~ 2 ~

DECLINE OF THE FISHERIES

> Abundant signs of the biosphere's limited resilience exist all around. The oceanic fish catch now yields $7.5 billion to the U.S. economy and $82 billion worldwide. But it will not grow further, simply because the amount of ocean is fixed and the organisms it can generate is static. As a result, all of the world's seventeen oceanic fisheries are at or below sustainable yield. During the 1990s the annual global catch leveled off at about 90 million tons. Pressed by ever growing global demand, it can be expected eventually to drop. Already fisheries of the western North Atlantic, the Black Sea, and portions of the Caribbean have collapsed. Aquaculture, or the farming of fish, crustaceans, and mollusks, takes up part of the slack, but at rising environmental cost. This "fin-and-shell revolution" necessitates the conversion of valuable wetland habitats, which are nurseries for marine life. To feed the captive populations, fodder must be diverted from crop production. Thus aquaculture competes with other human activity for productive land while reducing natural habitat. What was once free for the taking must now be manufactured.
>
> —Edward O. Wilson, *The Future of Life*, 2002

The marine ecosystem has traditionally been considered safe from human degradation, mostly because of its size and depth. There was just too much of it for our puny efforts to have much of an effect, and the creatures that lived in it seemed infinite in variety and endless in number. John Seabrook noted in a 1994 *Harper's* magazine article:

> Marine-fishery management has always rested on the assumption that the number of fish in the sea is limitless. Other of our natural resources—timber, bison, land, wild horses—used to be managed in the same way, and each time we neared the end of the resource the philosophy changed. Ocean management has not yet changed, although

> it has begun to adapt. The ocean is still free, as it has been forever. Traditionally, if you wanted to buy a factory trawler, hire a crew of a hundred men, and go out and catch tens of thousands of fish a day, you didn't have to pay the government anything for the use of the resource—no rent, no special taxes. In fact, the government would help set you up in business with tax incentives and low interest loans.

At his inaugural address to the International Fisheries Exhibition in London in June 1883, Thomas Huxley spoke of the state of the fisheries. Not even a salmon river could be exhausted, he said, because the men who fished the river were "reachable by force of law." That is, they could be restrained by law if the fish population was seen to be threatened. He continued:

> Those who have watched the fisheries off the Lofoden Islands on the coast of Norway say that the coming of the cod in January and February is one of the most wonderful sights in the world; that the cod form what is called a 'cod mountain' which may occupy a vertical height of from 20 to 30 fathoms—that is to say, 120 to 130 feet, in the sea, and that these shoals of enormous extent keep coming in in great numbers from the westward and southward for a period of something like two months.

On these and other grounds, it seemed to Huxley that "this class of fisheries—cod, herring, pilchard, mackerel, &c.—might be regarded as inexhaustible."

In 1961, Hawthorne Daniel and Francis Minot published *The Inexhaustible Sea,* a book described on the jacket as "the exciting story of the sea and its endless resources." But Daniel and Minot hadn't been reading the newspapers carefully: while they were writing their book, journalists were reporting that the anchovy population off the coast of Peru was crashing. Anchovies (genus *Engraulis*) and sardines (genera *Sardina* and *Sardinops*) are among the most important of all commercially fished species. The California sardine fishery, celebrated by John Steinbeck in his 1945 novel *Cannery Row,* peaked at 1.5 billion pounds in 1936 but had ceased to exist by 1962. Anchovetas (*Engraulis ringens*) were so abundant off Peru Current in such vast numbers that they once headed the list of largest commercial catches: more than 12.1 million tons were caught in 1967. But this fishery completely collapsed in 1973 (a result of not only overfishing but also the El Niño of that year), and the anchoveta, once considered the most numerous fish in the world, is now greatly reduced in numbers. And the codfish, responsible for the discovery and early industrial success of New England, is essentially gone, its "inexhaustible" fishery closed indefinitely.

At four o'clock every morning of the year, the Tsukiji Fish Market in Tokyo opens with five acres crammed with sea life of every description: finfish, sharks, octopuses, squid, sea urchins, shrimp, lobsters, sea cucumbers, seaweed, and some things that appear to defy categorization. By ten o'clock, everything is gone, the market has closed, and workmen are swabbing the wooden floors of the buildings. Every day, it looks as if the fishermen have vacuumed another part of the ocean to fill the market's stalls with an incredible display of sea life.

The fishermen are fishing as if there were no tomorrow. An article titled "Diminishing Returns" in the November 1995 issue of *National Geographic* begins with these words:

> The unthinkable has come to pass. The wealth of oceans, once deemed inexhaustible, has proven finite, and fish, once dubbed "the poor man's protein," have become a resource coveted—and fought over—by nations.

Even this is an understatement. The fishing off Japan, the decimation of the California sardine fishery, and the crash of the Peruvian anchoveta population are just a few moments in a process that has been going on for decades at an accelerating pace. Throughout the world's oceans, food fishes once believed to be immeasurable in number are now recognized as greatly depleted and in some cases almost extinct. A million vessels now fish the world's oceans, twice as many as there were twenty-five years ago. Are there twice as many fish as before? Hardly.

Close to the precipice of extinction, if not already over the edge, is the white abalone (*Haliotis sorenseni*) of Mexican and California waters. It was said to have occurred in densities of as many as 10,000 individuals per hectare less than half a century ago (a hectare equals 2.47 acres). By the early 1970s, "ab divers" were harvesting these small abalones in substantial quantities because their tender meat made them even more desirable than the larger and tougher pink, red, and green abalones. In 1972, seventy-two tons of white abalone were landed, but after that the catch steadily dwindled; by the early 1990s, the species had virtually disappeared. For almost two years, biologists and divers Gary Davis, Peter Haaker, and Daniel Richards searched areas of "suitable habitat" that were known to have supported this species, and in that time they managed to find only three live individuals, approximately one per acre. "The prognosis for white abalone recovery," wrote Davis and his colleagues in 1996, "is poor, even with immediate active intervention. Wild white abalone broodstock needs to be located quickly and protected, and additional broodstock needs to be produced before significant restoration effort can begin. Population recovery without human intervention is highly unlikely, and white abalone extinction appears imminent." By 1999, the picture had not improved, and in an article titled "Extinction Risk in the Sea," Callum Roberts and Julie Hawkins listed *Haliotis sorenseni* among the soon to be missing. The following year, the National Marine Fisheries Service (NMFS) made it a candidate species under the Endangered Species Act of 1973, and in May 2001, the white abalone became the first marine invertebrate to receive federal protection as an endangered species.

In the past, fish populations were depleted by the simple but lethal expedient of catching too many of the target species, thus reducing the numbers available for future capture and breeding. The introduction of new fishing technologies in the latter half of the twentieth century changed the nature of the industry. Now fishermen deploy longlines that may be a hundred miles long and hung with thousands of baited hooks, which may be intended to catch a particular kind of fish—marlins and swordfish, for example—but catch everything else too, including thousands of unwanted species of fish, sea turtles, dolphins, and seabirds. Drift nets and gill nets sometimes float unattended for years, killing fish and other ocean wildlife that no one will ever harvest. Bottom trawlers scrape the seafloor clean of every living thing, from bottom-dwelling fishes to corals.

No phase of the industry exemplifies "progress" better than the tuna fishery. Once upon a time, tuna of various species were commercially caught on hook and line, with men lined up along the rails of the fishing boats dropping unbaited hooks into a frenzy of feeding tuna, which would snap at anything. The hooked tuna were then yanked from the water, high over the shoulders of the fishermen, and dropped onto the deck. "Their great weight and strength," wrote Robert Morgan (1955), "often make landing by one man with a line impossible . . . and therefore, each hook is operated by two and sometimes three men." In some regions today a similar technique is employed, but the hooks, lines, and jigs are mechanized and there are no fishermen, just a battery of rods bobbing and yanking tuna out of the water and onto the deck.

The biggest change in tuna fishing, however, came with the introduction of the purse seine. Here, a motorboat dispatched from a larger fishing boat encircles a school of tuna with a net, and when the school is completely surrounded, the net, which is closed at the bottom like a colander, is "pursed"—the lines around the top are pulled together—and everything in the mesh is trapped and hauled aboard. Purse seining revolutionized the tuna fishery, particularly in the eastern tropical Pacific, producing catches that dwarfed all previous efforts. But the expeditious capture of albacore and yellowfin tuna had an unexpected downside: for reasons not clearly understood, herds of spinner and spotter dolphins associated closely with the schools of tuna, and when the nets were pursed, the dolphins were trapped too. The term used for the unintentional capture of species not targeted by the fishery is *bycatch*, perhaps the most insidious euphemism in the modern fishing lexicon.

Bycatch refers to the unwanted fish hauled in with the nets, species or sizes that are not marketable—young fish, for example, that have not reached breeding age and thus will never mature and propagate. The term also applies to animals other than fish that are caught in the nets, such as seabirds, dolphins, whales, and turtles. Between June and December 1990, U.S. observers from the National Oceanic and Atmospheric Administration (NOAA) traveling aboard Japanese ships in the northern Pacific sampled 4 percent of the fleet's catch. In addition to catching 7.9 million squid (the target species), seventy-four Japanese vessels took in a bycatch that included 82,000 blue sharks, 253,000 tuna, nearly 10,000 salmonids, 30,000 birds, 52 fur seals, 22 sea turtles, 141 porpoises, and 914 dolphins. Many of these animals are air-breathers; entanglement in fishing nets prevents them from surfacing to breathe, and as a consequence they drown. In the Bering Sea, fishers discarded 16 million undersized red king crabs in 1990—more than five times the number of crabs they were able to bring to market.

The most visible of all bycatches, of course, was the hundreds of thousands of dolphins that were trapped and killed in the tuna nets of eastern tropical Pacific fishermen in the 1960s and 1970s, but this was far from the most harmful and wasteful example. "For every 10 pounds of Gulf of Mexico shrimp scraped from the sea floor," wrote Sylvia Earle in 1995, "80 to 90 pounds of 'trash fish'—rays, eels, flounder, butterfish, redfish, batfish, and more, including juveniles of many species—are mangled and discarded, in addition to tons of plants and animals not even considered worth reporting as 'bycatch,' i.e., starfish, sand dollars, urchins, crabs, turtle grass, seaweed, sponges, coral, sea hares, sea squirts, polychaete worms, horse conchs, and whatever else constitutes the seafloor communities that are in the path of the nets." In a 1996 discussion of the Gulf of Mexico shrimp fishery, NMFS fishery management specialist Steve Branstetter reported in a similar vein that "shrimp constituted 16% of the total catch by weight, other invertebrates 16%, and finfish 68%." The most abundant species in the bycatch were longspined porgy, brown shrimp, croakers, lizardfish, pink shrimp, and butterfish. Juvenile red snappers made up only 0.4 to 0.5 percent of the total catch by weight, but this percentage was calculated to number between 10 million and 35 million individuals annually, which indicates the incredible extent of the bycatch problem in this region.

With reported landings of 154,083 tons in 1999, shrimp is among the most valuable commercial food fisheries in the United States. According to a statistical database of the Food and Agriculture Organization of the United Nations (FAO), the world's shrimp fisheries hauled in 4,423,673 tons of shrimp and prawns in 1999. If other shrimpers are as efficient as Americans operating in the Gulf of Mexico, that adds as much as 30 million tons—*60 billion pounds*—of wasted fishes, sharks, rays, turtles, starfishes, sea anenomes, and cephalopods (squid and octopuses) that are bycatch in the shrimp fishery.

Stretching as far as a hundred miles, longlines consist of thousands of baited hooks for tuna, swordfish, and other billfishes. But longlines also kill young tuna, swordfish, and marlins that should be allowed to grow and breed, as well as sharks, birds, and other sea life in large quantities. Swordfish can be caught with harpoons, and tuna can be caught with hook and line, but these older ways require more work and are therefore less cost-effective. And if there was ever an industry based on cost-effectiveness, it is the modern fishery. Often marginal, and even more often unprofitable, modern mechanized fisheries are driven to wring every dollar, yen, or kopeck from the sea before the fish populations crash or before interfering legislators make them follow regulations that might actually protect the stocks of fish.

Longline fishing is an especially powerful threat to almost all of the twenty-four recognized living species and subspecies of albatross. Baited hooks are "set" from the rear of the fishing vessel, and before these hooks sink to their optimum fishing depths, the albatrosses dive for the still-floating bait, become hooked, and are dragged underwater and drowned. Each year, the Japanese fishing industry alone sets 107 million or more hooks and is responsible for at least 44,000 albatross deaths. Additional losses are caused by fishing fleets from Argentina, North and South Korea, Indonesia, Uruguay, New Zealand, Taiwan, Peru, Brazil, Hawaii, Namibia, and Australia. At least 60,000 albatrosses and other seabirds may be hooked and drowned by longline fishing vessels engaged in the pirate fishery for Patagonian toothfish, which sets anywhere between 50 million and 100 million hooks in the Southern Ocean each year.

Between 1980 and 1986, the southern bluefin tuna fishery may have accounted for an annual mortality of 2–3 percent of adult wandering albatrosses and 14–16 percent of immature birds nesting on South Georgia Island (Croxall et al. 1990), in addition to numerous deaths at the Crozet Islands in the South Indian Ocean. It is estimated that as many as 1,500 Tasmanian shy albatrosses, out of a total breeding population of 12,000, are killed each year on longlines. Long-lining contributes to the observed decreases of other albatross populations as well, including the black-footed and Laysan albatrosses of the Northern Hemisphere, especially in the northern Pacific Ocean, the Bering Sea, and the Gulf of Alaska. In recent years, an estimated 4,500 black-footed albatrosses have been killed annually by longline vessels fishing in Hawaiian waters alone. Given the circumpolar distribution of the black-browed albatross and the overlap of its range with fishing efforts, this species may face the greatest threat from fisheries of any albatross. Many of the dead albatrosses (of all species) appear to be inexperienced young birds in their first years of oceanic wandering, which means that the albatrosses lose the young of previous seasons and therefore lose potential breeding adults, leaving a dwindling, aging population. As Carl Safina (2002) pointed out:

> At one time, albatrosses survived extermination only by being at sea. Today, most albatrosses are safe only on land—where they spend just 5 percent of their lives. Hunting and killing on land in decades past was certain to miss at least some islands and some nests and some birds. But nowadays, every albatross, no matter how remote its nest, finds numerous opportunities to die on a longline. If it does and it has a chick on the nest when that happens the chick starves.

There is some cause for hope, however. A new device developed by Ed Melvin and others at the Washington Sea Grant Program could substantially reduce the number of albatrosses caught by long-liners. Each long-liner would be required to fly streamers suspended from strings behind the boat that would flutter in the wind and keep the birds from snatching at the baited hooks. In their 2001 report, Melvin and his colleagues commented, "In 2000, paired streamer lines virtually eliminated both Laysan albatross and northern fulmar attacks on baited hooks, and completely eliminated the albatross and northern fulmar bycatch." Safina, in his book titled *Eye of the Albatross: Visions of Hope and Survival*, continues:

> The birds are now reasonably secure on their islands, where once they were hunted mercilessly. The main threat now comes from longline fishing, but where longline fishing pressure has softened, some albatross populations have begun to trend upward. For example, Wanderer populations on Crozet and Kerguelen Islands in the Indian Ocean, which had plunged by more than half between 1960 and 1990, are now increasing because many longline boats have moved away from these birds' main feeding grounds (after depleting the Southern Bluefin Tuna

they'd targeted). Antipodes Albatrosses increased from about eight hundred pairs in the late 1960s to over five thousand pairs by the mid-1990s—by far the greatest increase for any great albatross population. The short-tailed has been increasing at 7 percent per year. Full recovery of these species could still require well over a century, and others are in trouble, but the point is this: these birds were in very bad shape, yet things have changed for the better.

Gill nets, still in common use, are submerged walls of netting whose meshes form a noose around the heads and bodies of fish that swim into them. They are used for surface, midwater, or bottom fishing and can be anchored or set adrift; in the latter case, they are referred to as drift nets. (Drift gill nets, a third type, are attached to the vessel at one end, with the other end drifting behind.) When Japan developed monofilament fibers that could be used in open-ocean drift-netting in the mid-1970s, it introduced the most destructive method of fishing ever devised. Large-scale high-seas drift nets were first used in the North Pacific by fleets from Japan, Taiwan, and South Korea. Because of the huge bycatch of marine wildlife in these nets, they have been labeled "walls of death"; hundreds of thousands of whales, dolphins, seabirds, sea turtles, sharks, and other nontarget species have been killed by them to date. Free from any connection with the boat, drift nets are set with floats at the top and weights at the bottom so that they drift passively in the water and trap fish that swim into them. Traditionally, these were small nets used in coastal waters to catch densely schooling fish, such as herring, but with the introduction of light synthetic netting, drift net fishing underwent a major change. The nets can now be used on the high seas, where they are very effective at catching wide-ranging species such as tuna and squid. Barely visible in the water, these nets are devastatingly effective at catching all other wildlife in their path. Each boat sets as much as forty miles of net, totaling some *40,000 miles* of drift net, every night—enough to circle the earth one and a half times.

Dolphins and porpoises are probably caught in drift nets because they cannot "see" the monofilament fibers. Even though the dolphins' mechanism of echolocation is incredibly sensitive, the thin strands of fiber that make up the drift net may not reflect sound well enough to provide an echo. And even if the dolphins receive a signal, they may not be echolocating at the moment before entanglement. They may well detect the plastic floats at the tops of the nets, but those would very likely appear to them as no cause for concern, and they certainly give no indication of the danger below. Because most dolphin species are gregarious—none more so than spinners and spotters, which aggregate in huge schools that may number in the thousands—if the "leaders" blunder into a monofilament net, the rest of the school may follow. The long snouts of these dolphins are pushed through the mesh; because the animals are unable to recognize the nature of the snare, they try to push forward and are trapped and drowned.

By 1987, the Japanese squid fleet consisted of more than 1,200 drift netters, each deploying thirty miles of net nightly during a season that lasted seven months. Various conservation organizations, particularly Earthtrust and Greenpeace, campaigned vigorously against this horrifically destructive method, but it would take years of outrage before anything was done. In 1989, videocameraman Sam LaBudde signed on a Panamanian fishing boat as a cook and surreptitiously filmed nets being hauled aboard with dead baby dolphins trapped in the mesh. The film that resulted, *Stripmining the Seas*, became an important weapon in the arsenal designed to bring an end to drift netting. In April 1990, the FAO announced that drift netting had been found even more destructive than previously reported. Between 315,000 and 1 million dolphins of various species, the organization estimated, were being killed annually—in addition to the 20,000 dolphins killed every year in the purse seine fishery for tuna. Although the United States and Japan signed a joint resolution to outlaw drift netting in 1991, Taiwan continued to build drift netters, deploying them off the coast of Africa to avoid detection and prosecution. Under intense international pressure, Taiwan finally shut down its drift net fishery in 1994.

The United Nations described large-scale high-seas drift nets as "a highly indiscriminate and wasteful fishing method" and adopted a resolution to ban them. In June 1998, the European Union moved to phase out all drift nets by European nationals and ban the use of drift nets in European waters. Despite this international condemnation, high-seas drift nets continue to kill thousands of dolphins and all manner of other marine life. In January 1999, NOAA banned the use of drift nets by U.S. fishermen in the North Atlantic swordfish fishery to reduce marine mammal bycatch. Because U.S. fishermen are not permitted to use drift nets in the South Atlantic swordfish fishery, this latest ruling bans the use of drift nets in the swordfish fishery throughout the Atlantic Ocean. Drift net fishing for Atlantic swordfish typically involved ten to twelve vessels per year for approximately fourteen days a year, but high bycatch rates of marine mammals and sea turtles prevented a reopening of the fishery.

A method of commercial fishing common in British waters, known as pair trawling, consists of two fishing boats towing a single gigantic net to ensnare fish between them. (Trawling differs from gillnetting in that the trawl is pulled behind a fishing vessel or vessels; gill nets are set and left to fish on their own.) With pair trawling, each vessel pulls on one side of the net, and by carefully coordinating the speed of their boats, the distance between the boats, and the length of their tow wires, the fishermen can precisely control the net's position. The target species is the sea bass, *Dicentrarchus labrax*, a fish that spawns in the Western Approaches, the area of the North Atlantic immediately west of the English Channel. Hundreds of thousands of sea bass gather between December and March every year, and the fry from their spawnings make their way back to the coast in search of sheltered waters in which to feed, grow, and mature. They are particularly fond of estuaries and even more fond of water warmed by the water discharged by nuclear power stations. The young bass are especially vulnerable in these inshore areas; many were being taken before growing big enough to journey back to the Western Approaches to spawn. "Nursery areas" were designated by the British government to give these immature bass some protection, and the number of bass returning to the spawning grounds increased. So many tons of valuable fish in the spawning grounds, however, proved to be too great a temptation, and the large pair trawlers moved in to exploit this otherwise unregulated fishery. French and Scottish pair trawlers had already devastated the black bream fishery for which they had been built, and now they were making massive inroads into the dolphin populations. As many as fifty common dolphins, harbor porpoises, and, occasionally, bottlenose dolphins may be caught in a single haul. Most of the bycatch in this fishery is unreported, but it has been estimated that as many as 2,400 dolphins are killed each year in this process (Deere-Jones 2001).

Before the advent of industrial fishing, some regions of the ocean were too distant or too deep for fishers to reach, and the fish that lived there remained untouched. But with the introduction of more and more sophisticated gear, no area is safe from human predations. Carl Safina (1998a) wrote: "Nowadays, every kind of seabed—silt, sand, clay, gravel, cobble, boulder, rock reef, worm reef, mussel bed, seagrass flat, sponge bottom, or coral reef—is vulnerable to trawling. For fishing rough terrain or areas with coral heads, trawlers have since the mid-1980s employed 'rockhopper' nets equipped with heavy wheels that roll over obstructions." Fishery workers can fish a mile down; they can locate schools of fish whose presence—whose very existence—was unsuspected; they can stay at sea for months and process the catch on board huge factory ships; they can deploy lines that stretch for fifty miles or nets that fish cannot see; they can see the bottom a mile down and drag their huge trawls over it, destroying an entire ecosystem; and they can completely change the character of the food chain.

Fisheries biologist Daniel Pauly is the author of the phrase (and the concept of) *fishing down the food chain*, which means first taking out the apex predators—large species such as cod, tuna, and swordfish—because they are the most desirable species, then, when they are gone, going down a trophic level and taking out their prey species (plankton-eaters such as anchovies), and then taking what's left. This downward shift has occurred as populations of predator fish have been decimated by overfishing and fishers have been forced to harvest what is left, species of the predators' prey. (From the Greek *trophe*, meaning "food" or "nourishment," *trophic level* refers to the position of organisms within food webs, and ranges from 1 [plant] to 5 [top predators].) To gauge the extent of this shift, researchers have assigned numbers to each trophic level, although the distinctions aren't as clear as one would like, given that many creatures feed at multiple levels. The predators at the very top of the chain, humans, are assigned level 5.0, and piscivorous apex hunters such as tuna and swordfish are assigned level 4.0; then 3.0 is given to the prey of these predators (squid, anchovies, and the like), 2.0 is reserved for the zooplankton (e.g., the copepods on which they feed), and 1.0 denotes the bottom level, the phytoplankton that support the whole structure. "We firmly believe," wrote Pauly and his colleagues in a 2000 *American Scientist* article, "that the mean trophic level of the catch . . . is truly declining":

> It takes very little to convince oneself that this situation is alarming—for seafood lovers as well as for environmentalists. After all, the average trophic level of the global catch has already slipped from 3.4 to 3.1 in just a few decades, and there are not many more appetizing species to be found below this level. [Recall that 2.0 corresponds to copepods and other tiny zooplankton, creatures that are unlikely ever to be filling one's dinner plate.] So if the trend continues, more and more regions are likely to experience complete collapse of their fisheries.

Because the top predators are usually sought first, Robert Steneck, a University of Maine marine biologist, said (1998): "It stands to reason that prey populations and their effects on marine communities will increase after release from predator control. Accordingly, fishing alters the organization and structure of entire marine communities via 'cascading' trophic chain reactions." Because the top predators are the least numerous, as one moves down a food web, biomass increases, but nowadays fish catches have stagnated as fishers have moved from top predators to species at lower trophic levels. Once a top predator has been depleted or exterminated by fishing, alternative predators, which are of no commercial value, thrive in the absence of competition and thus deplete the biomass of prey species at lower trophic levels.

"Fishing down the food chain," of course, is not restricted to human fishers, but the concept is important to an understanding of the ripple effect of overfishing by humans. In Monterey Bay, California, the sea otters were hunted to near extinction, which meant that the sea urchins on which they fed could proliferate unchecked. The urchins in turn gnawed on the holdfasts that anchored the giant kelp, which was thereby cut loose to float on the surface, thus eliminating the entire habitat of the fishes that called these great kelp forests home. When great whales and sea lions began to disappear from Alaskan waters (the whales because they were hunted by humans, the sea lions perhaps because of the removal of pollock, their primary food source), as argued by James Estes of the University of California, Santa Cruz, and colleagues (1998), the killer whales descended one trophic level and began preying on sea otters.

In the northwestern Mediterranean Sea, fishing has depleted sea urchin predators, causing a great increase in the region's dominant sea urchin, *Paracentrotus lividus,* which has grazed the seafloor into "a relatively featureless and largely inedible crustose coralline community" (Steneck 1998). Sea urchins, however, though they might have a low trophic level, filling a niche that has been left vacant by the removal of higher predators, must be recognized as a legitimate part of the marine community, and in some instances the removal of sea urchins has had a calamitous effect on an ecosystem. Around 1983, a still-unidentified pathogen arrived in the western North Atlantic Ocean and began killing off the superabundant sea urchin known as *Diadema antillarum.* The herbivorous *Diadema* kept the reefs clean of "turf algae" and permitted the corals of the Caribbean, the Gulf of Mexico, the Bahamas, and Bermuda to proliferate. When the urchins died, the algae enveloped vast tracts of the underwater landscape, smothering the corals.

The tremendous increase in aquaculture (fish farming) in recent years has been offered as a possible solution to the problems of worldwide overfishing, but aquaculture has its own problems, and in some cases it may be contributing to, rather than solving, the overfishing problem. The species most prominently farmed around the world are carp, salmon, trout, shrimp, tilapia, milkfish, catfish, crayfish, oysters, hybrid striped bass, giant clams, and various shellfish. Of these, shrimp and salmon make up only 5 percent of the farmed fish by weight but almost 20 percent by value. Farming is the predominant production method for salmon, and aquaculture accounts for 25

percent of world shrimp production—a tenfold increase from the mid-1970s (Naylor et al. 1998).

By a substantial margin, China leads the world in aquaculture, and most of the fish farmed in China are carp, used for regional consumption in low-income households. In other parts of the world, farmed tilapia, milkfish, and channel catfish have replaced depleted ocean fish such as cod, hake, haddock, and pollock. Worldwide landings for the "capture fisheries" (those in which wild fish are caught at sea) have leveled off at around 85–95 million metric tons per year, with most stocks being recognized as fully fished or overfished. In 1990, the figure for aquaculture was 10 million tons, but by 2000 it had nearly tripled (Naylor et al. 2000). Global aquaculture now accounts for more than one-quarter of all fish consumed by humans.

Each species of farmed fish (shrimp and shellfish are also known as fish in aquaculture-speak) has its own requirements, and it is impossible to generalize about the benefits or detriments of fish farming as a whole. Carnivorous species, such as salmon and shrimp, are usually fed fish meal, made from ground-up fish. The cost of providing food for farmed salmon is nearly as high as the price the salmon can command; moreover, in this case, farming contributes to overfishing because the small fish—such as Peruvian anchovetas—are harvested almost exclusively for fish meal. (It is not only fishes that eat fish meal, of course; most of the processed fish meal is fed to chickens and pigs.) To feed the carnivores, fishermen are fishing for fish to feed to fish.

Carp, tilapia, and milkfish are herbivores and can be fed plant food or prepared fish food not unlike that which hobbyists sprinkle into their home aquariums. Could the vast amount of fishes and other creatures caught incidentally in a particular fishery and usually discarded—the bycatch—be saved and used for fish meal instead of targeted fishery species, such as anchovies? This, unfortunately, would require fishers to use valuable space aboard their ships for storage of bycatch, which are worth less per fish than the expensive fish they are seeking. In a 2001 article on the effects of aquaculture on world fish supplies, Rosamond Naylor (an economist and recognized authority on aquaculture) and two colleagues pointed out:

> Carps and marine molluscs account for more than three-quarters of current global aquaculture output, and tilapia, milkfish and catfish contribute another 5% of total production. Fed mainly on herbivorous diets, these species provide most of the 19 Mt [megatons] gain in fish supplies from aquaculture. . . . But market forces and government policies in many countries favour rapid expansion of high-value,

> carnivorous species, such as salmon and shrimp. Moreover, fish meal and fish oil are already being added to carp and tilapia feeds for weight gain, especially in Asia where farming systems are intensifying as a result of increased scarcity and value of land and freshwater resources. Given the huge volume of farmed carp and tilapia in Asia, significant increases in the fish meal and fish oil content of feed could place even more pressure on pelagic [open-ocean] fisheries, resulting in higher feed prices and harm to marine ecosystems.

Shrimp farming is one of the phenomenal success stories in aquacultural history. More than 880,000 tons of shrimp are produced annually from 2.96 million acres of ponds around the world. Annual revenues are estimated to exceed U.S.$6 billion, and the industry is said to be particularly beneficial to developing countries, providing jobs, alleviating poverty, and in some cases even putting food on otherwise barren tables. (Many fishers, however, lost their livelihood.) However, because shrimp farming can be a boom-and-bust phenomenon, environmental and socioeconomic disasters frequently accompany this branch of aquaculture. Shrimp farms often displace home owners, which serves to increase poverty and homelessness; and when rice paddies or mangrove swamps are appropriated for shrimp farms, the net loss to the community cannot be overstated. Ponds located inland often seep saline waters into the surrounding area, which affects the growing of rice and other crops. Aquaculture may provide a long-term solution to the problems of overfishing, but as currently conceived, it often raises more problems than it solves. Here are Naylor and colleagues again:

> Growth in aquaculture production is a mixed blessing, however, for the sustainability of ocean fisheries. For some types of aquaculture activity, including shrimp and salmon farming, potential damage to ocean and coastal resources through habitat destruction, waste disposal, exotic species and pathogen invasions, and large fish meal and fish oil requirements may further deplete wild fisheries stocks. For other aquaculture species, such as carp and molluscs, which are herbivorous or filter feeders, the net contribution to global fish supplies and food security is great. The diversity of production systems leads to an underlying paradox: aquaculture is a possible solution, but also a contributing factor, to the collapse of fisheries stocks worldwide.

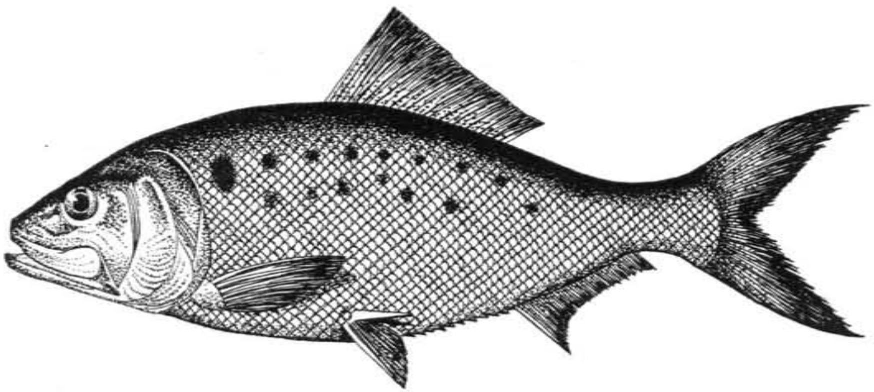
In late 2001, Rosamond Naylor was flying over Sonora looking for shrimp farms, expecting to find "clusters of scattered ponds separated by huge tracts of sere land." Instead, it looked as if the Gulf of California had risen and swept

across more than forty-two square miles of the Sonoran Desert: everywhere were "patches of blue, pools of shrimp, one after another, all down the coast," in the words of Marguerite Holloway (2002). Aquaculture, the "blue revolution" of Holloway's article, is by now "a $52 billion-a-year global enterprise involving more than 220 species of fish and shellfish that is growing faster than any other food industry."

We all know that most of the earth is covered with water, but typically we see only the top of it. Beneath its shimmering surface there is a world of life, more intricately woven than that of any rain forest. The occupants range in size from the great whales, the largest animals ever to live on the planet, to microscopic dinoflagellates and submicroscopic viruses. Humans have taken advantage of the ocean's bounty for virtually all of recorded history, probably starting when a prehistoric beachcomber found a dead fish washed ashore, still relatively fresh. From that innocuous beginning or something akin to it, humans became whalers, sealers, aquaculturists, netters, trollers, purse seiners, long-liners, bottom trawlers, rod-and-reelers, dynamiters, poisoners, and myriad others dedicated to removing living things from the ocean. Sometimes the animals were killed for oil, sometimes for baleen, and sometimes for their fur coats, but for the most part they were used for food, and this seemed more than enough justification for the continuing slaughter of the oceans' wildlife. People had to eat, didn't they? Besides, the ocean was so big and so deep and so filled with edible items that there seemed no end to its productivity. If one population of whales (or seals, or fishes, or sharks) was depleted, the fishers simply moved to another area and attacked another population, or changed the object of the fishery. A number of fish species, previously regarded as so plentiful as to be unaffected by human enterprise, have instead shown themselves to be vulnerable to fishing to such a degree that they are now considered endangered. The idea that Mother Ocean would continue to provide for her dependents forever has shown itself to be another gross misjudgment on the part of those dependents.

THE LOWLY MENHADEN

Almost all species of commercially caught fishes are in trouble. Take the lowly menhaden (*Brevoortia tyrannus*), for example. Also known as mossbunker and pogy, this foot-long, one-pound member of the herring family is found in the continental waters of the United States from Maine to Florida. These fish are too bony and oily to be served at the dinner table, but the menhaden fishery is the largest on the Atlantic and Gulf coasts, exceeding the tonnage of



MENHADEN *(Brevoortia tyrannus)*

all other species combined (Franklin 2001). Menhaden are silvery in color with a distinct black shoulder spot behind their gill opening and a variable number of smaller spots on their sides. They have a deeply forked tail fin, and, like shad and herring, they have a keel of sharp spines on the belly. Menhaden are consumers of phytoplankton and plant detritus and, in turn, are fed upon by almost every species of predatory fish, including striped bass, mackerel, cod, bonito, bluefish, swordfish, and tuna, as well as mammals and birds. Until the human industrialization of fishing, however, their numbers were more than adequate to feed their myriad predators.

In the past, menhaden could be found in immense schools, sometimes numbering in the millions "with their heads close to the surface, packed side by side, and often tier above tier, almost as closely as sardines in a box" (Goode and Clark 1887). The modern menhaden industry emerged in New England early in the nineteenth century, after it was recognized that the species could provide a valuable alternative to whale oil in the production of lubricants, fuel for lamps, soap, and paint. Factories for rendering menhaden were first built on the shores of Massachusetts, Maine, New York, and Connecticut. By the beginning of the twentieth century, menhaden also served as a component of fertilizer and animal feed and was used in the manufacture of substances such as fingernail polish and perfume.

Menhaden taken in Atlantic coastal waters from Maine to Florida and in the Gulf of Mexico provide the major source of fish meal in the United States. The fish are ground, cooked, and processed to yield press cake, fish solubles, and oil. The chicken industry is currently the largest user of menhaden meal,

followed by turkey, swine, domestic pet food, cattle, sheep and goats, and, more recently, aquaculture. In Europe, the oil is refined and used extensively in cooking oils and margarine. In 1989, the U.S. Food and Drug Administration (FDA) concluded that fully and partially hydrogenated menhaden oil is a safe ingredient for human consumption. In 1990, the FDA proposed an amendment based on an industry petition to permit the use of marine oils. It was approved in 1997 and could provide a significant new market for menhaden oil, which is rich in omega-3 fatty acids. More recently, it has also been used as a cooking oil and an ingredient in processed foods such as cookies and cakes.

Chesapeake Bay once produced more seafood per acre than any other body of water on earth, and the largest proportion of this seafood was menhaden. The menhaden fishery had spread south from New England after the Civil War, when the purse seine was introduced, allowing the fishery to expand. Coal-fired steamers gradually replaced sailing ships as carrier vessels in the late 1800s; diesel and gasoline engines gradually replaced the steam engines following World War I. The use of purse seines to harvest menhaden continues today, but since the development in the 1950s of the hydraulic power block for pulling up the net, there has been no need for large crews. Other midcentury refinements included lighter, faster, and more maneuverable aluminum rather than wooden purse boats with motors instead of oars; more durable nylon seines instead of natural fiber nets; and large fish pumps, which eliminated the difficult work of transferring the catch from the net into the hold. In addition, spotter planes took over the work of sighting schools of menhaden, radioing locations to captains on board ship. With these changes, harvesting efficiency increased dramatically, with a subsequent drop in catches.

The average tonnage caught from 1996 to 1999 was only 40 percent of the annual take between 1955 and 1961. In the year 2000, the catch was 183,700 tons, the second lowest since 1940, when the National Marine Fisheries Service began keeping records. Maryland has outlawed purse seining in Chesapeake Bay, but Virginia has not. The largest U.S. fisher of menhaden and producer of fish oil and products from it, Houston-based Omega Protein Corporation, founded by former U.S. president George H. W. Bush, accounts for more than 60 percent of the menhaden catch from the Virginia waters of the bay. Omega Protein, which maintains that "the menhaden resource is healthy and self-renewing," is the maker of the so-called long-chain omega-3s that some doctors recommended for self-applied control of cardiovascular disease, cancer, and arthritis.

Despite the company's public optimism, in 2000 Omega Protein laid up thirteen of its fifty-three ships and grounded twelve of its forty-five spotter planes (Franklin 2001). The menhaden fishery has clearly suffered a decline, primarily as a result of international market conditions affecting the price of menhaden products, and, not surprisingly, a shortage of fish. The number of processing plants on the Atlantic coast declined from eight in 1981 to only two at the close of the twentieth century. Still, the menhaden support the largest single-species fishery on the Atlantic coast, the most concentrated fishery in Chesapeake Bay, and, after Alaskan pollock, the second largest fishery in America.

If the mossbunker population is indeed dwindling over the long term, it spells big trouble for Chesapeake Bay. Like oysters in the lower layers, menhaden are filter feeders, removing plankton from the waters of the bay. The Chesapeake Bay oysters have been driven to near extinction; if the menhaden go, there will be nothing to clean the estuaries. Native and alien jellyfish are proliferating, perhaps because the menhaden no longer keep their numbers down by feeding on the larval, planktonic stages.

THE GREAT AND WONDERFUL TUNA

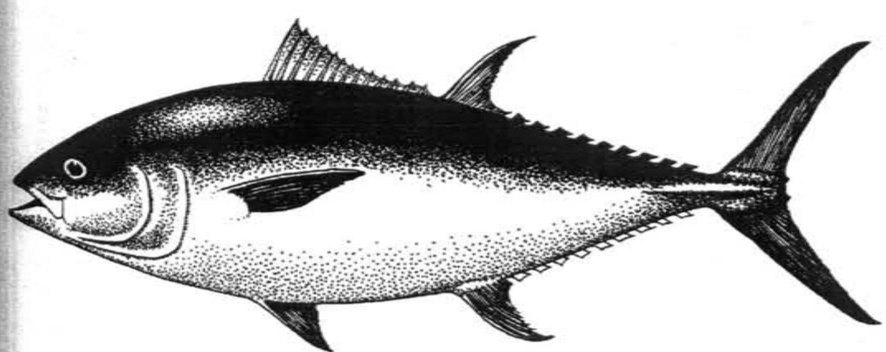
> Tokyo, January 5, 2001 (AP). An enormous bluefin tuna—a fish prized as sushi—sold for a record $173,600 Friday in the first auction of the year at Tokyo's main fish market. At $391 a pound, the 444-pound fish was the most expensive auctioned off at the Tsukiji Central Fish Market in years. In 1996, a 250-pound bluefin fetched $44,100. Called *honmaguro* in Japanese, bluefin tuna is popularly served raw as sashimi or sushi in restaurants where a plate of slices can command a bill of more than $100. Both fish were caught in the Pacific Ocean off Aomori Prefecture in northern Japan, an area known for the quality of its tuna. "It's kind of like a brand name," market official Takashi Yoshida said.

Every day in the Tsukiji Fish Market, which handles about 90 percent of the seafood that ends up on Tokyo's tables, the most valuable fish in the world appears as an arrangement of headless, tailless, ice-rimed blocks. These rock-hard carcasses have been trucked in from Japanese ports or flown from the distant waters of New Zealand, Australia, or New England. Here, they are auctioned off to brokers, who will auction them to restaurant owners, who will in turn sell the red, fatty meat as sashimi at upward of $75 per portion. There are a lot of two-ounce portions in a 600-pound bluefin tuna.

The bluefin tuna is probably the most endothermic of all living fishes.

Along with the broadbill swordfish and certain sharks, such as the mako shark, great white shark, and porbeagle, the tunas have developed a circulatory mechanism that enables them to elevate their internal body temperature to as much as twenty-five degrees higher than the water in which they are swimming. The rete mirabile, a sheet of tissue that places the veins and arteries close to each other, functions as a countercurrent heat exchanger. In a 1973 article in *Scientific American,* Frank Carey explained: the "venous blood warmed by metabolism gives up its heat to cold, newly oxygenated arterial blood fresh from the fish's gills. The effect is to increase the temperature and thus the power of the muscle." Heated muscle makes for more efficiency—think of an athlete warming up—and only the sailfish and some of the marlins can equal the estimated fifty-mile-per-hour swimming speed the bluefin tuna may attain. The swordfish, a deepwater hunter, heats up its brain and huge eyes, but tunas and mackerel sharks heat up their brains, their eyes, and their whole bodies. (The differences in these mechanisms have led biologists to suggest that the heat-conservation strategy evolved independently in the sharks, tunas, and swordfish.)

Along with warm-bloodedness, the bluefin has other characteristics that contribute to its speed and efficiency. Whereas the eyes of most fishes protrude, those of the bluefin are flush with its head, further decreasing the drag on what is probably the most hydrodynamically advanced body design of any fish. The bluefin's body is a slick, scaleless teardrop, with slots into which it can fold down its dorsal and pectoral fins. Along its narrow tailstock is a series of finlets; their function is not clearly understood, but they probably help reduce turbulence as the fish rockets through the water. The "drive train" of the tuna consists of a crescent-shaped tail moved from side to side



BLUEFIN TUNA *(Thunnus thynnus)*

by powerful muscles. (Most fishes move the after part of their bodies, but the tuna propels itself by moving only its lunate tail.) In his 1991 discussion of the mechanics of swimming, Chris McGowan commented: "The additional drag that accompanies lateral movements of the body is greatest at the tail end, where the displacement is highest, and this explains why endurance swimmers have a narrow caudal peduncle. It also explains why having a stiff tail is more efficient than having a flexible one. The most efficient swimming strategy is therefore to have a stiff body and tail and to allow only the tail to move, as in the tuna."

The largest of the tunas—and one of the largest of all the bony fishes—the bluefin (*Thunnus thynnus*) can reach a length of twelve feet and a weight of three-quarters of a ton. (The International Game Fish Association's record for a bluefin caught on rod and reel is 1,496 pounds.) The word *magnificent* is often applied to the bluefin, and it is exquisitely applicable. They are bluewater (open-ocean) schooling fishes that not only swim incredibly fast but also make some of the longest migrations of any fish. Specimens tagged in the Bahamas have been recaptured in Newfoundland, Norway, and even Uruguay. The northern Pacific bluefin (*Thunnus tonggol*) ranges across the entire northern Pacific, migrating from California to Japan and back (the $173,000 fish was one of these) and sometimes detouring as far south as New Guinea. The southern bluefin, *Thunnus maccoyii*, a very similar species, lives only in the Southern Hemisphere and makes similar migrations. Bluefins feed on mackerel, herring, mullet, whiting, eels, and squid.

Long before the Japanese elevated it to the heights of gastronomic desirability, the bluefin was considered one of the world's premier game fishes. The great weight and sheer power of giant tuna made fishermen eager to do battle with them, even though there were few success stories. Zane Grey, the author of popular western novels in the 1920s and 1930s, was a passionate big-game fisherman, spending most of his not inconsiderable royalties (his books sold 13 million copies) on fishing trips, fishing boats, and fishing gear. In addition to books such as *Riders of the Purple Sage*, he wrote about his fishing experiences. In *Tales of Swordfish and Tuna* (1927), he described his battles with giant bluefin tuna, first in California and then in Nova Scotia waters. After many tries, he hooked one and fought it for four hours:

> To me he seemed enormous, supremely beautiful and unattainable. He flashed purple, bronze, silver-gold. When he went under he left a surging abyss in the water, a gurgling whirlpool. This sight again revived me. I was a new man, at least for a little while. I turned that tuna round. I pulled the launch toward him. I held him so that he towed us stern first. In short I performed, for the time being, miraculous and hitherto unknown feats of rod endurance. I would have cheerfully walked overboard into the sea for that fish.

Brought to the dock, the tuna measured eight feet, eight inches in length and six feet, four inches in girth and weighed 758 pounds. In the prose for which he was famous, Grey described the vanquished fish:

> I was struck dumb by the bulk and beauty of that tuna. My eyes were glued to his noble proportions and his transforming colors. He was dying and the hues of a tuna change most and are most beautiful at that time. He was shield-shaped, very full and round, and high and long. His back glowed a deep dark purple; his side gleamed like mother-of-pearl in a lustrous light; his belly shone a silver white. The little yellow rudders on his tail moved from side to side, pathetic and reproachful reminders to me of the life and sprit that was passing. If it were possible for a man to fall in love with a fish, that was what happened to me. I hung over him, spellbound and incredulous.

Bluefin tuna are still prized as big-game fishes, but it is the Japanese sashimi market that sets the astronomical prices on these fish. When a big, top-quality tuna is caught in New England, Australia, or New Zealand waters, it can sell on the dock for more than an average two-bedroom house, and by the time it is served in a restaurant, its value may have increased tenfold.

Because of the prices they can fetch, bluefins have been overfished, and their North Atlantic breeding populations are estimated to have declined by about 90 percent since 1980. As with all fish populations, exact counts are impossible, so there are vast gaps between the high estimates made—to no one's surprise—by the fishermen and the low estimates made by those who would protect the tuna from overfishing. From dock to cabinet ministry, there have been endless discussions about solving the problem at every level, but few protective measures have been taken because to do so would require unprecedented domestic and international cooperation. There is an organization that is supposed to oversee the tuna industry, the Madrid-based International Convention for the Conservation of Atlantic Tunas, known as ICCAT (pronounced "eye-cat," and ridiculed as the "International Conspiracy to Catch All Tuna"). In response to dwindling catches, ICCAT's twenty-two member countries divided the North Atlantic Ocean into eastern and western sectors, each with its own quota. In 1991, when Sweden submitted a proposal to ICCAT that the bluefin be listed as endangered, it was immediately voted down by the United States and Japan, countries with a strong economic interest in catching tuna. Conservationists, fishermen, and bureaucrats continued to draft position papers and proposals while the tuna populations plummeted and the prices rose. As John Seabrook wrote in 1994, "one reason that the price is so high is that there are so few of them left in this part of the ocean, and one reason that there are so few of them is because the price is so high." If someone is willing to pay $173,000 for a fish, a lot of fishermen will be looking to be the lucky one to cash in.

When Gramps took little Billy to the Old Fishin' Hole, he had a pretty good idea that there would be sunfish or crappies there and it would be a simple matter of dropping in a hook baited with a worm. But commercial pelagic fishing bears no resemblance to a fishin' hole. In order to catch fish—or, for that matter, to protect a species—people have to understand where the fish go and when. Nowadays, every available technological and biological advancement is employed in the never-ending quest to understand the behavior of fish. To locate them, fishers use radar, sonar, loran, and spotter planes; to catch them, they deploy drift nets, gill nets, purse seines, and gigantic trawls; and to process and transport the catch, there are powerful, far-ranging factory ships.

In 1996, Molly Lutcavage of the New England Aquarium, along with Paul Howey of Microwave Telemetry, Inc. in Columbia, Maryland, began to develop microprocessor tags that could be attached to Atlantic bluefins in an attempt to better understand their migration and biology. In previous tagging systems, the tag included only information about where and when it was inserted, so when a fish was caught, the most researchers could learn was how long the fish took to get from there to here. The new tags, however, logged the fish's temperature hourly, averaged the temperatures, and stored the figure. After sixty days, the tiny computer shut down, an electric current was generated to corrode the wires fastening it to the fish, and the tag floated to the surface, transmitting its data via satellite to waiting scientists. Barbara Block of Stanford University launched thirty-seven of Howey's pop-up tags but then employed an "archival" tag, which was lodged in the tuna's abdomen and measured not only water temperature but also light, depth, and internal body temperature until the fish was caught and the tag recovered. Among the more surprising findings revealed by the microprocessor tags was that tuna, long believed to travel and hunt near the surface, made regular dives to a depth of 3,300 feet while feeding on squid and could maintain a body temperature of 80°F or higher in the ink-black, icy cold waters more than half a mile down. (Most other fishes, commonly known as cold-blooded, would have a body temperature of 39°F in 39°F water.)

By 2000, a total of 377 fishes had been tagged along the eastern coast of North America with both types of microprocessor tags, pop-up and archival. In a report published in *Science* magazine the following year, Block and her colleagues showed that the migratory behavior of the bluefin was far more complex than anyone had imagined. Rather than segregating into eastern and western Atlantic populations, the tuna "mixed," which further complicated the already thorny issue of who has the right to catch which tuna. Moreover, this mixing did not occur just near the midline: some tuna were found to have traversed the entire ocean—some 1,670 nautical miles—in less than ninety days' time. Before the tagging data were analyzed, it was thought that perhaps 2–4 percent of the tuna crossed ICCAT's line (the forty-fifth meridian) separating the "American" tuna from the "European." ICCAT had established quotas on the assumption that there were two distinct populations that did not mix, but it now appears that although there are two distinct spawning areas—the Gulf of Mexico and the Mediterranean Sea—the fish migrate across the Atlantic Ocean at will until they attain sexual maturity, at eight to ten years of age, at which time they migrate to their particular spawning grounds. Both eastern and western populations feed at western foraging spots, but they separate for breeding. Moreover, it was not 2–4 percent of the bluefins that crossed the ocean; it was closer to 30 percent.

The tuna of the eastern zone, which are caught by Europeans, are managed under a strict annual quota set by the European Union, whereas those of the western Atlantic, targeted by American fishermen, have been managed under strict catch quotas since 1995. (As we shall see, neither of these quotas includes "farmed" tuna.) Nevertheless, in both areas, the stocks of bluefin tuna have fallen dramatically: there has been an 80 percent decline in the eastern (European) stock since 1980 and a 50 percent drop in the western Atlantic population.

Management is a fine and noble goal, but there has to be something left to manage. During the 1960s, bluefin catches peaked at about 38,500 tons, but less than a decade later, overfishing sent the catch plummeting to less than half of that figure, and a 1964 peak of 22,000 tons in the western Atlantic fell to 6,710 tons in 1978. The collapse of the New England tuna fishery has been comprehensively documented, most eloquently by Carl Safina in *Song for the Blue Ocean,* but where the big fish were before they arrived off Georges Bank is still a mystery. The same is true for the massive schools of tuna that every year entered the bottleneck of the Strait of Gibraltar and swam into the functional equivalent of a gigantic fish trap: the Mediterranean.

For thousands of years, men have fished for tuna in the Mediterranean. In her brilliant little book *Mattanza* (an Italian word that means "the killing"), Theresa Maggio chronicles the long, noble history of *tonnara* (tuna fishing), from the time of the Carthaginians and Phoenicians five centuries before Christ right up to present-day Sicily. "The bluefin were to ancient Mediterranean peoples what the buffalo were to the American Plains Indian," Maggio wrote, "a yearly miracle, a reliable source of protein from a giant animal they revered, one that passed in such numbers that the cooperation of an entire tribe was needed to kill them, and preserve their meat. Around the Mediterranean the migrating bluefin was a staple food for entire civilizations." Oppian, the second-century Greek poet and naturalist, wrote a poem on fishing called *Halieutica*, in which he described a second-century *tonnara:*

> Dropped in the water are nets arranged like a city. There are rooms and gates and deep tunnels and atria and courtyards. The tuna arrive in great haste, drawn together like a phalanx of men who march in rank: there are the young, the old, the adults. And they swim, innumerable, inside the nets and the movement is stopped only when there is no more room for new arrivals; then the net is pulled up and a rich haul of excellent tuna is made.

The *mattanza* of the village of Favignana, located on one of the Egadi Islands off the western tip of Sicily, is the most famous of recent *tonnare* (tuna fisheries) and one of only two remaining. A complex arrangement of gigantic nets is deployed along the tuna's expected route, and the fishermen wait for the great fish to swim into them. The nets are hung from ropes, "arranged like a city" as they were in Oppian's day, and stretched to the bottom by massive anchors. "The trap is oblong," wrote Maggio, "except for a widening at the shoulders that makes it look like a widening coffin. It is divided into seven rooms by net walls with gates in them. . . . It is fifty meters squared." The last "room" the tuna will ever see is the *camera della morte*—the "chamber of death"—the only room with a net bottom, which the *tonnaroti* raise by hand from seventy-five-foot-long open boats.

In *The Silent World*, published in 1953, Jacques Cousteau described his experience in a tuna net in Tunisia, where the death chamber is called a *corpo:*

> Marcel Ichac filmed the spectacle from a boat above the *corpo*, while Dumas and I dived into the net to record it below. Sunk in the crystalline water we could not see both sidewalls of the *corpo*, and imagined that the fish could not, either. We had unconsciously taken on the psyche of the doomed animals. In the frosty green space we saw the herd only occasionally. The noble fish, weighing up to four hundred pounds apiece, swam around and around counter-clockwise, according to their habit. In contrast to their might, the net wall looked like a spider web that would rend before their charge, but they did not challenge it. Above the surface, the Arabs were shrinking the walls of the *corpo*, and the rising floor came into view. . . . The death chamber was reduced to a third of its size. The atmosphere grew excited, frantic. The herd swam restlessly faster, but still in formation. Their eyes passed us with almost human expressions of fright.
>
> My final dive came just before the boatmen tied off the *corpo* to begin the killing. Never have I beheld a sight like the death cell in the last moments. In a space comparable to a large living room tunas and bonitos drove madly in all directions. It took all my will power to stay down and hold the camera into the maddened shuttle of fish. With the seeming momentum of locomotives, the tuna drove at me, head-on, obliquely and crosswise. It was out of the question for me to dodge them. Frightened out of sense of time, I heard the reel run out and surfaced amidst the thrashing bodies. There was not a mark on my body. Even while running amok the giant fish had avoided me by inches, merely massaging me with backwash when they sped past.

The nets were raised and the struggling fish gaffed as they came to the surface. Cousteau: "The fishermen struck at the surfaced swarm with large gaffs. The sea turned red. It took five or six men whacking gaffs into a single tuna to draw it out, flapping and bending like a gross mechanical toy. The boats rocked with convulsive bleeding mounds of tuna and bonitos." In the Favignana *tonnara* in 1957, at the height of the fishery, 7,480 tuna were killed.

I have never seen a *mattanza*, but I have seen films of one, and the sight of these sleek, graceful creatures being gaffed is heartbreaking. One moment they are on what Cousteau called their "honeymoon," and the next they are thrashing in a panicked mêlée as heavy steel hooks are smashed into their bodies and they are hauled ignominiously from the only element they have ever known into the one where they will die. Bluefins are among the most powerful and beautiful of the oceans' top predators, and seeing them gaffed is like watching a thoroughbred racehorse being hacked to death with an ax. Tuna of all kinds are among the world's most popular food fishes, and people are no more interested in knowing how they die than they are in visiting a terrestrial slaughterhouse. It might change our attitude toward tuna sandwiches or $75 pieces of sushi if we realized that tuna are wild animals, which happen to live in the ocean and therefore cannot be viewed like herds of zebras or wildebeest or packs of wolves. They are the oceans' nobility, described by Carl

Safina (1997) as "half a ton of laminated muscle rocketing through the sea as fast as you drive your automobile[; they are] among the largest and most magnificent of animals."

Tuna fishing was once one of Sicily's most important and profitable industries. Until the first decades of the twentieth century, coconut fiber nets more than a mile in length were deployed by the hundreds, but diminishing numbers of tuna, and market laws that make this fishing technique more capital-intensive, have left only about ten *tonnare* in the Mediterranean region; in Sicily, only Bonagia and Favignana remain. What was once a source of pride and the primary source of income for entire communities is now a tourist attraction, providing a few makeshift jobs for the unemployed in a social context poor in prospects and kept alive by the obstinate will of the remaining *tonnaroti.* The canneries in Sicily are closed; almost all the tuna caught in Favignana is shipped to Japan, where, like everyone else, buyers await the annual *mattanza.* There is a rumor in Favignana that the gaffing will be eliminated and the fishermen will simply wait for the tuna to die in the nets because the gaffs make too many holes in the flesh. "Once," wrote Theresa Maggio (2001), "the tuna snares thrived in Algeria, Corsica, Tunisia, Malta, Dalmatia, and Turkey. In Portugal they were called *armaçoes;* in Spain, *almandrabas;* in France, *madragues.* The cause of abandon: insufficient fish to make a profit. Once there were tonnaras all over Sicily. . . . Gone, all gone."

A loophole big enough to drive a factory ship through has been discovered in the regulations governing Mediterranean bluefin tuna fishing, and it could signal total extinction of the Mediterranean's bluefin population within a few years. Although there are strict quotas on the number of fish that can be caught in nets or by harpoons (*spadare*), no regulation whatsoever applies to "post-harvesting," the practice of catching wild tuna and keeping them in pens before they are slaughtered. Post-harvesting "farms" in the waters off Spain, Italy, Malta, and Croatia account for some 11,000 tons of tuna caught in 2001, compared with a total of 24,000 tons caught throughout the Mediterranean region by direct fishing. More than 90 percent of the post-harvested tuna goes to Japan, where the appetite for tuna belly-meat is insatiable. "If nothing is done," says Paolo Guglielmi of the Mediterranean Programme Office of the World Wildlife Fund (WWF), "wild bluefin tuna will completely disappear from the Mediterranean, perhaps with no possibility of rebuilding stocks" (Tudela 2002a).

Post-harvesting has completely reshaped fishing in the Mediterranean, and the fish are much the worse for it. Not only are the tuna threatened, but the fish caught to feed them while they are in the pens are also being fished to

destruction. Almost all the countries that fish for tuna in the Mediterranean are switching over to tuna farming. In each country, purse seine catches have declined while the total catch has increased. The entire catch of the Croatian tuna fleet (which increased from nineteen boats in 1999 to thirty in 2000) consists of undersized fish destined for the pens. According to the WWF report cited earlier, "in the Mediterranean, tuna farming started just a few years ago, but estimated production in 2001 gives an indication of the huge development of this activity in the region. In fact, production in the Mediterranean is likely to make up more than half of the world total and is almost exclusively destined for the Japanese market." Given the eagerness with which Mediterranean nations sell their fish to Japan, it is not a little surprising to learn that Japan maintains a thirty-five-vessel longline fleet in the western Mediterranean, targeting large tuna before spawning. Perhaps they believe they can avoid the cost of the middleman. In a further attempt to avoid European prices, Japan has introduced its own tuna farms, with pens in eighteen Mediterranean locations.

Sergi Tudela (2002b), project coordinator of the World Wildlife Fund's Mediterranean Program, wrote:

> In sum, all the usual ingredients are there in the case of tuna fattening farms: privatization of a common good (in this case, with the added risk of its probable destruction in the short- to medium-term); concentration of the benefits into a few hands; public aid provided to pillage a natural resource; dispossession of the traditional resource users; social and economic deconstruction of the traditional fishing sector; complete lack of a regulatory framework; connivance of the administration; ineffectiveness of international supra-Statal organizations; and growing demand for the product from a powerful market.

This sort of thing seems to have originated a world away from the Mediterranean, in Port Lincoln, South Australia, where the southern bluefin (*Thunnus maccoyii*) is caught and raised—again primarily for the Japanese market. Kiwi White, a pilot for the South Australian Tuna Association, captured the basics in this 1996 account:

> The whole tuna industry now concentrates on catching fresh fish in the wild using purse seiners transferring the live fish to huge floating cages and then towing these cages with up to 100 tonnes of live fish hundreds of miles back to our home port. There are many problems with bad weather smashing the cages and huge tides that slow the towing boats

> down to less than a knot and it is not uncommon for boats to be actually going backwards. The fish are fed twice a day on pilchards (sardines) and each cage requires 3 or 4 divers to clean out the dead fish, repair any holes, etc. . . . The tuna boat operators now have a supply of fat healthy tuna in the bay so when the fish are needed in Japan a team is sent out to harvest kill and prepare these fish ready to be airfreighted. These fish command huge prices (up to $50 a kilo) and they have been the savior of the fishing industry in Port Lincoln, many people are now employed and the owners are building huge mansions, driving the latest Mercedes and in general spending large amounts around our town.

Good for the fishermen, not so good for the fish. In April 1996, South Australia's tuna industry was crippled by a fierce storm, which caused the deaths of thousands of captive fish that would have been worth more than $55 million. The fish, kept in floating pens and unable to escape the storm, were suffocated as their gills became clogged in swirling clouds of silt, excreta, and sediment. Between 65,000 and 75,000 tuna died, representing about half the population of Port Lincoln's nine farms in Boston Bay. The mass deaths were a serious setback but evidently not a lasting one for the booming Port Lincoln tuna-farming industry, which has grown at a phenomenal rate since the first experimental farm was established, in 1991. The $100 million fish-fattening industry now constitutes a whopping 60 percent of the Australian tuna industry's 5,200-ton annual quota—and it will probably rise even higher.

Whether raised in pens or caught in the open sea, tuna represent Port Lincoln's most important product, celebrated annually in the Tunarama Festival during the Australia Day (January 26) weekend by a fair, a parade, a rodeo, fireworks, a race meeting (for horses), and the World Champion Tuna Toss, the "undisputable highlight of the Tunarama Festival with competitors travelling from far and wide in an effort to gain the coveted title." As noted at the World Wide Web site for the Port Lincoln Visitor Information Centre, the world record for throwing a seventeen-pound tuna 122 feet was set in 1998 by a former Olympic hammer thrower.

Even though post-harvesting is classified as aquaculture, the fish are all wild-caught, just as if they had been harpooned or purse seined. True aquaculture requires that the fish be raised from eggs, not simply moved from one place to another to be fattened, but even though the Australian system (also practiced in the Mediterranean) does not qualify under this strict definition, it demonstrates all the ills that besiege legitimate aquaculture, such as that practiced with Atlantic salmon, as we shall see. Like salmon, tuna are carnivorous, and when raised in captivity they must be fed large quantities of small

fishes, which themselves may be threatened by overcollecting. This kind of "farming" thus does not relieve commercial fishing pressure—it increases it. Waste from the pens is another problem, as is their location, close enough to shore and urban centers to disrupt and often pollute the littoral (nearshore) zone. Moreover, because tuna farming falls between the definition of a fishery and true aquaculture, it is completely unregulated on a world scale.

And now tuna farming has come to Mexico. In an article published in the *New York Times* in April 2002, R. W. Apple discussed the "new kind of mariculture" that was taking place off the Pacific coast of Baja California. Mexican fishermen net young bluefins and tow them to special enclosures in Puerto Escondido, near Ensenada, where the fish are kept in circular pens and fed live sardines three times a day for six to eight months. When they reach a weight of about 190 pounds, they are killed and frozen, mostly to feed Japan's appetite for fatty tuna. "Despite the lasting slump in the Japanese economy," wrote Apple, "the meat sells for as much as $45 a pound."

For all their vaunted migratory capabilities, no tuna ever swam from New England to Japan, but, as Safina (1997) wrote, "probably more bluefins from the east coast of North America cross the Pacific because the next step in the transaction is a one-way air-freight ticket to Tokyo." The same is true of the Mediterranean bluefins. The future of the bluefin tuna, then, is written in Japanese. There is a better than fifty-fifty chance that people enjoying *maguro* in Japan are eating fish that were fattened in pens in the Mediterranean. Compared with almost nothing five years earlier, the twelve Mediterranean tuna farms produced 11,000 tons of tuna in 2001, more than half the world's total. It is more than a little painful to realize that *Thunnus thynnus*, the most beautiful fish in the world, is literally being eaten out of existence.

Tuna, and swordfish as well, among the most magnificent fish in the ocean, have the misfortune to be at or near the top of the list of most desirable food fishes. At the dock and in restaurants, prices for these fishes rise as their numbers diminish. This sounds like nothing more than a traditional supply-and-demand equation, but the difference between fishing and manufacturing is that once the fish are gone, you cannot make any more.

THE MIGHTY SWORDFISH

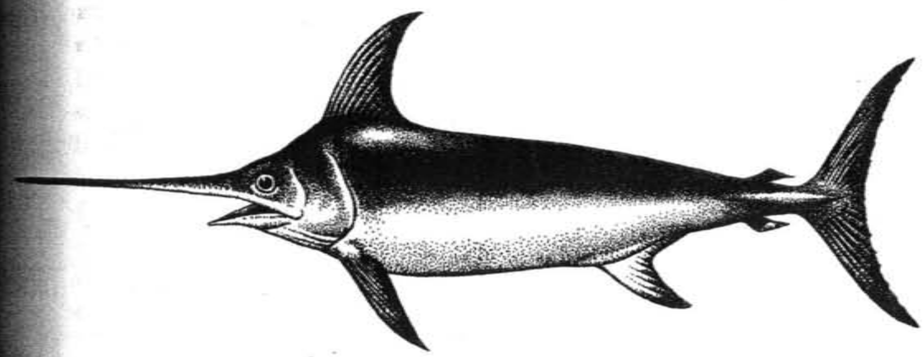
During the latter part of the nineteenth century, the broadbill swordfish (*Xiphias gladius*) was considered one of the world's premier game fishes and had a reputation for unmatched pugnacity. G. Brown Goode, assistant secretary of the Smithsonian Institution and a prodigious author and editor of

American fisheries literature, wrote the following (Goode 1887b) about "the perils and romance of swordfishing":

> The pursuit of the swordfish is much more exciting than ordinary fishing, for it resembles the hunting of large animals upon the land, and partakes more of the nature of the chase. There is no slow and careful baiting and patient waiting, and no disappointment caused by the accidental capture of worthless "bait-stealers." The game is seen and followed, and outwitted by wary tactics, and killed by strength of arm and skill. The swordfish is a powerful antagonist sometimes and sends his pursuers' vessel into harbor leaking, and almost sinking, from injuries inflicted by a wounded swordfish. I have known a vessel to be stuck by a wounded swordfish as many as twenty times in one season. There is even the spice of personal danger to give savor to the chase, for the men are occasionally injured by the wounded fish.

In 1940, E. W. Gudger published a lengthy discussion in the *Memoirs of the Royal Asiatic Society of Bengal* of "the alleged pugnacity of the swordfish and the spearfishes as shown by their attacks on vessels." Beginning with an account by the ancient Greek geographer Strabo of an attack on a fishing boat by a swordfish in the Strait of Messina (located between Sicily and the toe of Italy), Gudger covered Pliny, Aelian, and Oppian, the Greek poet in whose *Halieutica* we learn that those who pursued *Xiphias* did so in "swordfish-shaped boats." He wrote, however, that in later years, some swordfish encounters were collisions with "ships in passage," but "the attacks were mainly on fishing vessels by harpooned fish." Most of these so-called attacks occurred in the western North Atlantic Ocean, "where harpoon fishing for swordfish has been for long, and is today, most extensively carried on." Gudger described no fewer than seven cases of swordfish charging dories. One of these accounts, from 1937, goes as follows:

> We were cruising around off Montauk, about July 12, hunting for swordfish when our lookout at the masthead sighted a fish right ahead. The owner of the yacht ran forward to the swordfish stand and harpooned the fish. But unfortunately the harpoon struck forward of the dorsal fin and near the head. It usually happens that when a swordfish is harpooned in or near the head it seems to go crazy and starts looking for something to attack. This fish came to the surface after the first plunge downward and started cutting circles around the boat. We went onto it again and a second harpoon was driven into it. Still the fish would not go down and I put out in a dory to play it. I hauled on the line from the keg till I got within about twenty feet of the fish. Then it suddenly turned and like a flash drove its sword through the dory. Fortunately the sword did not strike me, but that was just my good luck. After striking the dory, the fish thrashed about so hard that it almost threw me out of the dory and did break off its sword at a point just below where it went through the bottom of the dory.



BROADBILL SWORDFISH *(Xiphias gladius)*

There are occasional modern instances of swordfish attacking boats, such as that in 1967 of a swordfish impaling itself on the submersible *Alvin*, which led to its being brought to the surface and eaten by the crew. But Gudger's description of the swordfish as "a pugnacious and vindictive fish" can only bring to mind the (largely undeserved) reputation of the sperm whale as a menace to the helpless whalers in their fragile boats, who were surprised that the whale would retaliate when it found itself with a spear stuck into its vitals.

If possible, Zane Grey admired the swordfish as much as the tuna. Of the broadbill he wrote in *Tales of Swordfish and Tuna:*

> Old *Xiphias gladius* is the noblest warrior of all the sea fishes. He is familiar to all sailors. He roams the Seven Seas. He was written about by Aristotle 2,300 years ago. In the annals of sea disasters there are records of his sinking ships. . . . Tales of his attacks on harpooners' boats in the Atlantic are common. In these waters, where he is hunted for the market, he has often killed his pursuers. In the Pacific, off the Channel Islands, he has not killed any angler or boatman yet, but it is a safe wager he will do so some day. Therefore, despite the wonderful nature of the sport, it is not remarkable that so few anglers have risked it.

Of course, the intrepid Grey was not to be deterred by a fish that fights back; he welcomed the challenge. In 1919, off Catalina Island, he hooked a swordfish:

> First he made a long run, splashing over the swells. We had to put on full power to keep up with him, and at that he took off a good deal of line. When he slowed up he began to fight the leader. He would stick his five-foot sword out of the water and bang the leader. Then he lifted his enormous head high and wagged it from side to side, so that his sword described a circle, smacking the water on his left and then on his right. Wonderful and frightful that sweep of sword! It would have cut a man in two or have pierced the planking of a boat. Evidently his efforts and failure to free himself roused him to a fury. His huge tail thumped out of great white boils; when he turned sideways he made a wave like that behind a ferryboat; when he darted here and there he was as swift as a flash and he left a raised bulge, a white wake at the surface. Suddenly he electrified us by leaping. . . . This one came out in a tremendous white splash, and when he went down with a loud crash, we all saw where the foam was red with blood.

After eleven and a half hours, the line went slack, and Grey lost his giant swordfish. He expressed his admiration for these most worthy of opponents by continuing to fish for them, and later he proudly brought in a 418-pounder. (For some reason, Grey referred to every big fish as "he.") Other big-game fishermen have sought the mighty broadbill, and many have written about their exploits. In 1940, an expedition from the American Museum of Natural History (AMNH) in New York set out to capture some of these "fighting giants of the Humboldt," as they were termed in the title of the *National Geographic* article written the following year by David Douglas Duncan. Because of the upwelling of nutrients there, the Humboldt Current, off the western coast of northern South America, is inhabited by immense schools of anchovetas, which attract swordfish and marlin, the largest of the pelagic predators, and the smaller Pacific bonito, *Sarda chiliensis.* Fishing off Chile, the AMNH expedition caught several broadbills, ranging from 570 to 630 pounds (Mather 1976), and set the stage for fishing in the area now recognized as the best place in the world for big swordfish. The current world's record catch, landed by Lou Marron in 1953 off the coast of Iquique, Chile, weighed 1,182 pounds.

Although swordfish are still considered premier game fish and are eagerly sought as trophies, the large ones are no longer being caught in the North

Atlantic. In the past, swordfishermen hunted their prey by sight, waiting for the telltale sickle-shaped dorsal fin and upper lobe of the tail to break the surface as the big fish "finned out." Then they would harpoon the fish from a specially designed "pulpit" that extended from the fishing boat's prow. The harpoon fishery for Atlantic swordfish was limited to the New England coast in the early 1800s. When David Starr Jordan wrote *American Food and Game Fishes* in 1923, he said this about the swordfish: "The species is rather abundant for so large a fish. Off the New England Coast, 3,000 to 6,000 of these fish are taken every year. Twenty-five or more are sometimes seen in a single day. One fishermen killed 108 in one year." "Them days," as the fishermen say, "is gone forever." Now the broadbill swordfish has been so overfished that it is considered an endangered species and, despite its popularity, there is a full-scale campaign called Give Swordfish a Break, dedicated to getting restaurant owners to take it off the menu.

Found worldwide in temperate and tropical waters, the broadbill swordfish gets its common name from its smooth, flattened bill, which is much longer and wider than that of any other billfish. The bill is used for defense and (maybe) to slash and debilitate its prey, which consists of squid, mackerel, bluefish, and many other mid- and deepwater species. Even today, we don't know how a swordfish uses its bill. The bill is horizontally flattened and sharp on the edges, so it has been assumed that the swordfish enters a school of fishes and slashes wildly, cutting or otherwise incapacitating its prey, which it then eats at its leisure. But since nobody has ever witnessed this activity, the actual use of the sword is conjectural.

In a 1968 study of the "food and feeding habits of the swordfish," W. B. Scott and S. N. Tibbo wrote: "The swordfish differs from the spearfishes (marlins and sailfishes) in that the sword is long and it is dorso-ventrally compressed (hence the name broadbill) whereas the spearfishes have a shorter spear and it is slightly compressed laterally. Thus, the swordfish appears to be more highly specialized for lateral slashing. Such a specialization would seem to be pointless unless directed to a vertically oriented prey, or unless the swordfish slashes while vertically oriented, as when ascending or descending." In contrast to almost every other suggestion about swordfish feeding techniques, Charles Mather (1976) stated, "Essentially a bottom feeder, a broadbill is believed to use his bill as a tool to obtain crustaceans from their cracks or attachments and to enjoy crabs and crayfish," an utterly preposterous suggestion. In *Living Fishes of the World* (1961), ichthyologist Earl Herald wrote, "the sword may be used to impale fishes during feeding," which seems highly unlikely because the fish to be impaled would offer no resistance to the impaler, and even if such a process could be made to work, the swordfish would be unable to get at the dead fishes stuck on the end of its nose.

Since the 1960s, pelagic longlines have been the primary gear used to capture swordfish. The area of U.S. commercial swordfishing has expanded to include the entire U.S. Atlantic coastline, the Grand Banks, the Gulf of Mexico, the Caribbean Sea, and the mid–Atlantic Ocean, making it possible to catch swordfish throughout the year. Today's deepwater swordfishers, like those unfortunate members of the *Andrea Gail* 's crew who did not return from their voyage in the "perfect storm" of 1991, set out miles of baited longlines. The expansion of the fishery into areas of warmer water means that younger, smaller swordfish are more often caught, which reduces the population by removing individuals before they reach breeding age. There is no way to prevent these smaller fish from taking the baited hooks; the only restrictions on the fishermen simply prevent them from selling the juveniles commercially. Whether they are sold or discarded, the younger fish die.

Here is a description of the longline fishery for swordfish by Carl Safina (1998b), founder and director of the National Audubon Society's Living Oceans Program:

> Today, the submarine canyons and banks these animals prowl is so spaghettied with baited lines that more than 80 percent of the female swordfish caught are immature, killed before they can breed. (Female swordfish take at least five years to reach sexual maturity, at which point they are almost six feet long.) With longlines taking 98 percent of the swordfish catch, large adult fish are rare in the North Atlantic. Between the early 1960s and today, the average size of North Atlantic swordfish dropped two-thirds, from almost 270 pounds to 90 pounds. In nursery grounds off Florida, off South Carolina, in the Gulf of Mexico, and elsewhere, longlines catch mostly juveniles. U.S. swordfishers in the Atlantic discard about 40 percent of the swordfish they kill; the fish are too small to sell. In 1996 they dumped 40,000.

In 1969, the U.S. Food and Drug Administration (FDA) discovered that swordfish flesh had a high mercury content, and the agency banned the sale of any swordfish with an excess of five-tenths part per million.* According to

*The swordfish scare was initiated by the 1956 discovery that families of fishermen near Minamata on the Japanese island of Kyushu were afflicted by a mysterious neurological disease with symptoms that included loss of coordination, tremors, slurred speech, and numbness in the extremities. The symptoms worsened and led to general paralysis, convulsions, brain damage, and death. A chemical factory belonging to Chisso *(continued)*

Charles Gibson's 1981 history of the North Atlantic swordfish fishery, "in effect, the mercury ban killed the fishery all the way from the Mississippi deltas to the Grand Banks." Massachusetts health authorities examined a piece of preindustrial swordfish and found that it contained the same amount of mercury as fish caught in the 1970s. They also found that the amount of mercury believed to be dangerous to humans was not evident in newly caught swordfish. They therefore ignored the FDA's warnings and allowed swordfish to be landed again. Other states quickly followed, and by 1973 the fishery was fully operational and the fish, which had been briefly spared, were being caught in unprecedented numbers on longlines. But the fish brought in were getting smaller and smaller.

Since the early 1980s, the commercial catch of swordfish has increased eightfold, but the average weight of fish caught has dropped from 115 pounds to 60. As mentioned earlier, many restaurants are refusing to put swordfish on the menu to discourage fishermen from bringing in the smaller fish. (At Manhattan's Fulton Fish Market, swordfish weighing 50 to 100 pounds are called "dogs," those 25 to 50 pounds "pups," and those weighing less than 25 pounds "rats.") Swordfish quotas have now been tied in with quotas for tuna and marlins, and despite the warnings that the North Atlantic stocks are continuing to decline, the U.S. Congress still allows more swordfish to be caught than would enable a declining population to recover. In "Song for the Swordfish," an article published in *Audubon* magazine, Carl Safina (1998b) wrote: "These days, most fishers know swordfish chiefly by their absence, by old-timers' stories and black-and-white photos on the walls of long-established harborside bars. . . . U.S. longliners claim that Atlantic swordfish can't recover unless all the countries catching them agree to coordinated measures. But in the 1970s, when concern over mercury levels in swordfish forced U.S. and Canadian longliners to stop fishing, the broadbills recovered within a decade. They were depleted to current lows after longlining resumed."

In 1990, swordfish and marlins were added to the species overseen by ICCAT. The Spanish longline fleet lands more swordfish than any other party to that convention. In 1997, Spain had a 45 percent share of the Atlantic swordfish fishery, but of the total of 36,378 tons landed in or imported into

Company, Ltd. that manufactured acetic acid and vinyl chloride and dumped its wastes into Minamata Bay was identified as the source of the mercury that had contaminated the fish and shellfish. Even with the source of this crippling and often fatal disease identified, the Japanese government did not order the plant closed until the 1970s. By 1997, more than 17,000 people had applied for compensation from the government. Since 1956, a total of 2,262 people have died of Minamata disease in Japan.

Spain in 1997, almost two-thirds was exported, primarily to Italy, where *pesce spada* is a particularly popular menu item. Although the Spanish catch of swordfish declined slightly in recent years, the Spanish fish-processing industry compensated for the decrease in domestic landings by importing catch from other countries. Spain is also a major player in the eastern Atlantic and Mediterranean bluefin tuna fisheries. Of all bluefin tuna landed in or imported into Spain in 1997, only one-third was consumed in that country, the remainder constituting a valuable export and one acknowledged to be a primary factor in recent increases in bluefin tuna catches in the Atlantic and Mediterranean.

The so-called regulatory agencies—ICCAT, the European Commission, and the General Fisheries Commission for the Mediterranean—have done little to stem the rising tide of swordfish overexploitation. In Spain, the power of the peso (now the euro) obliterates environmental concerns. Protests from conservation organizations, such as the World Wildlife Fund (WWF), Greenpeace, and the Asociacíon de Naturalistas del Sureste (ANSE) of Spain, have made people aware of the problems but otherwise have accomplished little. In April 2002, representatives of WWF, Greenpeace, and ANSE sailed to the fattening facility at Cape Tiñoso to protest, in that case, not swordfish but Mediterranean bluefin tuna farms. The Spanish navy in Murcia stopped the environmentalists' sailboat and prevented them from approaching.

In the United States, where the problem was first identified, a concentrated campaign to protect the swordfish seems to have worked. In 1998, the organizers of the Give Swordfish a Break campaign, SeaWeb and the Natural Resources Defense Council (NRDC), along with other conservation organizations, successfully advocated recovery measures to restore North Atlantic swordfish. The campaign was launched in January 1998 when twenty-seven leading East Coast restaurateurs announced the removal of swordfish from their menus. Leading cruise lines followed suit. By November 1999, ICCAT was forced to acknowledge the campaign, and for the first time it adopted quotas. The campaign officially ended in August 2000 when the U.S. government closed swordfish nursery areas to fishers in U.S. waters, thus meeting the second goal of the campaign. In October 2002, ICCAT announced that over the previous three years North Atlantic swordfish had recovered to 94 percent of levels considered healthy. On the recovery, an editorial in the *New York Times* of October 13, 2002, commented:

> This is the best news for fish since the striped bass recovery of the late 1980s, and the lesson for future recoveries is much the same: if you leave the fish alone, or at least give them some space, they will repay the effort.

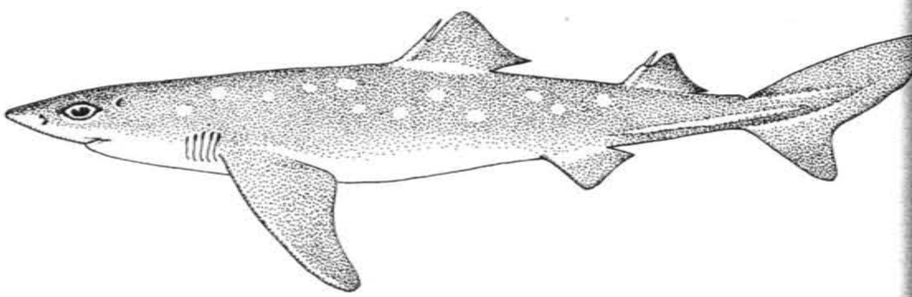
The recovery of the swordfish is one of the few bright lights in the otherwise dismal story of overfishing the fishes at the top of the trophic pyramid. By and large, the hunters have become the hunted. No group of fishes, cartilaginous or bony, is more readily identified as apex predators than the sharks, and no group of fishes is in greater danger.

SHARK-EATING MEN

There are some 350 species of shark in the world's oceans, and most of them do not fit the public's preconceptions of large, toothy predators cruising menacingly offshore ready to gobble somebody up. Most living shark species are less than two feet long and are harmful only to the small fishes and cephalopods that make up their usual diets. (There are even sharks, known as heterodontids, whose teeth aren't sharp at all but are pavement-like, enabling them to crush the shells of bivalves.) Many of these mini-sharks are deepwater inhabitants whose populations would be only minimally affected by fishermen even if they were deemed edible. But some of the larger species *are* edible or otherwise desirable to humans and are found in nearshore waters, which puts them at risk. Indeed, an important 1999 analysis of the world's shark populations by José Castro, Christa Woodley, and Rebecca Brudek of the National Marine Fisheries Service laboratory in Miami concludes that "nearly all species for which we have catches and landings data for more than ten years are in severe declines."

Sharks (and other elasmobranchs—"strap-gills"—including skates and rays) are particularly vulnerable to overfishing. They are what biologists call K-selected, which means they have large young, slow growth rates, late sexual maturity, and long lives, all of which result in low rates of population increase. Moreover, shark fisheries have expanded worldwide, as pointed out in a 1998 report by Merry Camhi and colleagues for the International Union for Conservation of Nature and Natural Resources (IUCN):

> Shark fisheries have expanded in size and number around the world since the mid-1980s, primarily in response to the rapidly increasing demand for shark fins, meat and cartilage. Despite the boom-and-bust nature of virtually all shark fisheries over the past century, most shark fisheries today still lack monitoring or management. . . . As a result, many shark populations are now depleted and some are considerably threatened.



SPINY DOGFISH *(Squalus acanthias)*

Among the most numerous of all sharks, the spiny (piked) dogfish (*Squalus acanthias*) aggregates in large schools throughout its cold- and temperate-water range around the world. It is fished heavily and used widely, in the words of Leonard Compagno (1984a), "fresh, fresh frozen, smoked, boiled, marinated, dried, salted, and in the form of fish cakes for human consumption; it is also utilized in liver oil, pet food, fishmeal, fertilizer and leather." It's no accident, then, that its numbers are in free fall. Castro and his colleagues classify the piked dogfish as a Category 4 species ("substantial historical declines in catches and/or locally extinct"). The spiny dogfish has the longest gestation period of any vertebrate—twenty-two months—so removal of adult females (which are larger than males and therefore more desirable to fishermen) is extremely hazardous to the population.

Spiny dogfish were long considered trash fish—those inadvertently trapped in nets set for other species and sometimes destroying the nets in their unwillingness to be caught. In the early 1990s, however, New England fishermen searching for alternatives to depleted stocks of cod, haddock, and flounder began fishing for the more plentiful, and unregulated, dogfish. Fishermen teamed up with politicians to promote dogfish consumption, in the process giving the species the more appetizing name of "cape shark." With the help of steady European demand—particularly in Great Britain, where the species constitutes a large proportion of the fish in fish-and-chips—the dogfish experiment quickly grew into a fully developed fishery, and that soon became a disaster. In 1998, scientists declared the northwestern Atlantic spiny dogfish population overfished, reporting dramatic declines in the number and size of mature females. After years of stalling, in March 2000 the New England Fishery Management Council submitted its final plan to the NMFS to restrict fishing for this species. But by then, Massachusetts fisher-

men had so overfished the little sharks that the secretary of the U.S. Department of Commerce, William Daley, imposed quotas of 4 million pounds effective May 1, 2000. Four million pounds may appear to be the opposite of a reduced quota, but the Atlantic States Marine Fisheries Commission (ASMFC) is under pressure to increase the quota for adult females after the emergency ruling expires in 2003. In October 2002, despite alarming scientific reports of an absence of dogfish pups, the commission voted overwhelmingly to double current dogfish quotas.

So far, Castro and his colleagues (1999) have not placed any shark species in Category 5 ("rare throughout the ranges where they were formerly abundant"), but several species other than dogfish qualify for Category 4. These are the thresher shark (*Alopias vulpinus*); the shortfin mako (*Isurus oxyrhinchus*); the porbeagle (*Lamna nasus*); the tope (*Galeorhinus galeus*); the leopard shark (*Triakis semifasciata*); the dusky shark (*Carcharhinus obscurus*); the sandbar shark (*Carcharhinus plumbeus*); and the night shark (*Carcharhinus signatus*). Individuals of all these species are relatively large, and all have been the object of a directed fishery. In every case, the sharks are caught for food, but sometimes leather and liver oil are by-products of their use.

A particularly insidious threat to shark populations is finning, the practice of catching sharks, cutting off their dorsal and pectoral fins, and then throwing them back in the water to die. The fins are used to make shark's fin soup, an expensive delicacy in China, Singapore, Hong Kong, and other Asian countries. In some restaurants, shark's fin soup may sell for $100 a bowl. Many shark fisheries around the world—in Mexico, for example—are in business largely to supply fins to this market. In some parts of the world, finning is so widespread that local shark populations have become endangered. In Honolulu, 2,289 sharks were landed in 1991. By 1998, the number had leapt to 60,857—a 2,500 percent increase—and of that total, 99 percent was for fins. Introduction of the Shark Finning Prohibition Act on March 13, 2002, banned U.S. fishing vessels—anywhere in the world—and foreign vessels fishing in U.S. waters from possessing fins unless the rest of the shark's carcass is also on board (Raloff 2002). In August of that year, U.S. Coast Guard officers boarded the Honolulu-based *King Diamond II* off Acapulco and found 64,000 pounds (32 tons) of fins and no other shark parts. The *King Diamond* had not actually caught the sharks; the Korean fin broker on board had evidently bought them from Asian vessels plying the eastern South Pacific around Fiji and the Solomon Islands and was planning to sell them in Guatemala. The fishing vessel was escorted to San Diego and the cargo confiscated. In the Pacific, where most finning takes place, there are no restrictions on finning or on bringing in severed fins, with or without the carcasses. (Fins can sell for a wholesale price of $200 per pound, whereas shark meat might bring 50 cents per pound, demonstrating the unfortunate economics of finning.)

Star of four Hollywood movies, the great white (*Carcharodon carcharias*) is the most famous shark of all. Although its anthropophagous inclinations were greatly exaggerated in *Jaws*, the great white actually does attack people every once in a while. Peter Benchley's 1974 novel (and the subsequent movies) assigned the shark such a reputation for malevolence that people decided the oceans would be safer if no great whites were around to threaten them. The vendetta against *C. carcharias* that commenced soon after publication of the novel is still going on. Brave fishermen set out to capture "the man-eater" to prove their manhood and to display mementos of their triumph above their fireplaces or around their necks. (A good white shark tooth, which could be more than two inches in length, sells today for about $150; a set of jaws might fetch more than $3,000.) A vengeful, dedicated hunt, conducted on a largely inshore species, has not benefited the scattered populations of *C. carcharias*. Castro and colleagues (1999) placed the great white in Category 3 ("species that are exploited by directed fisheries or bycatch and have a limited reproductive potential") and observed that "populations may be small and highly localized and very vulnerable to overexploitation." Although we still know too little about the migratory habits of the great white, it is now protected in those waters where it is most likely to show up. White sharks were first protected in South Africa in 1992; since then, Namibia, the Maldives, Malta, Florida, and California have fully protected the species, with fishermen no longer allowed to catch them.

Because of their cosmopolitan distribution, it might be possible to reduce or even eliminate a local shark population without raising the specter of global extinction. "Local extinction," wrote Castro and colleagues (1999), "refers to the disappearance of a species or population in a given geographic area, while the species is still extant in the rest of its range. Extinction refers to the disappearance of the species on a global scale. . . . There are few recorded cases of local extinction of sharks or elasmobranchs in general. . . . Nevertheless, it is possible that given enough time and sufficient fishing pressure, some sharks could become globally extinct." Jack Musick and Beverly McMillan (2002) asked, "What are the chances that some species of sharks, or many, will go extinct?" Their answer:

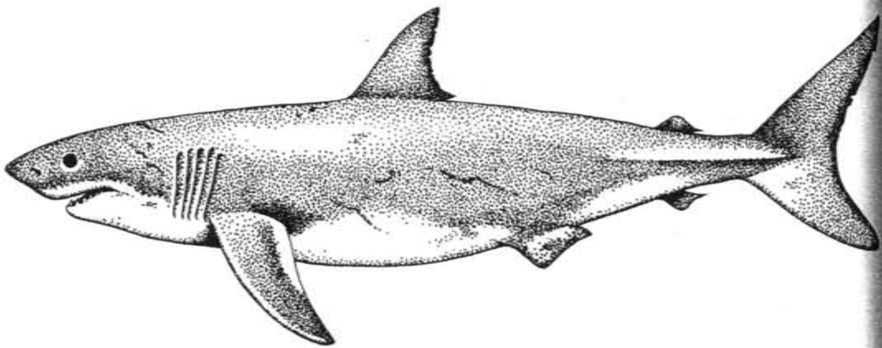
> Some scientists argue that it is impossible to drive widely distributed coastal shark species, like sand tigers and the handsome duskies that used to be regular visitors to the Virginia coast, to extinction. [We] believe they are wrong—that there is a point of no return at which remnants of populations become so few that there are not enough breeders to continue. We may be on the brink of finding out just where that point is.

Perhaps the greatest misconception about sharks is that they are particularly dangerous to people. The truth is closer to the opposite. Twenty-five years after the publication of *Jaws*, Peter Benchley wrote an article for *Audubon* magazine titled "Swimming with Sharks," in which he noted: "Somewhere between 40 million and 70 million sharks were killed in 1994. The International Shark Attack File estimates that for every human being killed by a shark, 10 million sharks are killed by human beings." Contrary to conventional wisdom, conflicts between man and shark almost always end in favor of the man, especially if the man is in his own element and not the shark's. Under those circumstances, the conflict is known as "fishing."

That there *is* a Shark Attack File speaks volumes about the nature of the eternal conflict between humans and sharks. Now housed at the University of Florida, the file was originally produced by the Shark Research Panel, founded in 1963 by the Office of Naval Research and the American Institute of Biological Sciences. Its mandate was to record as accurately as possible shark attacks around the world, with the idea that some attacks could be prevented if we had an idea of why they occurred in the first place. Coincidentally, the same year *Jaws* was published, H. David Baldridge (1974b) analyzed the accumulated data and published "Shark Attack: A Program of Data Reduction and Analysis," which showed that shark attacks occurred much less frequently than people thought they did, but people were frightened in anticipation of them out of all proportion to their frequency or the actual danger involved in swimming where sharks were known to be present.*

As the author of *Jaws*, however, does Benchley accept any responsibility for the shark mania that swept the country after the book (and four related Hollywood movies) appeared? No, nor should he. He was writing fiction, not a scientific treatise. In his 1998 *Audubon* article, he stated: "Now it is widely accepted that sharks in general, and great whites in particular, do not target

*In the same year, Baldridge also published a popular version of this report. Titled *Shark Attack*, it bore this line on the cover (which of course featured a photograph of a great white shark): "True tales of shark attacks on man—facts more terrifying than the fiction of JAWS." Obviously, the public hungered for more accounts of gory shark attacks, but without the graphs and tables.



GREAT WHITE SHARK *(Carcharodon carcharias)*

human beings. When a great white attacks a person, it is almost always an accident, a case of mistaken identity." In the summer of 2002, with attendant publicity and appearances on every network television talk show, Benchley published *Shark Trouble,* in which he commented:

> Shark attacks on human beings generate a tremendous amount of media coverage, partly because they occur so rarely, but mostly, I think, because people are, and always have been, simultaneously intrigued and terrified by sharks. Sharks come from a wing of the dark castle where our nightmares live—deep water beyond our sight and understanding—and so they stimulate our fears and fantasies and imaginations.

The success of *Jaws,* both book and movie, is attributable to Benchley's imagination and skill as a writer of thrillers, but another element raises it above most other horror stories: unlike the giant gorilla in *King Kong* or the assorted Godzilla monsters, the villain of *Jaws* really exists. There really *are* large great white sharks out there, and though it doesn't happen very often, they have attacked enough people to make all of us pause—if only for a moment—before going for a swim. As I commented in *Great White Shark* (Ellis and McCosker 1991), "anything that can provoke that same brief, dark thought in all of us is a powerful force indeed."

For many years, "shark tournaments" were held in various locations on the Pacific and Atlantic coasts of the United States in which the object was to catch as many sharks of as many species as possible; winners were chosen on the basis of accumulated poundage caught, largest single shark of a particular species, and so forth. In the early days of these tournaments (the 1960s and

1970s), the carcasses were weighed and measured and then discarded at sea or in garbage dumps. (Some fishermen might have saved the jaws, and Asian restaurateurs might occasionally have collected the fins, but for the most part, the entire shark was wasted.) Scientists subsequently realized that these sharks represented a potential treasure trove of data on growth rates, reproductive biology, distribution, and dozens of other useful subjects, so they began attending the "shark derbies," cameras and calipers in hand, and recording information that would otherwise have been lost.

In a 1973 article co-authored with his wife, Claire, Perry Gilbert, a shark expert and, later, director of Mote Marine Laboratory in Sarasota, Florida, sang the virtues of sharks:

> The shark, with a modicum of fine traits, might be considered one of the most successful animals that has ever lived. To other animals it is far from delicious. Its tough hide makes it almost inedible, and while it has the grace that sheer power bestows, it is not really beautiful. . . . It has, however, one enviable attribute and this has contributed greatly to its success. . . . Cancer is virtually absent from its primal myomeres.

Some researchers decided that shark cartilage contains a protein that inhibits the angiogenesis (development of new blood vessels) needed to provide nourishment for tumor and cancer growth. Tumors need a large supply of blood to survive, and cartilage contains substances that prevent the formation of blood vessels. Since 1979, at Mote Marine Laboratory, Carl Luer has been exposing nurse sharks and clearnose skates to powerful carcinogens, including aflatoxin B and methylazoxymethanol, and has been unable to get tumors to grow at all. Working with A. B. Bodine, Luer has seen that the carcinogens reach the DNA of the elasmobranch cells, but the cells seem to repair themselves before any sort of mutation can result. In an article in the *Journal of the National Cancer Institute* in 1993, James Mathews wrote, "Most researchers agree that continued study of the shark's intriguing anatomy may yield answers to treating cancer in humans." Certainly an animal that is so successful in resisting cancer is worth more to medical and pharmaceutical researchers than to those who would hack off its fins to make soup out of them.

Despite the total absence of evidence, someone, somewhere was going to cash in on the possibility that shark cartilage could prevent cancer in humans. First came a New Jersey company called Cartilage Consultants, Inc., which obtained a patent for pills made of powdered shark cartilage. The *Journal of the National Cancer Institute* announced that "there is no proof that it is effective when taken this way," and Luer, in an article written for Mote Marine Laboratory, asserted, "The statements made by cartilage pill promoters that it is cartilage that gives sharks their immunity to cancer, then, are inaccurate and irresponsible." We are still a long way from finding—or even suggesting—a shark-related cure for cancer. Indeed, although irresponsible medical research might serve no useful purpose for humans, it might further endanger the sharks. In February 1993, the television program *60 Minutes* aired a story on shark cartilage as a treatment for cancer in humans, bringing forth an outraged response from the people who were doing the research. In the March 1993 newsletter of the American Elasmobranch Society, Carl Luer wrote, "We cannot support the marketing of shark cartilage for this application, especially since the promoters of the product intend to rely on the natural resource as an endless supply of material." If it were true that shark cartilage could somehow prevent cancer in humans, perhaps the taking of sharks might be justified, but since no such evidence exists, they should not be caught and ground up for their components. In a letter to the same newsletter, Kumar Mahadevan, director of Mote Marine Laboratory, stated, "No evidence—not even a logical connection—exists at this stage to assume that shark cartilage tested on blood vessel growth in the laboratory should produce significant tumor regression when given to cancer patients." Assuming that we could consume shark cartilage to protect ourselves from cancer was like believing that we could eat sawdust made from redwood trees to make ourselves taller.

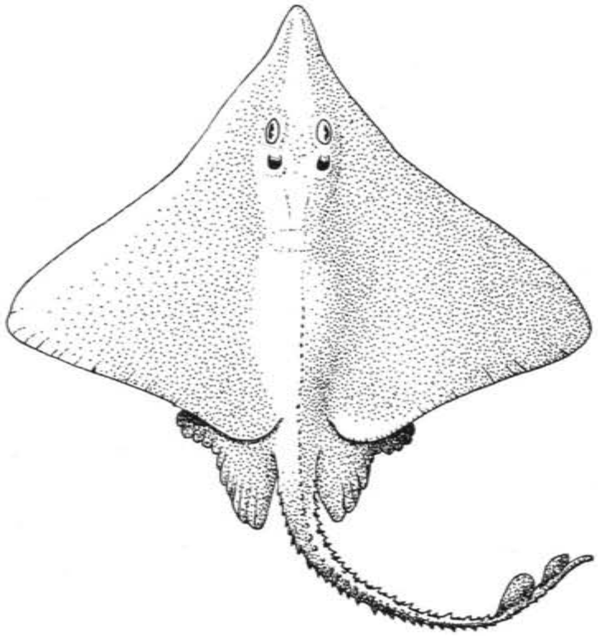
Regardless of opposition from the scientific community, those who wanted to believe that sharks held the key to a cancer cure continued to do so. In 1992, I. William Lane published a book called *Sharks Don't Get Cancer* in which he argued that shark cartilage is the reason. Perhaps not coincidentally, through BeneFin, a company run by his son Andrew, he packaged and sold powdered shark cartilage made from the skulls and backbones of sharks. Thousands of sharks were being killed annually to provide the cartilage that Lane's company ground up. Lane and his family probably made a lot of money from BeneFin, but did he actually believe it worked? In a well-written summary of the entire shark cartilage story published in the *Amicus Journal*, Michael Rivlin (2000) reported:

> Everything Lane had written led me to think he truly believed that shark cartilage could work miracles. But when I interviewed him, his final comments left me shocked. I had asked him how the cartilage market is holding up, and whether he still has faith in the product. "Cartilage is a faddist industry," he replied. "The fad was real and it lasted a long time. Now, there are a number of other products that have some effect against cancer, and they're easier to take than shark cartilage." And then he started pitching Lane Labs' newest product, "an incredible immune stimulator" made from rice bran and shiitake mushrooms.

In 2000, a new chapter opened in the shark cartilage story. A study published then concluded that sharks not only get cancer but even get cartilage cancer. Gary Ostrander and John Harshberger found at least forty cases of cancer in sharks and other cartilaginous fishes after surveying scientific papers and tumor samples from the National Cancer Institute's Registry of Tumors in Lower Animals. In an article published in *Science* magazine on April 14, 2000, Ostrander is quoted as saying that he hopes the study will help explode the "huge myth" that sharks are immune to cancer—a misapprehension shared even by "people in my own field." It's hard to believe that susceptibility to cancer can save your life, but that's what happened to the sharks. Chalk up one for the elasmobranchs.

Cancer notwithstanding, elasmobranchs (sharks, skates, and rays) are far from immune to overfishing. The thornback ray (*Raja clavata*) is now considered close to extinction, according to monitors of the North Sea populations. With the decline of cod and haddock, fishers have trawled for bottom dwellers and have virtually eliminated them—as well as destroying the seafloor. Replacing the ubiquitous fish-and-chips, skate-and-chips became for a time a popular menu item, as did skate with black butter; with overfishing, however, these dishes have become as rare as dodo pudding.

Probably the most surprising and unexpected near extinction in recent years has been that of the barndoor skate (*Raja laevis*), which nobody was fishing for at all. For generations, cod fishermen hauled in these unwanted elasmobranchs, which, at a total of sixteen square feet, approach the dimensions of their namesake. Like many elasmobranchs, *R. laevis* is K-selected; that is, it is slow to mature, reproduces slowly, and has offspring that are small in number but large in size. Indeed, newborn barndoor skates are already ten inches across, sizable enough to get caught in trawls from their day of birth and therefore never having a hope of reproducing. "Forty-five years ago," Jill Casey and Ransom Meyers noted in a 1998 *Science* article, "research surveys on the St. Pierre Bank (off southern Newfoundland) recorded barndoor skates in 10% of their tows; in the last 20 years, none has been caught and this pattern of decline is similar throughout the range of the species." What happened? When the distant-water fleets were scooping up codfish, redfish, and everything else that swam in eastern Canadian and New England waters in the 1970s, a large part of the bycatch was barndoor



BARNDOOR SKATE
(Raja laevis)

skates. Fisheries biologists, lately studying the decline of more valuable food fishes, didn't notice the disappearance of barndoor skates until it was too late. "If current population trends continue," wrote Casey and Meyers, "the barndoor skate could become the first well-documented example of extinction in a marine fish species."

Carcharias taurus, the grey nurse shark (spelled that way because it is an Australian species), is a popular resident in public aquariums; as it swims slowly around the tank with its baleful, pale eyes and snaggletoothed grin, it is everything visitors expect a shark to look like. Unfortunately, this very "sharkiness" has proved its undoing. Although the grey nurse is not really a threat to divers or swimmers unless provoked, many shark attacks have been incorrectly attributed to this species, perhaps because of its fierce appearance (Last and Stevens 1994). The grey nurse shark's reputation led to indiscriminate killing of the species by spear and line fishers. For years, Australian divers demonstrated their bravery by spearing grey nurse sharks, largely because they *looked* as if they were dangerous. The toothy jaws mounted on a mantelpiece or over a garage door served to show that the diver or fisherman could conquer a "man-eater." This wanton and misdirected slaughter has produced an utterly unexpected outcome.

The grey nurse shark became the first protected shark in the world when the government of New South Wales declared it a protected species in 1984. The species is currently listed as nationally vulnerable under Australia's Commonwealth Environment Protection and Biodiversity Act 1999. It is also protected under fisheries legislation in New South Wales, Tasmania, Queensland, and Western Australia. Globally, the species was listed as Vulnerable in the *IUCN Red List of Threatened Species* in March 2000.

In a way, sharks are bellwethers for the conservation of marine life. They are largely unpopular animals with an almost completely unfounded reputation that includes a nasty disposition, a mouthful of razor-sharp teeth, and an inclination to use them on people. Most of the known shark species are small and harmless; only the great white, mako, tiger, bull, hammerhead, whaler, and oceanic whitetip have ever been implicated in deliberate attacks on people. The number of people attacks on sharks, however, has reduced some shark populations to tatters. With her colleagues from Dalhousie University, Julia Baum analyzed logbook data from shark fisheries and U.S. longline fleets targeting swordfish and tunas in which sharks were bycatch. In *Science* on January 17, 2003, Baum and her colleagues reported that from 1986 to 2000, populations of shark species in the northwestern Atlantic declined by an average of 61 percent. Blues fell by 60 percent, tigers by 65 percent, oceanic whitetips by 70 percent, great whites by 79 percent, threshers by 80 percent, and hammerheads by an astonishing 89 percent.

Before we can protect a species, in the sea or out, we need to realize that it has as much right to be there as we do. To see any animal as inferior insults that species and all life on the earth. A more appropriate view was suggested by Henry Beston in 1928:

> We need another and a wiser and perhaps a more mystical concept of animals. . . . We patronize them for their incompleteness, for their tragic fate of having taken form so far below ourselves. And therein we err, we greatly err. For the animal shall not be measured by man. In a world older and more complex than ours they move finished and complete, gifted with extensions of the senses we have lost or never attained, living by voices we shall never hear. They are not brethren, they are not underlings; they are other nations, caught with ourselves in the net of life and time, fellow prisoners of the splendour and travail of the earth.

THE CODFISH

The codfish (*Gadus morhua*) has historically been one of the world's most important food fishes, and its exploitation has played a significant role in the economic development of the countries that border the North Atlantic Ocean, the home and breeding ground of this species. Among those countries that can attribute a portion of their history to the fortuitous occurrence of shoals of cod are Iceland, Norway, Britain, France, Spain, Portugal, Canada, and, of course, the United States.

The Basques of the tenth century were among the first European fishermen to work North American waters. From their own waters in the Bay of Biscay, the intrepid Basques (also the first people to hunt whales systematically) wandered north, locating and relocating the right whales of the British Isles, Iceland, and Greenland, and eventually fetching up in Labrador, where they pioneered two important industries: whaling and cod fishing. There, at a place called Red Bay, evidence of the first Basque whaling settlement has been found, with ship relics dating from approximately 1540.

A century earlier, a Portuguese named Diogo de Tieve, who discovered the Azorean islands of Flores and Corvo in 1452 while searching for the nonexistent "Island of the Seven Cities," found himself off the coast of Newfoundland, and when he returned to Portugal, he reported great schools of cod. This news was welcomed by the Portuguese, who had been catching, drying, and salting the cod caught in their own waters for well more than a century by that time. (Cod are found on both sides of the North Atlantic, but they are far more plentiful in the western quadrant.) No sooner had de Tieve returned from the Grand Banks—for that is surely where he was—than the name *Terra Nova do Bacalhau* began to appear on maps and charts; the New Land of the Codfish was becoming an integral part of the cartography of the known world.

The Black Death ended in England around 1350, and although the documentation is sparse, it is believed that the British resumed sending fishing boats to Iceland as early as 1397. According to historian G. J. Marcus (1981), "during the spring of 1408 or 1409 . . . English fishermen had begun to work the Iceland fishery; and had thereby opened a new and significant chapter in the history of English maritime enterprise." They came in "doggers," craft believed to have been designed for fishing, ranging from forty to eighty tuns burthen. In England and France, a ship's size was reckoned as a function of capacity. A tun was a double hogshead (252 gallons) used for shipping wine, and a ship's burthen was the number of tuns the ship could carry.

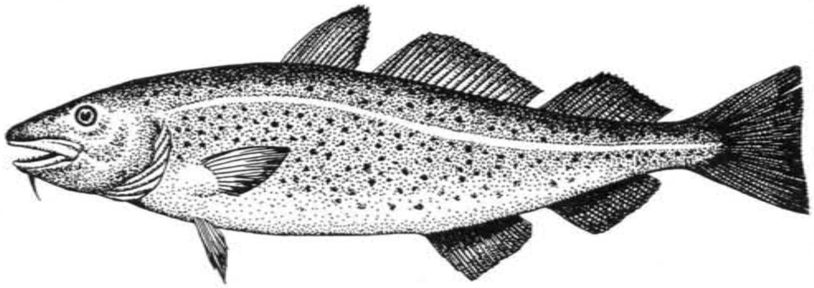
Other innovations that affected ship design in the early fifteenth century were the addition of a second mast, which altered the way ships could be sailed, and the introduction of sailing by latitude, which meant the end of "rock-dodging," sailing only with the next landfall in sight or nearly so. Once the British mariners crossed the Atlantic to Iceland, they overwhelmed the Icelandic fishermen and practically turned the cod fishery into an English enterprise. Two centuries later, English settlers (as opposed to adventurers such as John Cabot) made their first landfall in America, at the narrow spit that in 1602 Bartholomew Gosnold christened Cape Cod because the eponymous fish were so plentiful there.

The eating of fish had positive religious connotations for medieval Christians, a factor that had kept demand for the fish high. The initial letters of the words *Iesous Christos Theou Hyios Soter* ("Jesus Christ, Son of God, Savior") are those of *ichthys,* the Greek word for fish. Moreover, fish became a staple of the European diet because eventually it could be eaten regardless of the intricate and variable schedule of fast days, on which people were forbidden to eat meat. (In Christianity's early years, fast days were literally that—the faithful were not to eat anything at all—but later, the days of abstinence were modified so that only certain foods were eschewed.) The most strictly observed of the fast days was Friday, in honor of the Crucifixion, but on occasion they included Wednesday, the day Judas accepted money for his promise to betray Jesus, and also Saturday, the day consecrated to Mary in celebration of her virginity.

Even more important for fish consumption than the weekly fast days, however, were the enduring fasts of Lent and Advent, which ushered in, respectively, the festive seasons of Easter and Christmas. Lent, which lasted for six weeks, was the major fast of the year, and although its observance included cutting down on meals and the amount of food consumed, the major modification in the dietary habits of the populace was the change from meat to fish. Bridget Henisch observed in *Fast and Feast,* a study of food in medieval society:

> Fish, providentially, had escaped God's curse on earth by living in the water. Water itself was an element of special sanctity, washing away the sins of the world in Noah's Flood, and the sins of the individual in baptism. Its creatures might be said to share something of its virtues. Once the choice had been justified, the rest was easy. Fish was plentiful, fish was cheap, and in the season of Lent, fish was king.

Herring was not eaten only during Lent, of course; it was a staple of the European diet throughout the year. After the discovery of the codfish stocks



CODFISH *(Gadus morhua)*

of the Grand Banks—and the still-unexplained disappearance of the Atlantic herring in the early fifteenth century—*Gadus morhua* displaced *Clupea harengus* as the predominant fish on European tables. No amount of fancy preparation could make the herring or the cod—or, for that matter, the hake, sole, plaice, whiting, or turbot—tasty or desirable to the medieval palate. They were primarily regarded as Lenten fare and, as such, foods to be *suffered* rather than enjoyed. But suffered or not, cod was in high demand as Lent approached.

Because cod will take almost any bait offered to them, the first Grand Banks fishermen simply baited their hooks with a piece of clam, a capelin, or a squid and hauled in a codfish. The first fishermen—the Basques, for example—fished either from the decks of their vessels or from smaller rowing boats known as *chaloupes*, but the object of their fishery was always the same: the *baccalao** first encountered in such profusion by John Cabot in 1497. (Cabot is said to have fished by lowering weighted baskets into dense schools of cod and simply hauling them up.) By the first decade of the sixteenth century, João Fagundes had traveled the coast of eastern Newfoundland, and the king of Portugal had applied a 10 percent tax on imported cod. (Samuel Eliot Morison—exclamation point and all—referred to this in 1971 as "the first European attempt to protect home industries from American competition!") Fish was also a major element in the diet of sixteenth-century Europeans; it

*Although *baccalao* is the Portuguese word for codfish, it is believed to have originated in the Basque language. As Francis Parkman pointed out in *Pioneers of France in the New World*, "if in the original Basque, *baccalaos* is the word for codfish, and if Cabot found it in use among the inhabitants of Newfoundland, it is hard to escape the conclusion that the Basques had been there before him."

was one of the few sources of cheap protein available to them. As historian J. H. Parry noted in 1974, "the import of great quantities of cod was in itself a significant economic event, in a continent where many people lived near starvation level for part of every year." In France, the fish were known as *morue;* in Spain and Portugal, *baccalao;* and in England, stockfish or poor-john.

The cod fishermen were soon to become the most serious rivals of the herring picklers; dried cod is much easier to handle than pickled herring, since the cod can be tossed around like cordwood, whereas the herring has to be stored in a barrel of brine. Once they had learned the basic facts about the natural history of their prey, the fishermen realized that no matter how important it was to be the first ones on the Banks, there was no point in getting there before May, when the capelin swarmed inshore and the cod followed them.*

The codfish is a shallow-water inhabitant; it is plentiful in areas such as the North American continental shelf, where the depth is rarely greater than two or three hundred feet. In the *Encyclopedia Londonensis* for 1810, the habitat and utilization of the cod were described thus:

> They are taken in vast quantities at Newfoundland, Cape Breton, Nova Scotia, and the coasts of Norway and Iceland; also off the Dogger-bank, but their principal resort for centuries past, has been on the banks of Newfoundland, and other sand banks off Cape Breton. That extensive flat seems to be the broad top of a subaqueous mountain, everywhere surrounded by a deeper sea. Hither the cod annually repair, in numbers beyond the powers of calculation, to feed upon the worms that swarm along the sandy bottom. Here they are taken in such quantities, that they supply all Europe with a considerable supply of provision.

As the fish were hauled in, they were gutted immediately, the tongues cut out (and used as counters to record how many fish had been caught by each man), and whatever was in the gut used to rebait the hook. The fish were thrown into the pound amidships, where the header and the dresser performed their functions. When the dresser had filleted the fish, he threw the pieces into the hold through a hole in the deck; there, the salter laid the fish in a bed of salt, where it would remain for twenty-four to forty-eight hours.

*The capelin (*Mallotus villosus*) is an incredibly prolific small fish of the smelt family, reaching a maximum length of six inches. In the spring, capelin aggregate in breeding schools that number in the millions and spawn at the surf line, where they are thrown up on the sand to die. On the coasts of Newfoundland, the capelin wash ashore in such quantities that the little fish are used as agricultural fertilizer.

(The salt, obviously one of the most important elements in this fishery, came at first from Brittany or Lower Normandy, but when local taxes made that too dear, the fishermen went to Spain and Portugal to obtain the substance. By the seventeenth century, they were getting their supplies from the salt pans of La Rochelle and its offshore islands, Île de Ré and Île d' Oléron.) The cod roe was kept as a special treat for the crew, the air bladders were made into glue, and the oil from the liver was used for lighting.*

Even more important than the salt cod fishery was the dried cod industry of the sixteenth and seventieth centuries. This fishery, known as the "sedentary" fishery because the mother ship remained anchored, colonized the beaches between Bonavista Bay and Cape Norman on Newfoundland, along the coast of Labrador, and even along the Gaspé Peninsula. The fishery lasted from June to mid-August, but the ships did not head home until the drying was completed, usually around the end of September. The boats were left on the beach, and the dried fish were laid on branches in the holds and transported back to Europe.

Even though John Cabot discovered the Grand Banks and claimed them for England, the British cod fishery began somewhat later than the French and the Portuguese. When John Rut visited Newfoundland in 1527 in the *Mary of Guilford,* he reported "eleven saile of Normans, and one Brittaine, and two Portugall Barkes and all a-fishing." In 1542, Henry VIII criticized his subjects for buying codfish from "Pycardes, Flemynghes, Norman and Frenchmen," and an act of Parliament suggested "the craft and feate of fishing" gave "great welthe to the Realme." Although the French—and, to a lesser extent, the Portuguese—dominated the fishery in the first half of the sixteenth century, the Spanish took the lead in the second half.

When Sir Humphrey Gilbert passed the Grand Banks en route to Newfoundland in 1583, he encountered Portuguese and French fishermen, "sometimes a hundred or more sails of ships; who commonly begin the fishing in April, and have ended by July." Edward Haye, whose account of Gilbert's expedition appears in Hakluyt's *Voyages,* wrote that "cod, which alone draweth many nations thither . . . is become the most famous fishing of the world." When Gilbert arrived at Newfoundland, he found an English "admiral" in charge of the camps, and although the fishermen ignored his pomp and circumstance—he had, after all, a patent from the Queen to claim the land for England—Newfoundland became the first English possession in the New World. Gilbert was lost at sea in the *Squirrel* shortly after leaving Newfoundland, but his enthusiastic writings are believed to have inspired another man from the West Country, his half-brother Walter Raleigh, to follow him.

*Although the medicinal qualities of cod liver oil were not fully realized until the twentieth century—it is especially rich in vitamins A and D—its virtues were known for hundreds of years to the Lapps, the Norwegians, and the Icelanders. In eighteenth-century continental Europe, it was prescribed by physicians for the prevention and treatment of gout, rheumatism, and even tuberculosis. In later years—much to the discomfort and distaste of innumerable children—it became known as an all-purpose tonic and vitamin supplement.

In 1603, the merchants of Bristol sent Martin Pring to check out the stories Gosnold had brought back. "Heere wee found," wrote Pring, "an excellent fishing for Cods, which are better than those of New-found-land and withall saw good and Rockie ground to drie them upon." Pring, a Devonshire seaman, commanded the *Speedwell;* the *Discoverer* was under William Brown. After being detained by the death of Queen Elizabeth on March 23, they sailed from Milford Haven on April 10, 1603, and arrived at Cape Cod Bay in June. Pring landed on Martha's Vineyard, headed south past the mouth of the Acushnet River at what would later become New Bedford, and entered Long Island Sound, opening trade with the Indians there. He sent the *Discoverer* home with a cargo of furs and sassafras and remained behind with the crew and passengers of the *Speedwell* for the rest of the summer, planting wheat, barley, oats, and peas. He arrived back in Bristol in early October, with useful information about "North Virginia," which would not be named New England until John Smith arrived there in 1607.

The colonists tried to set up fishing communities at Weymouth and Cape Ann, Massachusetts, but these failed. The first successful venture was at Salem in 1628, followed quickly at Dorchester, Marblehead, and Scituate. Along with the lumber industry, fishing became the colony's first business, but only after the development of a "winter fishery" around 1630. Farmers who tilled the soil in spring and summer turned to the sea in winter and were thus able not only to feed themselves and their families but also to provide a commodity that could be traded. It was a happy quirk of nature that the cod approached the shores of New England in winter to spawn, since they were much farther offshore in summer, on Georges Bank, the Grand Banks, and Jeffries Bank. The Europeans who held no colonial interests in North America had no such opportunities for a winter fishery, since they would have had to sail across the hostile North Atlantic in late fall, the worst possible time of year.

The Reverend Francis Higginson, the first minister of Salem, died in 1630, but in *New England's Plantation* he left behind a delightful account of the treasures of Massachusetts Bay:

> The abundance of sea-fish are almost beyond believing, and sure I should scarce have believed it, except as I had seen it with my own eyes. I saw great store of whales and grampusses, and such abundance of mackerels that it would astonish one to behold, likewise codfish in abundance on the coast, and in their season are plentifully taken. . . . Also there is an abundance of herring, turbot, sturgeon, cusks, haddocks, mullets, eels, crabs, muscles and oysters.

With such variety and abundance, the colonial fishery prospered, especially when it was discovered that the poorer grades of fish could be exported along with the tobacco that was grown in Virginia. Toward the end of the century, the "triangular trade" was in full swing: New England ships carried fish and lumber to the West Indies; fish to England, Spain, Portugal, and the Mediterranean; rum to Africa; and slaves from Guinea and Angola. Cordage, iron, hemp, fishing tackle, and other products necessary for industry were exchanged for cod and brought back to the burgeoning colony. In March 1643, a Boston-built ship returned from a voyage to Fayal (in the Azores), where it had sold fish and pipestaves (the slats used in the manufacture of barrels, or "pipes"), bought wine and sugar, and sailed for St. Christopher, where it exchanged the wine for cotton, tobacco, and iron. The premium dried cod from Massachusetts was sent to France, and the inferior grades went to Spain and the West Indies. In 1700, with a population of some 14,000 people, Boston had a fleet of about 300 trading and fishing vessels engaged in commerce with Nova Scotia, Virginia, the West Indies, and Madeira. That year, the city exported some 50,000 quintals (a quintal equals 100 kilograms, or what was eventually known as a hundredweight) of winter-cured fish, and more than three-quarters of it went to the Spanish port of Bilbao, on the Bay of Biscay.

By the second half of the seventeenth century, France also had possessions in the West Indies (St. Christopher, Martinique, Guadeloupe, the Tortugas, St. Martin, St. Lucia, St. Croix, Grenada, and St. Bartholomew, in order of acquisition) and settlements in North America. French shipping was heavily engaged in the sugar, tobacco, and slave trades—it was estimated that the sugar plantations of Martinique required more than a thousand new slaves every year—and these people needed food. The French developed locations in Newfoundland and the Strait of Belle Isle where they could fish on their own and not depend on trade from the British or the Americans. One of these was Placentia, which was particularly desirable because it was free of ice in the spring. By 1668, the French were loading more than a hundred ships per year, in contrast with ten or twelve the year before.

Unfortunately, Placentia was on British territory, and the British were not happy about the French settlement there. They tried to oust the French interlopers, but the French dug in and even established stations along the Gulf of St. Lawrence and on Anticosti Island. The French cod fishery peaked between 1678 and 1689, but in 1699 Parliament prohibited settlement on Newfoundland except as necessary to maintain the cod fishery, and for the next 150 years the island was run as a private fiefdom ruled by commercial fishing interests.

As the French retreated from Cape Breton and the Gulf of St. Lawrence, the British moved in. They filled the void and filled their holds in Quebec (the Gulf of St. Lawrence), Newfoundland, and Nova Scotia. With the decline of the French and the New England concentration on Newfoundland, the fishery expanded to the shores of Labrador, and production increased dramatically. In 1763, the Massachusetts fishery brought in an estimated return of £164,000. Marblehead and Gloucester led the way with 150 and 146 vessels, respectively.

Since the New England fishermen were producing so much fish for West Indian consumption, they had to be able to import a commensurate amount of molasses. If the imported molasses was heavily taxed, it meant that fishing had to be reduced, a serious threat to American industry. On May 24, 1764, a Boston town meeting denounced taxation without representation, and by the following year, policies of nonimportation of British goods had begun throughout the colonies. The increasing hostilities between Britain and its colonies in North America were as important to the history of the fishery as to the history of the country. The Boston Massacre occurred in March 1770; the Boston Tea Party, in December 1773. By 1774, as the conflict was heating up, Britain passed the New England Restraining Act, which restricted New England trade to British ports, and then an embargo was placed on trade with Nova Scotia, Newfoundland, and the West Indies. New England fishermen and privateers roamed the coasts of Newfoundland and Nova Scotia capturing British and Newfoundland fishing boats, along with their crews and cargoes, as another device to harass the British.

The war was concluded with the Treaty of Versailles in 1783. The treaty explicitly awarded Americans the right to fish the Newfoundland Banks and take fish on the British portion of the Newfoundland coast, but they were not allowed to dry them there. They were, however, given liberty to dry and cure fish on the unsettled harbors, bays, and creeks of Nova Scotia, the Magdalen Islands, and Labrador, so long as those locations remained unsettled. By the turn of the century, it was becoming apparent that the ships sent over from Europe—especially from Britain—were economically unable to compete with the Newfoundlanders themselves, especially since the Newfoundland "bankers" did not have to make a transatlantic crossing. The Newfoundland residents or settlers, known as "planters," could prepare fish more cheaply than the merchants, since they had no wages to pay. Once again, the specter of war appeared on the horizon, and only twenty-nine years after the Treaty of Versailles was signed, the British and the Americans were at it again, in the war known in Britain as the Anglo-American War and in the United States as the War of 1812.

The rise of a fishery in Newfoundland ousted most of the British ships, and by 1823 the British fishing fleet, which had numbered more than three hundred in 1792, was reduced to some fifteen ships. Newfoundland received a charter (and a resident governor and council) in 1824. The charter was known, significantly, as the Newfoundland Fisheries Act, demonstrating the overwhelming importance of the fishery in the settlement of this island. During the nineteenth century, the cod fishery continued to grow and to dominate the commerce of Newfoundland and New England.

The early 1890s were good years for fishing in Massachusetts, particularly for Gloucester. At the World's Columbian Exposition of 1893 in Chicago, Gloucester mounted an elaborate exhibit featuring a scale model of its thriving waterfront. At the same time, Rudyard Kipling was holed up in Brattleboro, Vermont, writing *Captains Courageous,* the story of the brave Gloucestermen who went down to the sea in schooners. In 1895, fishermen caught 60,000 tons of cod in the waters off New England, including the 211-pound "patriarch" cod, the largest codfish ever recorded.*

By the turn of the century, the stocks of codfish were largely unscathed, and it appeared that the fishery could go on forever. In 1883, Thomas Huxley could say, "I still believe the cod fishery . . . and probably all the great fisheries are inexhaustible; that is to say that nothing we do seriously affects the number of fish." Huxley, one of the late nineteenth century's most eminent scientists and famous for his staunch defense of Charles Darwin's theories, could not have been more wrong. He could not have predicted the effects on the fish stocks of the otter trawl, a British invention introduced around 1880 and adopted by New England fishermen in 1905.† Nine years later, in 1914, the

*Nowadays, a cod weighing more than 50 pounds is considered large, and 100 pounds is truly exceptional. Curiously, the cod, which puts up very little resistance when hooked, is considered a game fish by the International Game Fish Association, and the modern record is a 98-pounder caught off New Hampshire in 1969.

†The otter trawl, now the standard bottom trawl, consists of a large, bag-shaped net that is towed through the water with its mouth held open by various ropes, *(continued)*

Commissioner of Fish and Fisheries had appointed a congressional committee to investigate the damage the otter trawl did to fish stocks. Fortunately for the cod, World War I intervened and the declining stocks had some chance to recover, but by 1919 the fishers were back in business. In retrospect, their business seems to have been to eliminate the codfish from the North Atlantic. In 1954, they received another enormous boost from technology when the British factory ship *Fairtry* entered the lists.

At 245 feet in length and with a displacement of 2,800 tons, the *Fairtry,* built by Salvesen of Leith, was far larger than the largest trawler of the day and could catch and process cod in unprecedented numbers. The trawl net was hauled up through a stern slipway, not unlike that of the whaling factory ships Salvesen also built. On the factory deck of the *Fairtry* there was a heading machine, as well as devices for automatically skinning and filleting the fish, and belowdecks were two sets of quick-freezers and fully refrigerated holds. There was also a cod liver oil plant. So as not to be left behind, other countries commissioned similar factory ships, and soon the Grand Banks were serving up their cod to the Soviet Union, Germany, Spain, and Poland, whose fishers were impervious to local restrictions. The catch of cod for 1968 was 810,000 tons, nearly three times the amount caught in any year before the *Fairtry* introduced her annihilative technology.

The story of the giant factory ships draining the North Atlantic of its heritage of fish stocks is well told in William Warner's 1977 *Distant Water* and can only be summarized here. Displacing the fleets of Norway, Iceland, and Denmark, in whose home waters they were fishing, the distant-water fleets of Germany, the USSR, Poland, Spain, and Japan took various species of cod and herring in staggering numbers. The *Fairtry's* displacement of 2,800 tons, which was once the largest, was soon superseded by Soviet ships that displaced 8,000 tons. (Warner quotes one incredulous observer as exclaiming, "They're fishing with ocean liners!") The nets used by these factory ships were enormous; some were large enough to swallow a dozen jumbo jets in a single gulp. In an hour, these leviathan ships could catch a hundred tons of fish, as much as a sixteenth-century codfish boat caught in a season. Increasingly sophisticated technology enabled fleets to process the fish at sea, not only gutting them but also filleting, freezing, and even packing them.

weights, and floats in conjunction with angled "otter boards" (also known as "doors"), which draw apart as the net is pulled over the seabed. Its depth and distance from the bottom can be controlled by floats. The narrow, tapered end of the net, into which the trapped fish gather, is known as the "cod end."

It was during this period that the "cod wars" between Britain and Iceland broke out. A "war" between fishing nations was a precursor of things to come; more and more boats would be vying for ever-decreasing numbers of fish. From 1919 to 1951, Iceland's fishery limit was fixed at 3 miles; any nation's boats could fish without protest to within 3 miles of its shores. To protect what it considered its own stocks of cod, Iceland increased the limit to 4 miles in 1952 and to 12 miles in 1958. In 1972, when most other countries maintained a 12-mile limit, Iceland unilaterally increased the limit around its shores to 50 miles. When British and West German trawlers ignored the restrictions, Iceland's coast guard vessels employed trawl-wire cutters to render the fishing gear useless; the British fishing boats tried to ram the coast guard cutters, and Britain sent Royal Navy frigates to Icelandic waters to protect its boats, but luckily no shots were fired. When the British and Icelandic prime ministers met in London to resolve this dispute, the British promised not to send their larger ships into Icelandic waters and not to fish in certain areas. But when Iceland later adopted a 200-mile exclusive economic zone (EEZ), British fishing boats again intentionally violated Icelandic space, and the cod war began anew. British frigates accompanied fishing boats into Icelandic waters, and the Icelanders deployed coast guard ships, planes, and helicopters. Unable to resolve their differences by diplomatic means, Iceland broke off relations with Britain, but in June 1976 the conflict was peacefully resolved, and again Britain agreed to reduce its presence in Icelandic waters.

To avoid such conflicts, the Canadian and U.S. governments contrived to extend their own fishing limits 200 miles offshore, thereby excluding foreign vessels from the productive waters of the Grand Banks. Instead of creating a sustainable fishery for their own fishers, however, the Canadians and Americans engaged in all sorts of "scientific" tomfoolery dedicated to finding out how many cod there had been before the decimation began. They had no way of accurately estimating the actual population, so they began catching the fish themselves in a misguided effort to count them or see how old they were when they died. This, of course, had no appreciable effect on the cod population because by that time—the mid-1970s—the population was so diminished that its recovery was almost impossible. Basing their assessments on the limited knowledge of cod biology at the time, the scientists decided that because the female cod lays millions of eggs every year, it would only be a short while before the population rebounded. For a couple of years, it appeared that the fisheries biologists were right; the catch did increase from its low point of 139,000 tons in 1975. In their wisdom, the Canadian bureaucrats increased the subsidies to fishermen and thereby increased the number

of boats fishing for cod. By overestimating the available stock and encouraging more trawlers (the Canadians and Americans never did acquire the factory ship mentality; theirs was more an old-fashioned catch-as-catch-can approach that emphasized the rugged individualism of the fishermen), the government was all but guaranteeing the demise of the codfish—and thereby, of course, that of the cod fishermen.

In time, the fishermen learned new techniques and found new fishing grounds, which made it look as if they were fishing on an increasing stock. Their catches were going up, weren't they? In fact, the cod population was declining at an alarming rate, sliding toward the brink of what had always been held to be an impossibility—extinction. Even with these catastrophic predictions in hand, the Canadian government was more protective of its human population, and not wanting to throw thousands of Newfoundland fishers out of work, it cut the quotas by a skimpy 10 percent. Even with this reduction, however, the fishers continued to *increase* their productivity, with the sadly predictable result that the cod population declined even more precipitously. By 1992, it was obvious that the fishery had run out of fish, and the Canadian government closed it down, not temporarily, but permanently. Of Newfoundland's total (human) population of 570,000, there were 30,000 out of work in 1997.*

And what of New England? Georges Bank and the Gulf of Maine were never as rich in cod as the Grand Banks of Newfoundland, but the United States followed closely behind the Canadians and systematically eliminated the resource that had sustained fishing communities such as Gloucester for two centuries. Foreign trawlers were banned from waters within 200 miles of shore, and the American fishing fleet doubled between 1977 and 1983. In 1982, the American catch reached a high of 53,000 tons, but it began to decline immediately. The Magnuson-Fishery Conservation and Management Act, passed in 1976 to oversee the management of American fisheries, left planning and quotas to "regional councils," which meant that every fishing community could set its own limits—a classic example of the fox guarding the henhouse. The stocks of cod (and also haddock and yellowtail flounder) dropped so precipitously that by 1993, the National Marine Fisheries Service had closed Georges Bank to fishing indefinitely. As of 1995, the U.S. government had paid

*Newfoundland seems to be perennially snakebit in its approach to natural resources. First, its pilot whale fishery was deemed ecologically unsound (fishermen drove the pilot whales into shallow water and slaughtered them by the hundreds); its practice of clubbing baby harp seals to death came under intense fire from conservation groups; then, in 1992, Newfoundland's cod fishery, deemed its last safe industry, was closed down entirely.

more than $60 million in subsidies to New England fishermen, and the Canadian government had supported its Newfoundland counterparts to the tune of $600 million.

On the other side of the Atlantic, similar problems were brewing. As of 1997, even though European cod fishermen had reduced their catch by one-third, the young fish had not reappeared. Off the coasts of Britain and Iceland in the 1980s, cod catches averaged 300,000 tons per year, but the total fell to around 100,000 tons. Robin Cook of Scotland's Aberdeen Marine Laboratory said, as quoted in a 1999 Fred Pearce article in *New Scientist,* "Even in the Barents Sea north of Scandinavia, cod are in dreadful shape." The International Council for the Exploration of the Sea (ICES) called for cuts of 40 percent in the North Sea catch to forestall the collapse of the fish—and the fishery. Because cod are a cold-water species, it has been suggested that the general warming of the North Atlantic is somehow responsible, but some fisheries scientists disagree, holding that overfishing is the obvious and primary cause of population reduction.

The primary cause of the decline in North Atlantic cod populations is certainly overfishing, but other factors may have contributed. Recent experiments in his laboratory at the University of New Hampshire have convinced Michael Lesser that reduction of the atmospheric ozone layer has resulted in an increase in ultraviolet (UV) radiation that is deadly to cod larvae. In a 2001 article in the *Journal of Experimental Biology,* Lesser, Julianne Farrell, and Charles Walker pointed out that harmful ultraviolet-B (UV-B) radiation can penetrate to depths of twenty-three meters (seventy-five feet). Although cod usually spawn in deep water, the larvae float up toward the surface, where they are exposed to the UV radiation that can kill or harm them. Even larvae that survived the UV-B irradiation showed damage to their DNA and were smaller than larvae that were experimentally shielded. Under normal circumstances, around 99 percent of the millions of cod eggs and larvae are eaten by predators, but if UV radiation also is killing many of them, the death rate could be even higher.

Some fishermen and government representatives have attempted to blame the crash in cod populations on harp seals, claiming that if the seal herds carry on unchecked, there will be no fish left for anyone. There is no evidence, however, to support such a declaration. In a 2001 report, Alida Bundy of Fisheries and Oceans Canada in Dartmouth, Nova Scotia, wrote: "While groundfish stocks collapsed, seal populations and invertebrates such as shrimp and snow crab increased in abundance. The model predicted these increases, while a simulated increase in harp seals further repressed the recovery rate of cod. It was concluded that these results are consistent with the hypothesis that the collapse of cod was caused by excess fishing and that cod recovery is retarded by harp seals." It must be noted that Bundy's analysis was based exclusively on computer modeling and not on field observations, so the seals' involvement in the decline of cod populations is purely hypothetical.

A more recent report from Bundy puts an even worse spin on the cod situation. When the stocks crashed around 1992, fishing for cod was banned to allow them to recover, but, says the report (Bundy, Lilly, and Shelton 2000), the population dynamics have been so drastically altered that cod may never reappear in their former numbers. Not only cod but virtually all high-quality table fish, such as tuna, haddock, and flounder, have fallen to about 16 percent of what their numbers were in 1990. In a 2002 article in *New Scientist,* Kurt Kleiner quoted fisheries biologist Daniel Pauly: "Jellyfish is already being exported. In the Gulf of Maine people were catching cod a few decades ago. Now they're catching sea cucumber." Reg Watson, Pauly's colleague at the University of British Columbia and another of the report's authors, said, "If things don't change, we'll all be eating jellyfish sandwiches."

"Every nation has its comfort food," observed Debora MacKenzie (2001a). "In Britain, it is a large chunk of white fish, battered and fried, with thick fried potatoes and a sauce made of green peas, all wrapped in paper. . . . Unfortunately, the latest evidence suggests Britain's favourite fish is, after umpteen warnings, really on the road to oblivion." The spawning stocks of North Sea cod have plummeted, from a high of 277,000 tons in 1971 to 59,000 tons in 2001, well below the level at which commercial fishing can be sustained. But commercial fishing not only has not been reduced, it has increased: the depleted stocks mean that more and more fishermen, trying to scratch out a living, are putting to sea in an attempt to catch fewer and fewer fish. Getting fishermen to lay up their boats has proven to be a political nightmare, and the British cod-fishing industry is efficiently putting itself out of business.

At a meeting of the European Union in November 2002, fisheries scientists recommended a ban on almost all commercial fishing in the North Sea because of the imminent collapse of the codfish stocks. In the *New York Times* of November 7, Craig Smith commented, "The cod crisis is one of many facing the international community as countries compete for thinning stocks in the world's once fish-thick seas." For many countries, fishing represents jobs, and few politicians are willing to protect fishes before their constituents. It is estimated that if the North Sea cod fishery is shut down, as many as 20,000 jobs would be lost in the United Kingdom alone. Studies by ICES indicate that unless drastic steps are taken, the fisheries of Europe will follow those of the United States and Canada, collapsing because there are no more fish to catch. "According to scientific surveys and catch statistics," wrote David Malakoff and Richard Stone (2002), "the North Sea's cod spawning schools have dropped to 15% of what they were in the early 1970s." Politicians and fishers argue that a reduction in fishing will enable the stocks to bounce back, but when this kind of short-term solution was applied as a stopgap in New England, it was too late and the fishery collapsed anyway.

"Fishing down food webs (that is, fishing at lower trophic levels) leads at first to increasing catches, then to a phase transition associated with stagnating or declining catches," say Daniel Pauly and his colleagues (1998). "The results indicate that present exploitation patterns are unsustainable." All over the world, people are failing to hear the message. Out of desperation, greed, ignorance, and mismanagement, people are finding the bottom line of fish stocks that once seemed bottomless. Yet it is still shocking that it should have happened to cod—stolid, prolific, resilient, numberless cod, the beef of the sea. Even though we hardly knew them, we took the cod for granted, rather like the buffalo when the prairies were black with them. There is no great mystery about what happened to the codfish of the North Atlantic. The fishermen caught them, and the rest of us ate them.

THE PATAGONIAN TOOTHFISH

On February 11, 1888, the research vessel *Albatross*, working off the southern coast of Chile, hauled in a beam trawl that had been cast into water more than 6,000 feet deep. Among the creatures dumped on deck was a five-foot-long, large-mouthed fish, the likes of which no one had ever seen. Charles H. Townsend and Theodore Gill, ichthyologists aboard the *Albatross*, had it photographed as it lay on the deck; then they had it placed in a rough wooden box and salted, to preserve it for later study. Unfortunately, an overzealous bosun's mate pitched the box overboard, and all that remained of the fish was the photograph. Townsend and Gill named it "*Macrias* with reference to its length as well as its bulk, and the specific name *amissus* is appropriate for it as an estray from its relatives as well as to indicate the loss of the type." *Macrias amissus* was by far the largest of all known deep-sea fishes, and in 1901 Gill and Townsend wrote a brief description of their lost specimen.

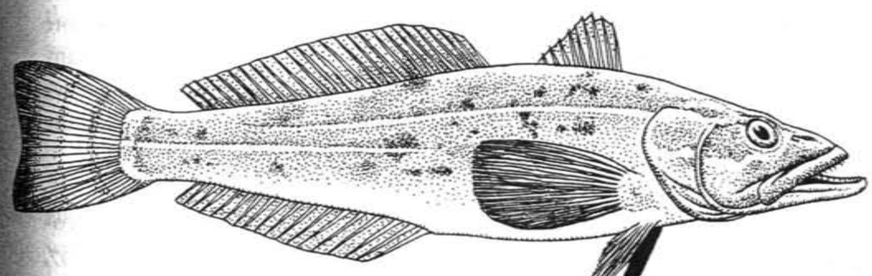
Thirty-six years later, Townsend wrote about it again, this time without Gill (who died in 1914), in an article published in the bulletin of the New York Zoological Society. (Townsend was director of the Society's aquarium, then

located at the Battery in lower Manhattan.) He had come across the photograph in searching through old records of the voyage of the *Albatross*, so this article, titled (as was its predecessor) "The Largest Deep-Sea Fish," included the subhead "A Long-Missing Photograph of the Monster Comes to Light after Nearly Half a Century." And there is *Macrias amissus*, on the deck of the *Albatross*. Townsend said:

> *Macrias amissus* never found its way into the published lists of fishes known to science. Perhaps the ichthyologists will relent when they see the photograph Dr. Gill and I regarded as that of a new fish from the depths and worthy of being described as something new to science, whether we had or had not, the type.

A couple of ichthyologists did relent, but not exactly as Townsend imagined they might. When Hugh DeWitt (1962) of Stanford University looked at the photograph, he "was immediately reminded of the illustration of *Dissostichus eleginoides* published by F. A. Smitt in 1898." Because of differences in Gill and Townsend's description (in *Science*) and Smitt's (in a Swedish journal), DeWitt decided that *Macrias amissus* was not exactly like *D. eleginoides*, and he therefore named it *Dissostichus amissus*.

DeWitt's article appeared in the ichthyological journal *Copeia* in 1962, but not many nonichthyologists read it. Somehow, the "*Albatross* fish" became one of the more popular subjects for those who would postulate large, unknown fishes lurking at abyssal depths. For example, Edward Ricciuti's 1973 *Killers of the Seas* has a section titled "Survivors from Past Ages," and there, of all things, is the photograph of the fish from the *Albatross*. The caption reads:



PATAGONIAN TOOTHFISH
(Dissostichus eleginoides)

STRANGE FISH. This fish, about 5 feet long, was dredged from a depth of 6,000 feet by the research vessel *Albatross* in 1888. Shortly after this photo was taken on deck, a crewman tossed the fish overboard, to the dismay of scientists who had never seen anything like it before.

Soviet cetologists, however, had certainly seen something like the *Albatross*'s fish; in fact, *Dissostichus* is a fairly common food item in the diet of Southern Ocean sperm whales. A. A. Berzin's 1972 monograph on sperm whales contains a photograph of a fish with this caption: "Specimen of *Dissotichus* [sic] *mawsoni,* from the stomach of a sperm whale." The stomachs of three sperm whales taken by Soviet whalers in 1963 contained approximately twenty fish per whale measuring seventeen to fifty-three inches long and weighing as much as 100 pounds. It is believed that sperm whales hunt at great depths, but how they are able to catch presumably fast-swimming fishes in the dark is unknown. We may not know how sperm whales catch these fish, but we know how people do, and they do it so efficiently that the fish is on the fast track to extinction.

Now known as the Patagonian toothfish, *Dissostichus eleginoides* was first caught on longlines by fishermen who were randomly fishing the subantarctic waters north of latitude 55° S around Patagonia, southern Chile, and islands such as the Crozets, Heard, Kerguelen, and South Georgia. Today, *Dissostichus* is more familiar to consumers around the world as the Chilean sea bass, black hake, or black cod. In Japan, its highly prized white flesh is known as *mero.* Although hardly any information is available about the growth rate of the fish or the size of the stocks, fishing boats flying the flags of Argentina, Chile, Norway, Denmark, and Spain are hauling in these fishes at a rate so egregious that the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR, usually pronounced "camel-R") has reported that instead of the allotment, 10,000 tons, fishers are taking more than ten times that. Antarctic and subantarctic waters are mostly outside any country's exclusive economic zone (EEZ) and therefore the limits involve islands owned by various nations, but the far greater problem is that in the Southern Ocean, there is hardly any way to monitor illegal fishing.

Mounting evidence of illegal, unreported, and unregulated (known colloquially as IUU) fishing in the Southern Ocean has forced CCAMLR to propose actions to halt the plunder of these seas. It is estimated that since 1997, IUU fishing for *Dissostichus* species in the Southern Ocean has been on the order of 99,000 tons, more than twice the level of toothfish catches taken in CCAMLR-regulated fisheries. This rate of extraction is unsustainable and has led to a significant and alarming depletion of toothfish stocks in some areas.

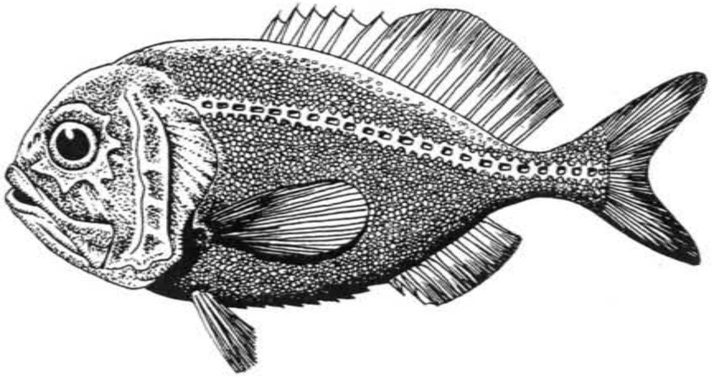
The legal fishery for toothfish, mostly in the South Atlantic Ocean and the southern Indian Ocean, is dwarfed by the take of the IUU pirates. Of the 64,900 tons of Patagonian toothfish caught in 1999–2000, the illegal and unreported portion could amount to as much as 36,300 tons. In October 2002, the Australian government announced that it was sending armed patrol boats to the Southern Ocean to protect legitimate Australian fishers and arrest toothfish poachers.

In his discussion of the extinction of the giant birds known as moas by the Maori people of New Zealand, Jared Diamond wrote: "Then, there were no more moas; soon there will be no more Chilean sea bass, Atlantic swordfish, and tuna. I wonder what the Maori who killed the last moa said. Perhaps the Polynesian equivalent of 'Your ecological models are untested, so conservation measures would be premature'? No, he probably just said 'Jobs, not birds,' as he delivered the fatal blow."

"Chilean sea bass" was first served in a Los Angeles restaurant in 1982, and since then, its soft, snow-white flesh and mild flavor have made it one of the most popular menu items in America's finer restaurants. (One Atlanta restaurateur said that he used to go through 1,200 pounds a week.) Because the unfortunate depletion of the world's marine resources is finally achieving a certain notoriety, the reduction in overfishing of endangered species has become a popular crusade in certain circles. One of the best ways to publicize illegal or overexploitive fisheries is to make the buyers of the fish—in this case, the restaurants that serve it—aware of the problems. As was done with the dwindling North Atlantic swordfish populations, a campaign has been started to have chefs remove Chilean sea bass from their menus. Take a Pass on Chilean Sea Bass, a campaign organized by the National Environmental Trust, an advocacy organization in Washington, D.C., claims to have signed on more than 800 restaurants in major cities across the United States. It seems to have worked for the swordfish; let's hope it is not too late for the toothfish.

THE ORANGE ROUGHY

The orange roughy (*Hoplostethus atlanticus*) is a foot-long, big-headed, laterally compressed (like a vertical pancake) deepwater fish that inhabits cold waters over steep continental slopes, ocean ridges, and seamounts. The name is derived from the bright orange or red color of its body and fins, although there are silver tinges on the flanks. Orange roughys have been recorded swimming as deep as 6,000 feet in the North Atlantic Ocean. They are also found in the Indian Ocean and deep below the surface on the continental



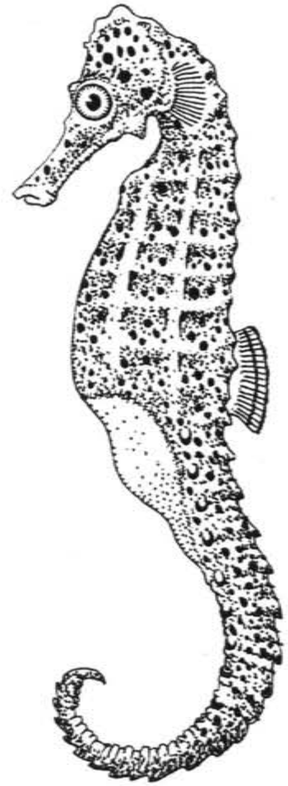
ORANGE ROUGHY
(Hoplostethus atlanticus)

shelf slope between Port Stephens in New South Wales and Cape Naturaliste in Western Australia. They are fished commercially in South Africa, South Australia, and New Zealand. The New Zealand fishery was begun only in 1979; at depths that range from 2,500 to 5,000 feet, it is the deepest commercial fishery in the world.

Orange roughys are among the most long-lived of all vertebrates. They do not mature until they are more than 30 years old, and there are records of individuals that reached 150, which means there are probably orange roughys alive now that hatched before the American Civil War. With advances in deep-sea trawling, fish that could not be caught before were hauled up in great quantities, and orange roughys were extensively exported to the United States. When the fishery began, fishers in Australia and New Zealand were ignorant of the population density and breeding habits of the object of their pursuit, and by the time they learned about the species, intense fishing pressure had seriously reduced the populations. Because orange roughys school tightly, a five-minute tow can fill a trawl net with an astounding ten to fifty tons of fish. This schooling pattern and the slow rate of growth and development make the orange roughy particularly susceptible to overfishing, and catches have fallen to a fraction of what they were earlier. Orange roughy was once a popular menu item in North American restaurants, but as it became scarce, and therefore uneconomical, it was replaced by another exotic Southern Hemisphere fish, the so-called Chilean sea bass. Because of its extremely slow rate of reproduction, the orange roughy will take a long time to recover from the blitzkrieg fishing efforts that nearly drove it to extinction.

SEA HORSES

What tiny fish has a prehensile tail but no tail fin, swims upright, and feeds through a tube? If you answered "Sea horse," you were correct, so here are some more questions: What tiny, slow-swimming fish is found in coastal waters, swims so slowly that it must depend on camouflage for escape, and is affected by pollution, dredging, seaside building, and fishing? The sea horse again. Last questions: What tiny fish is caught by the millions annually, primarily for use in Chinese medicine, but also for the home aquarium trade, and dried as souvenirs? Right. *Hippocampus.* And finally, as revealed in a 1994 *National Geographic* article, what did Amanda Vincent discover was the most valuable fisheries export of the Philippines? You guessed it.



LINED SEA HORSE
(Hippocampus erectus)

There are some thirty-five species of sea horse, ranging in size from the tiny pygmy (*Hippocampus zosterae*), which at maturity is less than half an inch long, to the eleven-inch *H. ingens*. Although a single pygmy sea horse wouldn't make much of a meal for a kitten, thousands of them would do, even for people. (In her *National Geographic* article, Vincent reported that she had found wok-fried sea horses on a menu in Hobart, Tasmania.) Sea horses harvested from the waters of Indonesia and the Philippines are used locally in folk medicine, but by far the largest numbers of sea horses are shipped to China (and, to a lesser extent, Korea and Japan), where for five centuries practitioners of traditional Chinese medicine have been using them to cure impotence and asthma and to lower blood levels of cholesterol, prevent arteriosclerosis, and even enhance virility. Dried sea horses are used to make key chains, jewelry, paperweights, Christmas tree ornaments, and other souvenirs. Because they occur in Indonesian and Philippine waters, sea horses are used in folk medicine in these island nations as well.

When Heather Hall began her research on sea horses, she found it "incredible that an animal that is so popular has been so little studied" (Milius 2000). With the support of Guylian, a chocolate company in Belgium that manufactures candies shaped like sea horses, Hall, Amanda Vincent, and Sara Lourie began Project Seahorse, dedicated to the identification and conservation of these little-studied—but utterly familiar—fishes. Even though some of them look like chessmen and others like soda straws or vegetation, all sea horses are proper fishes; they are cold-blooded vertebrates that breathe with gills and swim with fins, just like sardines, salmon, and swordfish. They differ from most other fishes, however, in their upright posture and prehensile tail, and they differ from all other fishes—and most other animals on the earth—in the male's role as incubator of the eggs.

The female produces eggs and deposits them in the male's pouch, where he then fertilizes them. Because the male broods the developing eggs, his condition can correctly be called a pregnancy. After a period that varies among species from ten days to six weeks, the male goes into labor and ejects tiny, fully formed sea horses from his brood pouch. The newborn sea horses receive no further protection from either parent and are potential prey for almost anything that swims in their vicinity.

And their vicinity includes a lot of territory. Sea horses are found in warm, shallow coastal waters of every continent, with most species in the Indo-Pacific region. Many species live among sea grasses, but others can be found in mangrove forests or in areas where sponges and corals abound. Seahorses' tubelike mouths enable them to suck in tiny prey animals, such as mysid shrimp, copepods, and other minute planktonic creatures. Seahorses swallow their prey whole, for they have no teeth and no stomachs. All thirty-five or so species belong to the genus *Hippocampus*.*

Shrimp trawlers using small-meshed nets often collect sea horses as bycatch, and these little creatures ultimately find their way into apothecaries or souvenir shops. Project Seahorse estimates that "total global consumption of seahorses was at least 20 million seahorses in 1995 (more than 56 metric tons) . . . [but] this now appears to be an underestimate; new and very incomplete data from Hong Kong show imports of nearly 13.5 tons from that region alone." At a Web page maintained by Project Seahorse titled "Seahorse Biology and Conservation," Vincent and Hall summarize what is known (and not known) about the sea horse population:

> Extracting seahorses at current rates appears to be having a serious effect on their populations. The impact of removing millions of seahorses can only be assessed indirectly because global seahorse numbers are unknown, taxonomic identities are unclear, geographic ranges are undefined, and fisheries undocumented. Nonetheless, most participants in established seahorse fisheries reported that catches were dwindling markedly. Indeed, fishers' reports and preliminary research indicate that seahorse numbers in sample populations from five countries indicate that seahorse numbers could each have declined by 50% over the past five years. Numbers in the best-understood Philippines populations are reported to have declined 70% between 1985 and 1995.

Neither size nor edibility of a fish is a criterion for its desirability to humans. We catch some species just so we can look at them. The inexpensive technology that makes artificial saltwater systems easily available means that home aquariums are no longer restricted to goldfish, guppies, swordfish, zebra fish, and tetras. Now exotic surgeonfish, triggerfish, butterflyfish, clown fish, and even moray eels and small sharks can be kept in the home, and many of these exotic creatures have to be caught in distant localities such as South

---

*Hippocampus was a mythical sea monster with the foreparts of a horse and the hindparts of a fish or dolphin. The name comes from the Greek *hippos*, which means "horse," and *kampos*, "monster." The sea horse is far from a scary monster, but with its horse-like head, prehensile tail, bony armor, and kangaroo-like pouch, it is a most unusual fish indeed. In the brain, the hippocampus is a horseshoe-shaped part of the limbic system, located in the temporal lobe, that is a center for short-term memory. The hippocampus helps humans construct a three-dimensional "mental map" of our surroundings and is crucial for our ability to move around in the world.

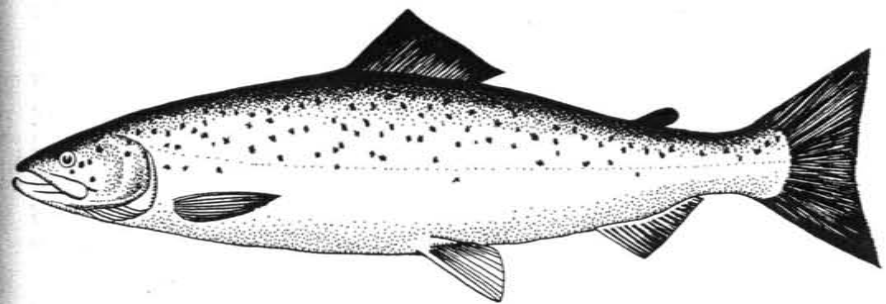
Pacific coral reefs. They are caught in huge numbers, and many of them die long before they reach the distributors. Sea horses, found throughout the world's temperate and tropical waters, are easy to catch and do well in home aquariums. Will the last sea horses be the ones the next generation watches through glass in the sanctuary of their homes?

THE ATLANTIC SALMON

> Travelers have left records of the teeming British rivers. For example, the Spanish ambassador Don Pedro de Ayala, who penetrated into the wilds of Scotland in 1498 as far as the Beauly and Spey, was astonished at the immense quantities of fish taken out of the waters. The Elizabethan "water poet" John Taylor noted the hauls from the prolific Tweed. Richard Franck, who made an angling tour of Scotland in the Cromwellian era, reported that at Stirling "the Forth relieves the country with her great plenty of salmon, where the burgomasters as in many other parts of Scotland, are compelled to reinforce an ancient statute that commands all masters and others not to force or compel any servant, or an apprentice, to feed upon salmon more than thrice a week."
>
> —Anthony Netboy, *The Salmon: Their Fight for Survival*, 1974

Found in the eastern North Atlantic Ocean from Greenland to the Bay of Biscay, and in the western North Atlantic from Hudson Bay to New England, the Atlantic salmon (*Salmo salar*) remains one of the world's most popular game fishes. A spindle-shaped, silvery fish, it is blue-gray on the back and freckled with little spots or cross-shaped markings. The world's record—caught in Norway in 1928—weighed seventy-nine pounds, but most are considerably smaller, around ten to twenty pounds. With the exception of some landlocked populations, Atlantic salmon are anadromous: born in fresh water, they migrate to the sea and then return to fresh water to spawn. Unlike Pacific salmon (genus *Oncorhynchus*), which die when they reach their freshwater spawning grounds, Atlantic salmon may repeat the cycle as many as three or four times.

At every stage of their growth, salmon acquire new names. The eggs remain in gravel substrates and hatch during winter, and the newly hatched fish, now known as alevins, emerge in the spring. The next stage is fry, and at the age of two or three months, they are called parrs. After several years in fresh water, they head for the sea as smolts, and they return to their streams of origin as grilse. Only the full-grown fish are called salmon, and these prizes



ATLANTIC SALMON
(Salmo salar)

are eagerly sought by fly fishermen in freshwater streams and rivers from Scotland to Maine. Because they are regarded as one of the world's premier food fishes, Atlantic salmon are also caught in great numbers by commercial fishermen—particularly gillnetters—leading not only to conflicts with sportfishermen but also to a catastrophic reduction in the salmon's numbers.

Wild salmon hatch in a multitude of rivers in countries with access to the North Atlantic. The far-flung salmon countries include Canada, the United States, Iceland, Norway, and Russia in the north; the United Kingdom, Ireland, and the Baltic countries in the middle of the range; and France and northern Spain on the southern margin. The young salmon leave their freshwater home and migrate thousands of miles to feed in the rich marine environment of the North Atlantic off Greenland and the Faroe Islands. After a year or more in these feeding grounds, the fish undertake their most impressive return migration to their rivers of origin, where they spawn and complete the cycle.

From time immemorial, the cycle of spawning, ocean feeding, and return migration went on as if the salmon were a permanent feature of the natural world—until the 1950s and 1960s, when developments occurred that began to threaten the fish radically. Their sea feeding grounds, long a mystery, were located, and international exploitation of the fish began at an alarming rate. New types of gear, such as the nylon monofilament net, were introduced, with disastrous results as unregulated ocean fishing fleets began to devastate the stocks of fish at sea. By the mid-1970s, as much as 2,700 tons of salmon were being taken annually from the ocean feeding grounds, and following this massive loss of stock, salmon numbers began to fall precipitously.

The Atlantic salmon's dependence on both fresh- and saltwater habitats has made it especially vulnerable to environmental pressures and overfishing. Over the past half century, the number of adult fish available to return to North American rivers is estimated to have dropped from approximately 200,000 to 80,000. The aquaculture industry's proposed use of foreign imports of farmed fish to supplement depleted ocean stocks poses a further major threat to wild salmon. When farmed fish escape from their sea cages, they invade the closest rivers, bringing with them the potential to transmit disease and parasites and to undermine the genetic diversity of wild salmon populations.

The historical North American range of Atlantic salmon extended from the rivers of Ungava Bay, Canada, to Long Island Sound. As a consequence of agricultural pollution, dam building, and industrial development, most populations native to New England have been extirpated. The remaining native populations of Atlantic salmon in the United States are now found only in eastern Maine.

If dams and pollution are hazards for the Atlantic salmon on its run to the spawning beds, the older and far more insidious problem has been high-seas fishing, which, until recently, was not subject to management regulation. In 1966, when reduced stocks caused concern on both sides of the Atlantic, Canada, the United States, and Spain banned high-seas salmon fishing, although other countries did not join the ban until ten years later. Since 1972, Canada has banned all commercial fishing of Atlantic salmon and, at great expense, has compensated fishermen for their losses. Sportfishing for salmon in the interior of Atlantic Canada and Quebec is now under strict government control.

In the 1970s, 1.5 million salmon made the migration from the sea each year, but since then the number of wild Atlantic salmon returning to spawn has steadily and significantly declined. By 1999, the number had been reduced to 350,000, a decline of more than 75 percent in less than thirty years. The Inner Bay of Fundy group of rivers consists of thirty-three rivers extending clockwise around the Bay of Fundy from the Mosher River in New Brunswick to the Annapolis River in Nova Scotia. Returns of salmon to these rivers are critically low (from a mid-1980s level of 40,000 to a few hundred in 2000), and special measures, including live gene banking, are ongoing to prevent complete extirpation. Largely as a result of legal pressure applied by Trout Unlimited and the Atlantic Salmon Federation, the unique strains of Atlantic salmon found in eight rivers (the Machias, East Machias, Dennys, Narraguagus, Pleasant, Sheepscot, Ducktrap, and Cove Brook, a tributary of the Penobscot) were formally listed as endangered species in November 2000. Yet

because these salmon migrate to the feeding grounds off Greenland shared by wild Atlantic salmon from other North American and European rivers, they are still in danger of being harvested.

A number of regulatory schemes have been put in place in both fresh and salt water, but overall, the wild Atlantic salmon population is in free fall. According to the latest report of the Northeast Fisheries Science Center (Kocik and Brown 2001), "the last two decades have seen a period of drastic decline in stock status for all Atlantic salmon populations of the North Atlantic." Angler catches in Maine have averaged approximately 486 salmon in recent years. Declines in runs have led to a no-retention policy statewide; thus, actual landings have been zero. Targeted fishing of Atlantic salmon in Maine was suspended in 2000 and will not be reopened until populations reach conservation targets. The Merrimack River brood stock fishery, which began in 1993, has resulted in an annual catch of approximately 1,000 salmon. The fisheries around Newfoundland and in southern Labrador have been closed under moratorium by the Canadian government since 1992 and 1997, respectively. The only remaining commercial fishery in Canada is a small fishery run by native peoples in Ungava Bay. In May 2001, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed the Bay of Fundy salmon as an endangered species—a species facing imminent extirpation or extinction.

Across the Atlantic, the North Atlantic Salmon Conservation Organization (NASCO) was established in 1983 to "promote the conservation, restoration, enhancement and rational management of salmon stocks in the North Atlantic Ocean through international co-operation." In 1993, a multi-year quota system for the Greenland fishery was agreed on within NASCO to provide a framework for quota setting based on a forecast model of salmon abundance, but the agreement had to be modified to allow for a local use fishery when stock abundance was found to be below recommended conservation levels.

If overfishing was not enough of a threat to the Atlantic salmon, they are now being attacked by disease. In 1998, Paul Bowser and James Casey, researchers at Cornell University's College of Veterinary Medicine, isolated what they believed to be the cause of salmon swim bladder sarcoma virus (SSSV), which, though apparently harmless to humans, was killing wild and farm-raised salmon in New England waters. The infected fish were found in a hatchery operated by the U.S. Fish and Wildlife Service in North Attleboro, Massachusetts, and in the Pleasant River in Maine. Earlier, cancer-like symptoms had been reported in farmed salmon from Scotland as well, but it was not until the development of advanced gene-sequencing techniques that the virus could be positively identified.

In 1984, a new virus was reported on fish farms in Norway and dubbed infectious salmon anemia virus, or ISAV. Then it was reported to have spread through the Bay of Fundy in New Brunswick, where it caused millions of dollars in damage to Canadian aquaculture operations. In an effort to stop further spread, in 1998 the Canadian government paid New Brunswick fish farmers more than $6 million to kill one-third of the province's total production. In early 2000, Eric Anderson, a professor of biochemistry and molecular biology at the University of Maine, warned that the virus might soon infect the aquaculture industry of New England, and that is exactly what happened. In July 2001, a single salmon infected with ISAV was caught in a trap in the Penobscot River in Maine and quickly quarantined, but it was too late. By September, the virus had spread throughout New England, and Maine fish farmers were forced to kill more than 900,000 salmon in an attempt to stop the spread of the deadly virus. Transmitted initially by the sea louse, a small marine crustacean that attacks a salmon's protective mucus, scales, and skin, infectious salmon anemia is highly contagious and incurable, causing massive internal bleeding and death.

In January 2002, 1.5 million farm-raised salmon (out of a state total of 30 million) were slaughtered in Maine to fight the spread of a virus infecting stocks in Cobscook Bay and threatening to spread. According to an article by John Richardson in the *Portland* (Maine) *Press Herald,* the shutdown was to be only temporary, but the fish kill could become a grim metaphor for Maine's aquaculture industry, which is fighting for its young life:

> Salmon aquaculture in Maine is under attack from all directions, with one crisis feeding off another. Infectious salmon anemia spread last year from Canada to Cobscook Bay, where more than half of Maine's salmon are raised.... Farmers in Lubec and Eastport killed one million fish by December 2001 to try to slow the spread of the virus. The U.S. Agriculture Department gave the industry $16.6 million over the next two years, to kill the remaining 1.5 million fish and clean out the bay. Most of the fish were too small to be processed into marketable fillets and are being turned into animal feed or fertilizer.

Until recently, the mechanism for the spread of ISAV over large geographic areas was not known, but a recent article in *Emerging Infectious Diseases* indicates that it can be transported in the ships that move fish between sites (Murray, Smith, and Stagg 2002). The authors cite the role of

ships in the introduction and spread of the Black Death in fourteenth-century Europe as well as the huge numbers of bacteria, including the agent of cholera (*Vibrio cholerae*), that have been detected in the ballast water of ships.* In Scotland and Norway, "well-boats," which contain massive tanks filled with live fish in water, have been identified more specifically as carriers of ISAV. The salmon die when the virus is introduced with the water; but it is not only fish that are at risk. The authors conclude, "Diseases potentially spread by shipping include waterborne diseases of humans such as cholera and potential viral zoonoses [naturally occurring viruses]."

To date, ISAV has not been reported in wild populations, but the Atlantic salmon, already classified as an endangered species, would be vulnerable to infection by occasional escapees from floating cages. Canada has 15 million farm-raised salmon, compared with 150,000 wild ones. The disease is still a problem for Norway's Atlantic salmon industry and continues to reduce production. Scotland, Canada, and the Faroe Islands have all been affected. Because the Atlantic salmon is such a popular subject for aquaculture worldwide, fish farms have been established far from the fish's nominal home ocean. For example, salmon farming is now well established in Tasmania, earning approximately $100 million (Australian dollars) in 2001. An outbreak of ISAV in Tasmanian fish farms would cause massive economic losses for the island state.

While natural populations are declining, the Atlantic salmon-farming industry continues to increase exponentially. Private aquaculture companies have explored several rearing options for Atlantic salmon, ranging from land-based freshwater rearing facilities to sea ranching and sea-cage rearing. In eastern Maine and the Maritime Provinces of Canada, companies typically rear fish to the smolt stage in private freshwater facilities, transfer them into anchored net pens or sea cages, feed them to accelerate growth, and then harvest the fish when they reach market size. In the northwestern Atlantic, 62 percent of salmon-farming production is based in Canada, with 99.4 percent of that in the Maritimes and 0.6 percent in Newfoundland. The balance occurs in eastern Maine. Production at these facilities and in sea-cage areas has grown enormously: by 1998, there were at least 35 freshwater smolt-rearing facilities and 124 marine production facilities in eastern North America. Since the first experimental harvest of Atlantic salmon in 1979 of 6

*Ballast is the additional weight a ship carries to give it stability. In older vessels, ballast sometimes consisted of iron bars, stone, or gravel stowed below, but more recently, ships flood certain designated holds with seawater because it can easily be taken on and discharged.

tons, the mariculture industry in eastern North America has grown to produce more than 32,000 tons annually since 1997. In Maine, production has exceeded 10,000 tons each year since 1995.

Large-scale salmon farming is practiced in Norway, Scotland, Finland, British Columbia, Iceland, Alaska, Italy, New Zealand, Australia, Japan, the Philippines, India, France, Bangladesh, Thailand, and Indonesia, and wherever it exists, there is controversy. Fish inevitably escape from open-water pens, especially during storm conditions. In some incidents, tens of thousands of farmed fish have escaped into surrounding waters. When fish escape from farms and survive in large numbers or establish their own breeding populations, they will compete with wild salmon. Efforts to secure facilities against these accidents may reduce the size and number of releases, but is unlikely to stop them altogether. If the escaped salmon are the same species as the wild salmon (e.g., Atlantic salmon grown in the Atlantic), there is the possibility of interbreeding between farmed and wild fish. Such interbreeding can significantly alter the genetics of the salmon population. Genetically engineered salmon in sea-cage farms—a distinct possibility in the near future—adds another layer of concern with respect to interactions with wild populations. If interbreeding were to occur as a result of escapes, such genes could be incorporated into the wild gene pool and possibly diminish the vigor of the wild population. According to Rosamond Naylor, Susan Williams, and Donald Strong (2001), "up to 40% of Atlantic salmon caught in the North Atlantic and more than 90% caught in the Baltic Sea are of farmed origin. More than a half-million Atlantic salmon escaped on the West Coast of North America between 1987 and 1997; they have been found in 77 British Columbian rivers and are spawning in some locations. In the New Brunswick–Maine region, farmed escapees vastly outnumber wild salmon in some spawning rivers."

Now there are even Atlantic salmon in the Pacific. *Salmo salar* has been farmed in Washington State since 1982 and in British Columbia since 1985, according to research conducted by Skip McKinnell and colleagues (1997). By 1995, more than 10,000 Atlantic salmon had been caught in the North Pacific out of a total of 140,000 that had escaped from aquaculture facilities in British Columbia. The majority were caught in the Johnstone Strait area, where most of the salmon farms are located. On July 2, 1996, high tidal flows destroyed seven of every ten sea cages near Cypress Island, Washington, releasing more than 100,000 Atlantic salmon into the sea. Over the remainder of the summer, many of the escapees were caught in the Strait of Juan de Fuca, at the southern tip of Vancouver Island. A single specimen was caught in a bottom

trawl in the Bering Sea in September 1997 (Brodeur and Busby 1998). "Without improvement in cage design, maintenance and farming procedures to improve containment," wrote McKinnell and colleagues, "the abundance of Atlantic salmon escapees is likely to expand if the industry is allowed to expand." Atlantic salmon roaming free in the North Pacific is but another element in the ecological chaos promulgated by the ignorance and carelessness of the fish farmers.

In the spring of 2002, an estimated 100,000 farmed salmon escaped from pens in the Orkney Islands off the northern coast of Scotland, raising fears that the escaped fish would overwhelm the gene pools of wild fish. In an article published in *Nature* on April 11, 2002, Natasha McDowell commented: "The offspring of farmed fish, some data suggest, are unable to complete the heroic salmon runs by which the natural species navigate between spawning grounds inland and breeding grounds in the ocean. Critics say that, together with the rampant transmission of lice and disease from fish farms to natural stocks, the result is threatening the very survival of natural salmon runs in countries such as Scotland, Canada, and Norway." Studies show that the mixing of farmed and wild salmon populations halves the differences between the two stocks every ten generations, meaning that it is only a matter of time before the wild salmon disappears entirely. Farmed salmon now pose more of a threat to wild ones than any fishermen ever could.

A special report on transgenic salmon was published in *New Scientist* in September 2002. Philip Cohen wrote: "A fierce debate still rages about the effects of releasing various genetically modified organisms. But most scientists and campaigners agree on one thing: GM [genetically modified] fish could create havoc if they escaped and interbred with their wild cousins, or outcompeted native species." Aqua Bounty Farms Inc., a company based in Waltham, Massachusetts, has already engineered fast-growing fish by inserting growth hormone genes into the fertilized eggs of salmon, trout, and arctic char, an intervention that causes the hormone to be continuously "switched on." The salmon reach market size in eighteen months rather than the normal thirty-six, and, according to Aqua Bounty's Web site, "the commercial advantage of this subtle genetic modification is that the fish grow at rates comparable to that of the other competitive types of livestock such as chicken or pigs." William Muir and Richard Howard (1999) identified another possibly disastrous result of producing transgenic organisms. "The transgene," they wrote, "though rare, can spread in a natural population. . . . A transgene introduced into a natural population by a small number of transgenic fish will spread as a result of enhanced mating advantage, but the reduced viability of offspring will cause eventual local extinction of both populations."

In early September 2002, Cohen reported, "Britain's Agriculture and Environment Biotechnology Commission (AEBC) called for a complete ban on GM fish-farming in pens open to natural waterways until there are 'watertight' technologies for preventing fish from escaping and breeding." Aqua Bounty's answer was to further modify the fish to make them all sterile females so they could not reproduce at all, regardless of whether they escaped from the pens.* "Then there's the possibility of human error or just plain stupidity," wrote Cohen. "In Washington state and Oregon, for example, some breeding stations for grass carp were built in flood-prone regions, allowing fertile grass carp to escape during floods." One answer to the problem seems to be raising the fish in closed systems, with a gauntlet of barriers to keep them from escaping. But this would be so much more expensive than floating pens that the ecologically responsible companies would be unable to compete with companies in Chile, Tasmania, and Argentina, and thus their profits—the beating heart of fish farming—would be substantially reduced.

Like many other people, Anne Kapuscinski is concerned about genetically engineered fish. As founding director of the University of Minnesota's Institute for Social, Economic and Ecological Sustainability (ISEES), she has produced the first set of environmental safety guidelines for research on this delicate subject. She wants to see that proper guidelines are followed, mostly to prevent genetically engineered salmon from escaping and interbreeding with wild salmon, which might result in corruption of the wild stock, leading to population declines or even extinction. Introduction of genetically engineered fish into the wild population could also produce a non-native exotic population, the long-term results of which would be unpredictable and maybe even catastrophic to the remaining wild salmon. Quoted in Erik Stokstad's 2002 article in *Science*, Kapuscinski said the only way to keep transgenic fish from interacting with wild populations is to have multiple barriers, such as sterility plus confinement on land.

In a remarkable display of unity and ecological sensitivity, 200 chefs, grocers, and seafood distributors across the United States have announced that they will not purchase genetically altered fish. According to an article published in the *New York Times* on September 18, 2002, "the campaign says it is concerned that if genetically altered salmon are approved by the Food and Drug Administration, they could escape from the pens in which they are raised and interbreed with wild salmon, endangering some species." The author, Marian Burros, points out that one-third of all fish consumed in the United States is farmed, but farmed fish are not necessarily genetically modified fish. The article continues: "Aqua Bounty is also growing transgenic arctic char and trout. Around the world, there are at least 20 fish species that have been genetically engineered. China is raising transgenic carp, and Cuba is raising transgenic tilapia. It is not clear whether any of this fish is being sold." (Stokstad noted in his 2002 *Science* article that the Cuban group—the Center for Genetic Engineering and Biotechnology in Havana—was "a few years away from commercializing the fish.")

Farmed salmon are fed meal and oils from wild-caught fish. Each pound of salmon produced requires at least three pounds of wild-caught fish, challenging the presumption that fish farming necessarily reduces commercial fishing pressure. In fact, there is a net loss of protein in the marine ecosystem as a whole when wild catch is converted into meal for aquaculture consumption. Pens full of salmon produce large amounts of waste—both excrement and unconsumed feed. This may result in unfavorable water quality conditions (such as high nutrient levels and low levels of oxygen) detrimental to both the farmed fish and the natural ecosystem. It is also suspected that nutrients released from salmon farms stimulate microalgal blooms, but proof is lacking because little research has been done. The densely packed conditions in pens promote disease, a common problem in most salmon farms. Furthermore, transmittal of disease from farmed salmon to wild populations has been documented, and the potential effects are serious. Although antibiotics are used to treat some diseases, the potential effects of antibiotic-resistant bacteria on human health are of concern. There has been an emphasis on developing vaccines to prevent specific diseases in order to reduce the need for antibiotics.

In some areas, landowners have opposed the siting of salmon aquaculture facilities near residential shorelines because they are unsightly and odoriferous and they interfere with the natural setting of the seascape. The density of

*Although not mentioned in Cohen's report, this is precisely the method employed by the scientists in Michael Crichton's 1990 novel *Jurassic Park* to ensure that the genetically cloned dinosaurs would not reproduce. As Rob DeSalle and David Lindley noted in *The Science of Jurassic Park and The Lost World* (1997), "The explanation, as Alan Grant [the dinosaur paleontologist in the novel] finally figures out, is that dinosaurs with bits of frog DNA in their genomes can change sex; females can become males because of some environmental influence." The pseudoscience of *Jurassic Park* should not be used to denounce the genetic modifications suggested by Aqua Bounty, but there certainly is an eerie coincidence. In the novel, the dinosaurs overcame the restrictions implanted in their genes and ran wild.

salmon in farms is variable, but the farmer is motivated to pack them in at high densities to increase profits. This exacerbates the problems of pollution and disease and places stress on the fish, which leads to an inferior product. The siting of salmon farms is often problematic, particularly if it does not adequately take into account the proximity to wild salmon migration routes, water flow and circulation patterns, the fate of waste materials, the number of facilities already in an area, and aesthetic concerns.

A salmon is a salmon is a salmon, right? Not exactly. Atlantic salmon live (mostly) in the Atlantic, but there are six species of endemic Pacific salmon: chinook (*Oncorhynchus tshawytscha*); coho (*O. kisutch*); sockeye (*O. nerka*); pink (*O. gorbuscha*); chum (*O. keta*); and cherry (*O. masou*). All occur on both sides of the Pacific Ocean except for the cherry salmon, which is found only off the coast of Japan. All are popular game fishes, and all are commercially fished in great quantities. Like their Atlantic counterparts, Pacific salmon are anadromous, breeding in fresh water, maturing at sea, and then returning to their hatching place to spawn. Pacific salmon species spawn only once and then deteriorate and die. In the process of ascending their natal streams, they undergo drastic physical modifications during which their jaws extend into hooks, their backs become humped, and their flesh and internal organs turn to mush. Even as they become weaker and weaker, they fight their way upstream, often leaping up waterfalls and traversing rapids to get where they are going. When females arrive at their nesting sites, they dig holes in the gravel with their tails and lay their eggs, which are then fertilized by the males. After a period of time ranging from a few days to several years (depending on the species), the young make their way to the sea. In California, Oregon, Washington, and Idaho, the long history of overfishing, the damming of the rivers up which the salmon must swim, and the destruction of breeding streams by timber interests have driven many populations of Pacific salmon to the edge of extinction, and all other Pacific salmon populations except those that breed in Alaska are considered endangered.

While populations of North Atlantic wild salmon have plummeted, more than 100 local populations in the eastern Pacific have disappeared. Salmon are extinct in 40 percent of the rivers where they once spawned along the Pacific coast of North America. The potential for interactions with farmed fish and transmission of disease from farmed to wild salmon is especially threatening in the context of these declines. Governments typically encourage aquaculture because it is viewed as economic development, but this often leads to the intensive, large-scale farming methods most often associated with environmental damage. Because the costs of this damage are not borne by the

industry, nor are the value of ecosystem services factored into the cost of production, there is no pressure on the industry to operate in environmentally sound ways.

Although farmed salmon accounts for some 40 percent of Scotland's food exports and is worth £650 million to its economy, the tide of public opinion in that country is turning against sea-cage salmon farming as people become aware of its environmental, economic, and social downsides. In May 1998, a salmon farm at Loch Nevis on the western coast of Scotland reported its suspicions of an outbreak of infectious salmon anemia. The suspicions were confirmed, and by early 2002 the disease had spread to an additional fifteen farms, not only on the Scottish mainland but also on Skye and Shetland. A 2001 report by Friends of the Earth Scotland (FoE Scotland) paints a picture of a vast food industry driven by multinational corporations, heavily dependent on chemicals—many of them deadly—and heavily dependent on public relations and government protection for its continued expansion. FoE Scotland maintains that the "alarming rise in the incidence of algal blooms and shellfish poisoning events have cast doubts on the compatibility of the two activities" (salmon farming and shellfish farming) and claims that salmon farming is compromising the high quality of water on Scotland's western coast. The report says it is not surprising that questions are now being asked, pointing to a 1999 calculation that for each ton of salmon produced, approximately 100 kilograms of nitrogenous compounds, including ammonia, were released into the sea.

The coincidence between the areas of the three main shellfish poisonings and the high density of salmon farms is remarkable. The report goes on to say that Scottish salmon farming is dominated by multinational companies driven by short-term economic priorities rather than long-term interest in the future of Scotland's environment. The estimated waste discharged from 340 Scottish fish farms in 2000, says the report, was equivalent to almost twice the annual sewage discharged by Scotland's entire human population. Wherever salmon are farmed, the neighbors are beginning to worry about the economic, environmental, and physical costs. Aquaculture may indeed provide plentiful salmon for salmon-hungry nations,* but the means by which this is accomplished are more than a little questionable.

---

*Salmon is one of the foods that supplies the "good" type of cholesterol, high-density lipoprotein (HDL). The "bad" cholesterol (low-density lipoprotein, or LDL) is believed to be responsible for clogging blood vessels, and HDL is reputed to "exile" the LDL to the liver, where it is destroyed. In August 2002, in an article in *New Scientist* titled "The Happy Fat," Meredith Small identified some ways in which the omega-3 fatty acids *(continued)*

As currently practiced, aquaculture has not provided a viable answer to the world's decreasing stocks of food fish. With invasive fishing practices adversely affecting diminishing populations, it seems only a matter of time before fisheries around the world will crash. Some of these vanishing species—particularly the cod and the salmon—were once paradigms of plentitude. From the mighty tuna to the humble sea horse, from the noble swordfish to the ignoble menhaden, from the menacing grey nurse shark to the harmless orange roughy, species whose numbers we once took for granted are disappearing at an alarming rate. "Give a man a fish," the saying goes, "and you help him for a day. Teach him to fish, and you help him for his whole life." Teach him not to fish so wastefully, and you might help the world.

---

found in fishes such as salmon and menhaden (as well as in flaxseeds, walnuts, and olive oil) are being investigated as an antidote to depression (Hibbein 1998) and even as a possible inhibitor of prostate cancer (Terry et al. 2001). In a 2002 *Newsweek* article about salmon, Jerry Adler wrote, "Even people that don't like salmon know by now that it contains omega-3 fatty acids, which are believed to protect against cancer and cardiovascular disease."

~ 3 ~

THE PLIGHT OF THE SEA TURTLES

> Nearly all sea turtle biologists, sooner or later, become turtle conservationists, at least by sympathy, and frequently as a major part of their professional activities. The reasons for this metamorphosis are clear enough; those who work in the field with sea turtles are inevitably distressed as the animals they study are slaughtered, often while actually on the nesting beach. The eggs too are all too frequently raided, either by man himself or by predators that in many cases have been introduced to the system by man or allowed to form unnaturally high population densities as a result of man's tinkering with ecological balances.
>
> —Peter Pritchard, "The Conservation of Sea Turtles," 1980

Modern sea turtles are presumed to have descended from land-based reptiles that returned to the sea, but hardly any transitional forms have been identified. There are fossil land turtles with columnar legs and feet with claws, and fossil sea turtles with flippers instead, but nothing that looks like a semi-aquatic turtle. One view is that sea turtles never left the water at all and developed directly from amphibians or early reptiles in the ocean, but this seems less likely than the idea that they had terrestrial origins. Robert Carroll, a specialist in the evolution of reptiles, wrote in 1988 that "no trace of earlier or more primitive turtles has been described, although turtle shells are easily fossilized and even small pieces are easily recognized. Apparently the earlier stages in the evolution of the shell occurred very rapidly or took place in an environment or part of the world where preservation and subsequent discovery were unlikely." Turtles are not dinosaurs; they are not descended from the first dinosaurs, and they have a shell, which no dinosaur ever had. Turtles represent a separate group of vertebrates, and one of the oldest of all continuous vertebrate lineages, dating to the Middle Triassic period, about 230 million years ago. Of the living vertebrates, only sharks and bony fishes have a