus on the negative effects of bycatch on well-known species such as dolphins, turtles, and seabirds, which are profiled below. However, it is important to remember that many other organisms besides these charismatic species are killed as bycatch, and usually in far larger quantities. Of particular importance for the sustainability of fisheries is the bycatch of non-target fish of commercial value and juveniles of target species. When these fish are killed, it jeopardizes the reproductive potential—and thus the future commercial viability—of the stocks.

How Does Bycatch Affect Dolphins?

Dolphins are fished commercially in many places, including Japan, Greenland, and India, but they are also a significant bycatch in some tuna fisheries (Fishstat 2003; Reeves et al. 2003). Unintended dolphin mortality during tuna fishing has been a prominent issue among civil society since the dimensions of the problem became public knowledge in the 1980s. Public awareness campaigns by environmental groups showing dolphins caught and killed in tuna nets triggered a long-standing "dolphin-tuna" debate, particularly in the United States.

In the early years of the tuna purse seine fishery in the eastern tropical Pacific, hundreds of thousands of dolphins were killed each year in tuna nets. Fishermen knew that tuna are often associated with schooling dolphins and would set their nets intentionally around the dolphins in order to catch the tuna. This "dolphin-set" technique contributed to a major dolphin population decline until the late 1970s. Estimates of dolphin mortality from tuna fishing during the 1950s and 1960s place the mortality rate as "very high," although actual data is limited (Hall 1998; Alverson et al. 1994). The available information at the time, however, led to considerable concern among scientists and environmental groups that bycatch mortality was depleting dolphin populations.

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Separating shrimp from bycatch, North Carolina, USA.

Public outrage from media images of dead dolphins put pressure on governments and the tuna industry to adopt practices that reduced dolphin mortality. Some of the measures included releasing dolphins from nets and using alternative purse seining methods. In the United States, where public reaction was strongest, the 1972 Marine Mammal Protection Act was amended in 1994 to include regulations governing the incidental taking of marine mammals in the course of commercial fishing operations. The intention was to reduce the "incidental serious injury and mortality of marine mammals to insignificant levels approaching a zero rate" (NMFS 2002a). In addition, a total annual dolphin mortality limit for tuna-related bycatch in the Eastern Pacific was set by the International Dolphin Conservation Program (IDCP) at 5,000 individuals, although this was a voluntary limit. Stock-specific limits are also established under the IDCP to ensure that no individual dolphin stock is adversely impacted.

Thanks to these efforts, dolphin mortality from tuna fishing has dropped considerably. In the eastern tropical Pacific Ocean, bycatch mortality of dolphins dropped by 99 percent, from 133,000 dolphins in 1986 to 1,636 in 2000—a level considered to be non-threatening to dolphin stocks (NMFS 2002a).

Unfortunately, there may be a darker side to this successful reduction in dolphin bycatch. Some scientists and fishermen claim that the current standard of "dolphin safe" labeling of commercial tuna is so strict that it has encouraged purse seine fishermen to use methods that may be dolphin-friendly, but detrimental to other species (see *Table 7-1*). For example, a common alternative to the "dolphin-set" technique is to set a net around a floating object, such as a log. These objects are known to attract tuna, but other fish species such as mahi-mahi, wahoo, sea turtles, and several shark species are also attracted and subsequently caught along with the tuna, in some cases increasing the bycatch of these species 10 to 1,000 times (Hall, 1998; Norris et al. 2002). Use of the "log set" technique also increases the bycatch of undersized, juvenile tuna by 10-100 times, and the total bycatch of all species combined is much higher than experienced with the "dolphin set" technique (see *Table 7-1*). This has led some scientists to conclude that the ecological price of using this "dolphin-safe" method is still inappropriately high (Norris et al. 2002).

Another tuna purse seine method that has lower levels of bycatch of juvenile tunas and other fish than the log-setting method, but also has very little dolphin bycatch is the location of the tuna school by surface activity (see *Table 7-1*). When schools of fish swim close to the surface of the water they create ripples and water movement that can be identified from a vessel or helicopter (CLS 1992). Once the school is detected, the purse seine is set. Unfortunately, this method takes more time and is not as reliable or as easy to put into practice; therefore it is not a preferred method for fishers.

How Does Bycatch Impact Seabirds?

There are numerous reported incidents of seabirds captured and drowned in fishing gears. In general, bird mortality related to bycatch is highest where fishers use driftnets, longlines, and set nets (Jennings et al. 2001). Up until the 1990s, driftnets on the high seas were the greatest source of seabird bycatch. Driftnet fisheries in the North Pacific, for instance, killed about 416,000 seabirds in the 1990 season alone; 80 percent of these were in the Japanese squid fishery (Johnson et al. 1993). Due to this high bycatch rate, the United Nations brokered an international treaty in 1992 that banned the use of large-scale driftnets in international waters (FAO 1998). According to the U.S. National Oceanic and Atmospheric Administration (NOAA), the implementation of the large-scale driftnet ban has been "generally successful" at the global level. In 2002, no cases of unauthorized large-scale high seas driftnet fishing were reported in the world's oceans and seas (NOAA 2002).

Today, longline gears, such as those used to catch swordfish, represent the greatest bycatch threat for seabirds such as albatrosses and petrels. These birds often get entangled in the nets as the lines are being baited at the surface, and drown as the nets sink to fishing depth. The Global Seabird Conservation Programme estimates that as many as half a dozen seabird species may be threatened with extinction due to mortality associated with longline fishing (Birdlife International 2003). Fortunately, a number of strategies—such as baiting fishing lines at night when birds are not present or using noisemakers to scare birds off—can enable longline fishermen to reduce seabird bycatch by up to 90 percent (Løkkeborg 1998). On the other hand, seabirds can sometimes adapt to these techniques, and bird bycatch remains a significant concern. The true dimensions of the problem are hard to quantify, since bird mortality is often not monitored in national waters.

How Does Bycatch Affect Marine Turtles?

Sea turtles are mainly caught in longline, set net, and trawl fishing gears. Since the early 1980s, shrimp trawls were recognized by U.S. scientists as a significant source of sea turtle mortality (Alverson et al. 1994). To address this, the U.S. National Marine Fisheries Services (NMFS) developed Turtle Excluder Devices (TEDs), a contraption that allows trapped turtles (and other by-catch animals) to escape. The NMFS required commercial fishermen in the United States to use the devices and any country wishing to export trawled shrimp to the United States must make sure its fleet uses TEDs or other similar measures.

Just how effective TEDs are is not immediately clear. A carefully designed TED can allow turtle escape rates of 95 percent (Epperly et al. 2002). However, other factors such as compliance and proper equipment use are important as well. In the United States, the effectiveness of the TED policy is hard to determine. The number of annual strandings of Loggerhead and Kemps Ridley turtles has actually grown since the TED requirement was put in place, but this is quite possibly due to an increase in the turtle population in general, an increase in shrimp trawling, or increased monitoring and reporting (Lewison et al. 2003). No one knows how high the turtle bycatch would be in the absence of the TED policy.

More certain is the fact that TEDs are not popular among fishers in developing countries in particular. Many shrimp fishers remain reluctant to use the devices, claiming that they reduce their catch. In developing countries, where government funding is limited and fishermen often cannot afford to replace equipment, TED regulations are difficult to enforce. Furthermore, in countries where sea turtles are used for food and other commercial purposes—mostly through illegal operations—experts argue that investment to encourage local people to stop consuming turtles, or penalizing the consuming and marketing of them, may yield similar or even better results in terms of turtle conservation rather than simply enforcing the use of TEDs (Chokesanguan 2001a).

How Does Bycatch Affect Sharks and Similar Species?

Shark fishing is common throughout the world and constitutes a substantial part of the commercial fishing industry. Sharks are caught in industrial and artisanal fisheries mainly by gillnet, hook, or trawl (FAO 2000e). However, in addition to this directed fishing effort, a great number of shark species are

Table 7-1: Bycatch by Tuna Purse Seine Method, 1998 (per 1,000 MT of tuna caught)

Species Caught as Bycatch	Type of Purse Seine Set Method: Dolphin-Set (no. of individuals)	Log-Set (no. of individuals)	Locating the Tuna School (no. of individuals)
Dolphins	19	0	0-1
Sea turtle	0-1	0-1	0-1
Billfish	6	11	10
Sharks and ray	35	236	134
Other large bony fish	15	5,444	751
Tuna discards (in tons)	6	146	38

Source: Norris et al. 2002.

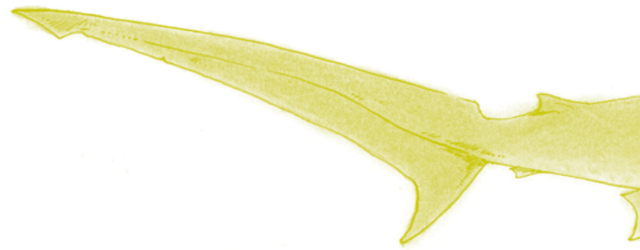
caught as bycatch in multispecies fisheries and in fisheries targeting highly valued fish, such as tuna, swordfish, shrimp, and squid (Vannuncini 1999). For instance, in the Canadian tuna and swordfish fishery, the bycatch of blue sharks often exceeds the amount of tuna and swordfish caught, with blue sharks accounting for 47 to 152 percent of the landings (DFO 2002). Longline fisheries in the high seas appear to be the most important source of shark bycatch, contributing about 80 percent of the estimated total shark and ray bycatch in terms of weight, and about 70 percent in terms of number of individuals caught (Bonfil 1994). The number of sharks caught each year in large-scale high seas fisheries during the period 1989-1991 was estimated at between 11.6 and 12.7 million animals. Shark species are considered to be a long-lived, slow maturing species with low reproduction rates, and are therefore highly susceptible to overfishing. Indeed many shark species are joining the list of threatened species of the world due to overexploitation (IUCN 2003) (see *Chapter 3: Table 3-2*).

Additional pressure on shark populations comes from an increase in commercial fishing efforts caused by a recent upswing in the international trade in shark fins and other related products (FAO 2000e). FAO reports that total world landings of sharks, rays, and chimaeras in 2000 reached approximately 856,000 metric tons (Fishstat 2003). Annual shark landings exceed 10,000 metric tons per year in 18 nations (IUCN/SSC and Traffic 2002). The true value of this catch, however, is likely to be much higher, given that there is a large underreporting problem in shark fisheries. In some cases, only the fins are retained and their weight reported on, while the rest of the shark—which may still be alive—is discarded at sea to die (Rose 1996). (See *Chapter 4* for further discussion on the trade in shark fins). According to several studies, the actual annual catch in shark species seems to be at least twice as high as that reported to the FAO (Bonfil 1994, Vannuccini 1999, Clarke 2002).

BYCATCH CONCLUSIONS

What Are the Ecological Impacts of Bycatch?

The additional mortality caused by bycatch and discards harms both targeted fish stocks and non-targeted animals. However, it is difficult to ascertain the overall effect of bycatch on the marine ecosystem because the impact of bycatch mortality differs depending on the life history of the species that is caught. For



example, incidentally killing a school of highly abundant small pelagic fish, such as mackerel and herring, may have less of an impact on their overall population than killing several individuals of a much less abundant and long-lived species such as loggerhead turtles.

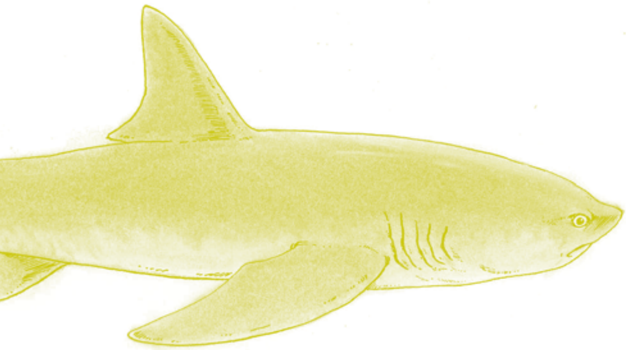
Until recently, much of the focus of policies meant to reduce bycatch has been on species such as dolphin, shark, albatross, and sea turtle. These animals are less abundant, have lower reproduction rates, take longer to reach maturity, and hence are more susceptible to extinction from fishing-related mortality. Although bycatch from commercial fishing is not the only threat these animals face, many of them have declined to the point where they are listed as threatened in the *IUCN Red List of Threatened Species* (IUCN 2003). The harbor porpoise (*Phocoena spp.*), the black-footed albatross (*Phoebastria nigripes*), the wandering albatross (*Diomedea exulans*), several species of dolphin (*Stenella spp.*), several species of shark, and six of the seven living species of sea turtle[7] are all classified as threatened with extinction by IUCN (IUCN 2003). (See *Box 7-1.* on ghost fishing for additional pressures on endangered species as an indirect result of commercial fishing operations).

Commercially important fish species are also severely affected by bycatch and discards. For example, since the 1960s, bycatch has risen to account for as much as 69 percent of the total commercial catch of halibut in peak years. Moreover, half of this bycatch is made up of juvenile fish, threatening the future of the halibut fishery itself. At present, the International Pacific Halibut Commission reduces the annual halibut quota by the amount of adult halibut caught as bycatch in other fisheries—such as shrimp trawls and crab pots—to offset the added mortality (Clark and Hare 1998).

How Should We Address Bycatch and Discards?

Definitive solutions to the problem of bycatch and discards are elusive. Better utilization of the incidental catch can reduce discards and make fisheries

[7] The seventh species of sea turtle, the flatback turtle is considered data deficient, therefore its conservation status has not been assessed.



When the bycatch of non-target fish of commercial value and juveniles of target species are killed, it jeopardizes the reproductive potential—and thus the future commercial viability—of the stocks.

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less wasteful, but non-target species, some of them endangered, may still be caught unintentionally. Clearly, modifications to fishing gear and methods that reduce bycatch are and have been an important part of the solution, driven by well-elaborated bycatch policies. A number of national and international regulations are already in place to protect some of the species seriously affected by commercial fisheries bycatch. These species have been mostly marine mammals, birds, and turtles. In the United States alone there are three pieces of legislation that provide the foundation for the U.S. National Bycatch Strategy: the Marine Mammal Protection Act, the Endangered Species Act, and the Migratory Bird Act. The United Nations ban on large-scale driftnets in high seas was also enacted to specifically address the bycatch issue of these same animals. In addition and as part of the elaboration of the Code of Conduct for Responsible Fisheries, FAO has developed two International Plans of Action: one on seabird bycatch and one on shark fisheries (FAO 1999d).

Unfortunately, all these regulations tend to protect only a few species. This narrow species-based approach is not enough to address the complex issue of bycatch because it ignores broader ecological considerations and trade-offs among different conservation goals. Focusing too much on a single charismatic animal can simply replace one problem with another. For instance, "dolphin-safe" tuna fishing methods may come close to eliminating dolphin bycatch, but can create a higher bycatch for sea turtles, sharks, and several fish species (Hall 1998). Adding to the complexity of the issue is that, according to a number of studies in European waters, millions of seabirds rely on discarded fish as a source of food. Reducing the discard may thus affect some seabird populations (Megapesca 1999).

Part of the problem with current approaches to bycatch is that our scientific understanding is still inadequate to appreciate its full ecological implications (Hall and Donovan 2002). Further research is urgently needed, especially in tropical multispecies fisheries, where the ecological impacts of bycatch have barely been studied. A better understanding and more data collection on bycatch itself will help inform and shape management plans, gear specificity, and other regulatory measures such as fishing seasonality. Meanwhile, the "precautionary approach" would argue for reducing pressure on those fisheries where the effects of bycatch have the greatest impact or where they are most uncertain, until there is a sound basis in science for bycatch-specific policies for each of these fisheries.

Even though the science of bycatch is still incomplete, some countries have taken decisive action to deal with potential effects. Countries such as Canada, Iceland, and Norway are the current leaders in addressing the bycatch problem. One concrete example is their 'no discard' policy, which means that fishing vessels engaged in specific fisheries are required to land all their catch—including the bycatch. This has created an incentive for fishers to minimize bycatch by improving the selectivity of their fishing gear and their fishing methods (Clucas 1997; OECD 1997). After all, if a vessel has a lot of bycatch that it cannot discard, it will have less space to store the higher-value commercial species it is actually targeting. Norway introduced the policy barring discards in all its fisheries in 1983 (FAO 1997b) and the policy is generally considered a success (Nordic Council of Ministers 2002; Megapesca 1999; also see *Chapter 11* for further discussion on management issues).

Coupled with adequate monitoring, surveillance, and technical advances, such discard ban policies can contribute to reducing bycatch rates in some fisheries. Yet, the effectiveness of these bans relies heavily on enforcement, usually accomplished by placing observers on fishing vessels to ensure compliance. Unfortunately, observer coverage, except on very large vessels, is still limited and costly (Morgan and Chuenpagdee 2003), making a discard ban an impractical approach in many countries, and the opportunities for noncompliance very great (Megapesca 1999).

ALTERATION OF COMMUNITY STRUCTURE: ARE WE "FISHING DOWN THE FOOD WEB?"

For millennia, humans have focused their fishing efforts on some species more than on others, but the rise in large scale industrial fishing has greatly magnified the biological impacts of the practice of selective fishing. The result is a profound shift in the community structure of marine ecosystems. Historical data suggest that removal of certain target fish from the oceans by overfishing can have potentially irreversible effects on the balance of the ecosystem and its biodiversity (Jackson et al. 2001).

PETER AUSTER. USED WITH PERMISSION.

Seafloor communities are severely affected after a dredge has swept the area.

In many fisheries, the most prized fish are large predatory species high in the food web— fish such as tuna, cod, or hake that feed on smaller fish. Once a desirable species at the top of the food chain has been overfished, fishing effort will expand to new species, often lower in the food chain—those fish that feed on plankton or small invertebrates, for example. This pattern of exploitation is known as "fishing down the food web," and was described by Pauly et al. (1998). The pattern implies that overfishing the top predators in the ocean food web allows expansion of fish stocks lower in the food chain, thus changing the species composition of the fish community.

The mechanism of such a change in the fish community is generally understood, but there is no comprehensive biological data that can reveal the full scope of the problem worldwide. Nonetheless, analyzing data from commercial fish catches over time can provide clues to how widespread are the effects of this practice in major fishing regions.

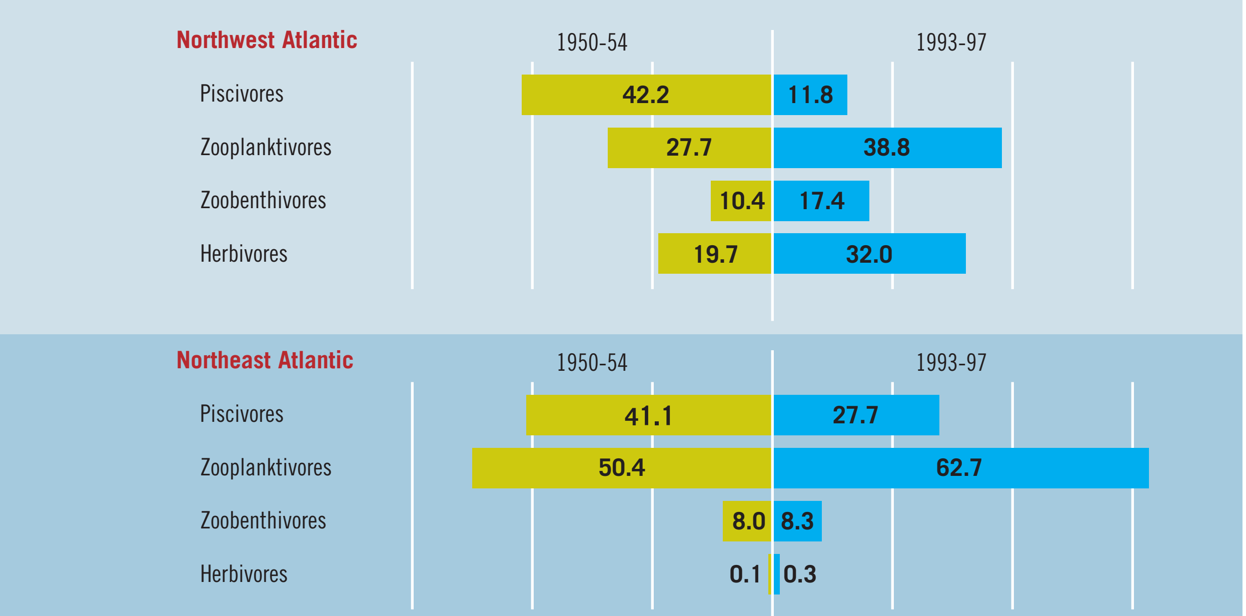
Results of such an analysis conducted by the FAO in 1999 (Caddy et al. 1999) show that the strongest evidence of the biological effects of fishing down the food web is found in the Northern Atlantic—a fishing area with the longest historical record of industrial fishing. There commercial landings show a progressive decline in the ratio of predatory fish high on the food chain (called piscivores) to those lower on the food chain (zooplanktivores) such as herring and mackerel, after a peak in the mid-1960s (see *Figure 7-1*). This correlates well with the overfishing of cod, hake, and other piscivores during this period and the subsequent collapse of these fish stocks. While top-of-the-food-web fish made up over 40 percent of the North Atlantic fish catch in 1950-1954, they comprised less than 12 percent of the catch in 1993-1997 (see *Figure 7-1*) (Burke et al. 2001).

The FAO analysis did not find as clear-cut evidence for fishing down the food web in other ocean regions as it did for the North Atlantic. This may be because overfishing has a shorter history in these areas, or its effects may be obscured by other factors such as changes in fishing technologies. Therefore, the results may not show up in catch statistics for some time (Burke et al. 2001).

HABITAT DEGRADATION BY FISHING GEAR AND PRACTICES

Some fishing practices and fishing gears significantly disturb seafloor and other marine habitats. For instance, bottom trawling, in which a trawling rig is dragged across the seafloor, is a significant source of pressure on the biodiversity of sea bottom (benthic) ecosystems in shallow as well as in deep-sea waters. Among the deep-sea habitats most affected by trawling are cold-water coral communities (Baker et al. 2001; Roberts 2002). Damage to seabed habitats from bottom trawling may be light, with effects lasting only a few weeks, or severe, with impacts on corals, sponges, and other bottom-dwelling species lasting decades or even centuries (Watling and Norse 1998). The degree of damage depends on a number of factors, including the frequency and intensity of trawling, and the type of seabed habitat. Habitat destruction is a factor in the decline of some fishing stocks in heavily trawled areas, since the carpet of

Figure 7-1: Catches by Trophic Level for the North Atlantic, 1950-54 and 1993-97



Source: Caddy et al. 1999.

vegetation and animals on the sea bottom normally acts as a refuge for the fry of fish species such as cod (Watling and Norse 1998).

Based on a review of scientific literature, expert consultation, and public meetings in North America and Europe, a 2002 study by the United States National Research Council (NRC) on the impact of bottom trawling and dredging on the marine environment concluded that repeated trawling causes considerable damage to the sea floor ecosystem. The study found that repeated trawling can shift marine species composition toward small opportunistic species—such as sea stars and small short-lived clams—while reducing the overall biomass of the area by removing aquatic vegetation and bottom-dwelling animals. The impact of prawn trawling in the Great Barrier Reef Marine Park in Australia, for example, shows that a single trawl removes 5-25 percent of the bottom-dwelling organisms, and that repeated trawling has a cumulative impact (Poiner et al. 1998). An accurate account of the geographic extent, intensity, and effects of bottom trawling operations worldwide does not exist, but one rough estimate puts the area affected by trawling at 14.8 million km^2 (Watling and Norse 1998). However, this estimate fails to capture the impacts of repeated trawling over the same area.

Poison fishing and blast fishing are other examples of highly destructive practices. The aim of poison fishing is to stun and capture live fish, which are then sold in the ornamental fish trade primarily in the United States and Europe, or cooked and served at high-end restaurants in China and Taiwan. The use of dynamite and sodium cyanide is especially prevalent among coastal and reef fishermen in Southeast Asia, but the practice is rapidly spreading east to the island nations in the Western Pacific (Barber and Pratt 1997).

Commercial use of poisons such as sodium cyanide to capture live reef fish began in the Philippines in the 1960s and soon spread to Indonesia, Vietnam, and parts of Malaysia. Many nontarget species and corals are damaged or killed by poisons. Dynamite used in blast fishing kills most nearby fish and damages reefs, often permanently. Over two-thirds of the coral reefs in the Philippines, Malaysia, and Taiwan, and over half of the reefs in Indonesia are threatened by these destructive fishing practices (Burke et al. 2002).

The use of cyanide and dynamite for fishing has been banned by governments in virtually all countries in Southeast Asia for some time. However, implementing and enforcing such laws remains a challenge (Barber and Pratt 1997; Cesar, pers. comm. 2003). For example, Indonesian fishermen are barred by law from using cyanide for fishing, but they are allowed to carry cyanide on their boats. This makes it virtually impossible to monitor and suppress the improper use of the poison (Cesar, per. comm. 2003).

Box 7-1: Impacts of Derelict Fishing Gear (Ghost Fishing)

What Is Ghost Fishing?

Modern fishing gear is often composed of durable, synthetic materials that are meant to last for years and even decades. When these fishing gears are lost or discarded at sea, they can entangle, trap, or kill fish and other aquatic animals. This phenomenon is called *ghost fishing*. Abandoned fishing gear also degrades marine and coastal ecosystems and sensitive habitats, and may even damage propellers and rudders of small vessels and recreational boats, at times endangering boat crews and passengers when vessels capsize. While the extent and impact of ghost fishing is only anecdotally documented, entanglement in, or ingestion of human-caused debris (including fishing gear and many other items) has been reported as a mortality factor for over 250 marine species (Laist 1997).

How Much Gear Is Lost and What Are the Impacts?

Information on how much fishing gear is lost or abandoned in the ocean is very poor. However, there are a few documented cases. In northwestern Hawaii, where ocean currents seem to bring a variety of marine debris from throughout the Northern Pacific—and possibly the entire Pacific basin—ghost fishing has become a serious problem. Between 1996 and 2000, over 78 tons of derelict fishing gear and other debris were recovered from the shallow coral reefs in northwest Hawaii mostly trawl nets and gillnets. Drifting gillnets, in particular, were the most dominant form of derelict fishing gear (Brainard et al. 2000).

Because they are left unattached in the water for relatively long periods of time, static gears such as traps, pots, and gillnets are subject to high accidental loss caused by bad weather or interactions with towed fishing gears. Although little is known about the frequency of net or pot losses, the few available estimates of gear loss indicate that it can be substantial in some fisheries (Jennings et al. 2001). Along the coast of Maine in the United States, an estimated 100,000-200,000 traps, or 5-10 percent of the 2 million lobster traps in use were lost in 1992 alone (Carr and Harris 1997).

Equally scarce is information on how many aquatic animals these derelict gears actually entangle and kill. Since 1982, beach surveys conducted by field crews at the National Marine Fisheries Service have reported more than 200 entangled Hawaiian monk seals—an endangered species with a population size of only about 1,400—including six animals that died from their entanglement (NMFS 2002b). From an economic standpoint, it is estimated that lost and abandoned gillnets in the Canadian Atlantic waters killed about 3,600 metric tons of fish of various species, valued at more than $3 million Canadian dollars (Brothers 1992).

Because governments often provide financial compensation for lost gear there is little incentive for fishers to try to recover their gear or not discard damaged gear over board. However, where ghost fishing is recognized as a problem, voluntary clean-up efforts are sometimes made. For example, when ghost fishing was highlighted as a threat to commercial stocks of Greenland halibut, commercial fishers led a voluntary clean-up program (Bech 1995). Because of the increasing problem with ghost fishing and its threats to species, commercial fisheries, and at times small-scale vessels and artisanal fishers, some policy measures are being considered. The International Marine Debris Conference on Derelict Fishing Gear and the Marine Environment has recommended that all states contributing to, or affected by, derelict fishing gear should encourage and fund the development of an International Plan of Action to Control and Minimize Fishing Vessel Gear Loss (Stewart and Koehler 2000). Such a plan of action could be coordinated jointly by the International Maritime Organization (IMO), FAO, and the Regional Fisheries Organizations (Stewart and Koehler 2000). Other conference recommendations encourage members of the IMO to take a hard look at the implementation of Annex V of MARPOL (i.e., the International Convention for the Prevention of Pollution from Ships). Annex V specifically covers the Prevention of Pollution by Garbage from Ships, including plastics. Finally the conference recommendations ask for the establishment of a mechanism for monitoring derelict fishing gear (Stewart and Koehler 2000). No international action plan has yet been established but some countries and states that have been heavily affected by lost gear have already established proactive measures to control and reduce the amount of derelict fishing gear. For example, the Washington Department of Fish and Wildlife in the United States has produced guidelines for the removal of derelict gear, an online form to report lost fishing gear, and has engaged several organizations to assist with derelict gear cleanups (WDFW 2003).

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Fur seal entangled in fishing gear.