OPEN OCEAN FISHERIES FOR LARGE PELAGIC SPECIES

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Introduction

Open-ocean fisheries for large pelagic species target relatively large organisms that spend most of their lives in offshore waters, usually within about 100–150 m of the surface. These large pelagic species include finfish, such as scombrids (tunas) (**Figure 1**), istiophorids (billfishes: spearfish, sailfish, and marlins), xiphiids (swordfish) (**Figure 2**), coryphaenids (mahimahi, or dolphinfish), and elasmobranchs (sharks), and also cetaceans (whales, dolphins, and porpoises). Many of these species do not spend their entire lives in the open ocean but, as their biological needs dictate, make sporadic forays into the coastal zone. Therefore, although they are captured mostly in the open ocean, they are sometimes taken near shore.

This article concentrates on fisheries for tunas and billfishes, because they account for by far the greatest proportion of the total catch of all large pelagic species. (In this article catch includes fish discarded at sea, but landings do not.) The various types of fishing gear and vessels used to catch large pelagics, and the magnitude of those catches, are reviewed. Because of their great size, speed, and stamina, these large pelagics are much sought after by recreational fishers, so sportfishing is also included in this article. Fisheries for sharks and other large pelagics are discussed only briefly, and whales and whaling are discussed elsewhere.

The Animals

Tunas, and many of the billfishes, comprise most of the world's catch of large pelagic species. They have many characteristics that set them apart from most other types of fishes and which contribute to their nomadic lifestyle. They have very high metabolic rates, resulting in high energy and oxygen demands. Tunas must swim constantly in order to pass enough water over their gills to meet this high demand for oxygen. Unlike most other fishes they cannot pump water over their gills, so if they stopped swimming they would suffocate, and they would also sink because they are denser than the water that surrounds them. They possess highly developed circulatory systems that allow them to retain or dissipate heat as needed for efficient operation of their nervous, digestive, and locomotor systems, and are capable of maintaining their body temperature up to 15°C above ambient. Their fusiform shape, highly developed swimming muscles, and crescent-shaped tail, which provides maximum forward thrust, enable them to swim at extraordinary speeds. Many of the other large pelagic species have a similar propensity for travel, but their adaptations to a nomadic life style are different.

Tuna tend to form large schools, which makes it relatively easy to locate and catch them.

Methods of Catching the Fish

Humans have most likely been fishing since the first days they walked the earth. The first marine organisms caught were probably taken by hand from

Figure 1 Yellowfin tuna (*Thunnus albacares*) (source: Inter-American Tropical Tuna Commission).

Figure 2 Swordfish (*Xiphias gladius*) (source: Inter-American Tropical Tuna Commission).

tidepools and beaches. As their fishing skills developed, early humans fashioned hooks, harpoons, traps, and nets to capture their prey. Archaeological evidence indicates that ancient man harvested large pelagic species: skeletal remains found in caves indicate that giant Atlantic bluefin (*Thunnus thynnus*) were caught near modern-day Sweden more than 6000 years ago, and similar evidence shows that giant Pacific bluefin (*Thunnus orientalis*), weighing more than 250 kg, were taken by native Americans in the region between the southern Queen Charlotte Islands, British Columbia, and Cape Flattery, Washington, more than 5000 years ago. Just how early humans caught these giant fish is uncertain, but probably harpoons or handlines with baited hooks were used.

As civilizations developed, so did trade in agricultural and natural resource products, including fish. Historical evidence indicates that nearly 3000 years ago the Phoenicians salted and dried tuna that they had caught, and traded it throughout the Mediterranean region.

Harpoons

The harpoon is simply a spear modified for fishing by attaching a line and buoy for retrieving both spear and prey. Harpoons have been used since early times for capturing large pelagics, but were perfected for whaling. For many years harpoons were the primary means of capturing swordfish, which have a tendency to bask at the surface of the ocean, and they are still used today in many parts of the world for this purpose. In recent years they have been replaced by more efficient forms of fishing, but harpoon-caught swordfish still command premium prices, apparently because of their better quality. Some marlin (*Makaira* spp. and *Tetrapturus* spp.) and giant bluefin tuna are also taken with harpoons. Vessels used for harpoon fishing have a long, narrow platform projecting from the bow, on which the harpooner stands, and from which vantage point there is a better chance of harpooning the fish before it is aware of the approach of the vessel.

Traps

Traps have been used extensively to catch tunas throughout the Mediterranean right up to the present time. The *almadraba*, a type of trap net used since the time of the Phoenicians, consists of corridors of netting, called leads, up to several kilometers long, up which migrating fish swim until they reach holding chambers, where they are harvested. Because the fish need not be pursued, vessels are not required to catch the fish, but only to transport the catch from the traps to shore.

Hook and Line

Hand lines The simplest form of hook-and-line fishing is a single hook attached to a hand-held line. The hooks, which can be baited with live, dead, or artificial bait, are generally set from a vessel or floating platform. All types and sizes of vessels, propelled by engine, sail or paddles, are used today to capture large pelagic fishes in various areas of the world. Hand-line fisheries, although primitive and, in a commercial sense, inefficient, are nevertheless widespread, and often spectacular to observe. In one such fishery, in Ecuador, the fishermen, frequently father and son, set out to sea shortly after midnight in sail-powered dugout canoes about 6 m long. Once on the fishing grounds, a single hook, baited with a small fish, is trailed several meters behind the canoe. When a fish, frequently large yellowfin tuna (*Thunnus albacares*) or black marlin (*Makaira indica*), which can weigh up to several hundred kilos, is hooked, the sails are reefed and the fishermen attempt to bring it to the boat. The struggle can last several hours, and once the fish is brought alongside it is clubbed in order to immobilize it. If it is too large to lift into the canoe, the fishermen enter the water, swamp the canoe, and roll the fish into it. They then bail out the vessel, hoist sail, and head for shore and the fish market. Scenes such as these are repeated in many artisanal fisheries throughout the world, but at diminishing rates as motorized fiberglass skiffs replace traditional canoes.

Pole and line Pole-and-line fishing is used in many parts of the world to catch large pelagics, principally tunas. The technique, which was developed independently in several separate regions of the world, is similar to that used for handlines, with the difference that the hook and line are attached to the end of a pole, giving greater reach and better leverage.

In the South Pacific, such fishing is done from canoes (**Figure 3**) and small motorized vessels using lures traditionally made from seashells (**Figure 4**). In Japan, commercial pole-and-line fishing for skipjack (*Katsuwonus pelamis*), yellowfin, and bluefin tunas was common in coastal waters for many centuries. During the twentieth century the Japanese developed larger pole-and-line vessels that were able to travel to all oceans of the world to fish for tunas. These vessels carry live bait in tanks of circulating sea water and crews of more than 25; they can freeze their catches and stay at sea for several

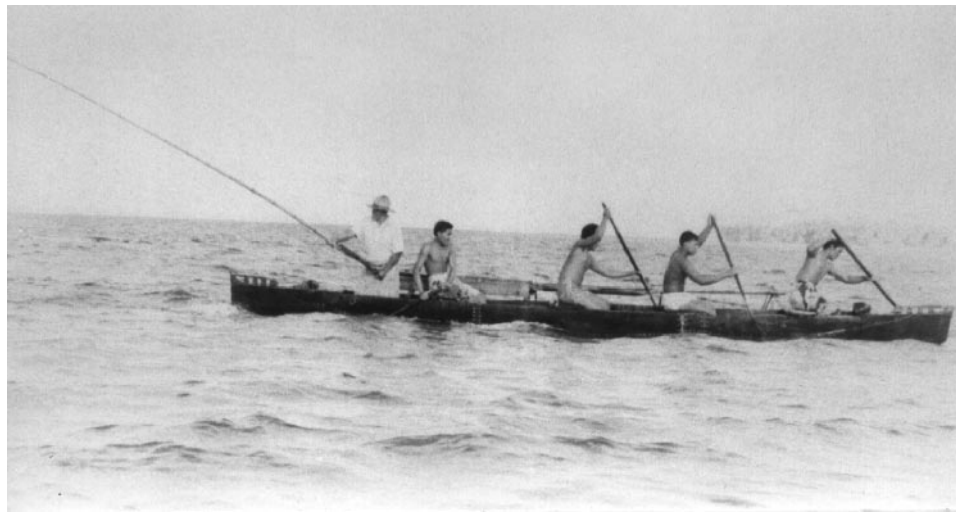

Figure 3 Pole-and-line fishing from a canoe in Tokelau (courtesy of Robert Gillette, Suva, Fiji).

months. Some now carry automated machine-operated poles; a single crewman can tend several poles at once, thereby increasing vessel efficiency.

In the Indian Ocean, the island nation of Maldives was 'built on the backs of fish,' as the majority of its people made their living or derived their sustenance from fishing. The major form of fishing is with poles and lines, targeting skipjack, yellowfin, and wahoo (*Acanthocybium solandri*), using small vessels originally powered by sail with compartments for live bait built into the hull through which water is circulated. This method of fishing, which uses both artificial and live bait and a hook of unique design, is distinctively different in detail from that of Japan.

In southern California, after the introduction of tuna canning in the early twentieth century, pole-and-line fishing was used to supply the growing demand for tuna. The first vessels were small, used ice to preserve their catch, and fished within a few days of port. As the demand for tuna grew, larger, longer-range boats were built. This was the origin of the 'tuna clipper,' pole-and-line vessels that could pack several hundred tons of tuna in refrigerated fish holds, carry large amounts of live bait, and stay at sea for many months; they plied the eastern Pacific between California and Chile. Typically a vessel would catch bait before putting to sea to search for tuna. On sighting a school, the 'chummer' would throw the chum, or bait, to bring the fish alongside the vessel, and fishermen standing in racks at water level on the port side and stern of the vessel would catch the fish, usually using artificial lures (**Figure 5**). Once a fish was hooked, the fisherman lifted the pole, jerking the fish from the water and over his head. The pole would be stopped in the vertical position, and the fish would fall off the barbless hook onto the deck. If the school was feeding well, a fisherman could catch fish as quickly as he could get the hook into the water. If the

Figure 4 Pearl shell lure for catching large pelagic fish, from Tokelau (courtesy of Robert Gillette, Suva, Fiji).

Figure 5 Pole-and-line fishing from a baitboat in Ecuador (courtesy of Robert Olson, IATTC).

Figure 6 Catching a three-pole yellowfin tuna from a US baitboat (courtesy of Pete Foulger, Harbor Marine Supplies, San Diego).

chummer was successful in keeping a large school feeding alongside the boat, several tons could be taken in a short time. Because many fish are too large to be lifted by one fisherman on a single pole, a single hook might be attached to two, three and even four poles (**Figure 6**). For economic reasons, pole-and-line fishing is no longer predominant in the eastern Pacific, and only a few vessels operate on a regular basis.

During the 1950s pole-and-line fishing was introduced off tropical West Africa by the French and Spanish; it is still practiced there today, but to a limited extent.

Longlines Longlines, as the name implies, consist of a long mainline, kept afloat by buoys, from which a number of branch lines, each terminating with a hook, are suspended (**Figure 7**). Longlines for large pelagics can have a mainline up to 125 km long, with as many as 500 buoys and 2500 hooks, and can take 8–12 h to set or retrieve. Longlines catch whatever fish happen to take the hook; a single set can capture several species of tunas, billfishes, and sharks. The distance between the buoys determines the depth of the hooks; they are normally suspended at depths between 100 and 150 m, where the water is cooler and large tunas are most likely to be. These large tunas, especially bigeye (*Thunnus obesus*), command high prices in the *sashimi* markets of Japan, and most of the larger longline fishing vessels of the world target this market.

Longline vessels vary in size. Small vessels use much shorter lines, and normally operate in coastal waters, whereas the larger vessels roam the oceans of the world in search of their prey and, supplied by tender vessels, can stay at sea for extended periods. Japanese vessels account for most of the longline catches, followed by Taiwanese and South Korean vessels.

Most billfishes are taken by longlines. During the last two decades longlining for swordfish has become very popular, and accounts for most of the landings of that species. Longline vessels targeting swordfish operate in the Atlantic, Pacific, and Indian Oceans.

Trolling In this method of fishing a number of lines to which lures are attached are towed from

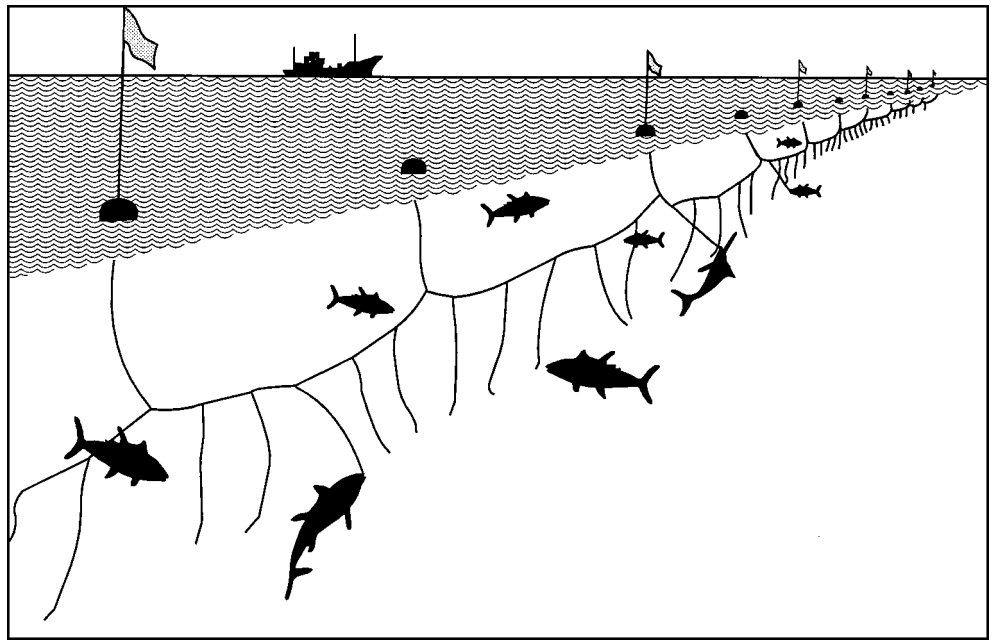

Figure 7 Diagrammatic sketch of longline fishing.

outrigger poles and from the stern of a vessel. When fishing for large pelagics, the lures are towed at a speed of several knots. Most troll fisheries target albacore tuna (*Thunnus alalunga*), but many other species, including bluefin, yellowfin, and wahoo, are also caught. This form of fishing is used throughout the world, usually from vessels of less than 20 m in length.

Nets

Gill nets Gill nets consist of a panel of netting, usually synthetic, held vertically in the water by floats along its upper edge and weights along its lower edge, in which fish become enmeshed when they attempt to swim through. The drift gill nets used to capture large pelagics in the open ocean consist of continuous series of such panels, sometimes more than 100 km long, and are very effective in catching the target species, but they also catch birds, sea turtles, and marine mammals. Because of these by-catches, and the fact that nets lost or abandoned at sea continue to catch fish ('ghost fishing'), in the late 1980s the United Nations recommended banning the use of drift gill nets over 2.5 km long on the high seas. However, such nets are still used within the Exclusive Economic Zones (EEZs) of some nations, particularly for catching swordfish and sharks.

Purse seines Purse seiners catch more tuna than all other types of vessels combined. Like a gill net, a purse seine is set vertically in the water, with floats attached to the upper edge; along the lower edge is a chain, for weight, and a series of rings, through which the pursing cable passes. Purse seines are constructed of heavy webbing, can be up to 1.5 km long and 150 m deep. When a school of tuna is sighted a large skiff, to which one end of the net is attached, is released from the stern of the fishing vessel (**Figure 8**). The vessel circles the school, paying out net, until it reaches the skiff, closing the circle. The pursing cable is winched aboard the vessel, closing the bottom of the net and trapping the fish; the net is then hauled back on board, concentrating the catch for loading. Purse-seine vessels fishing for large pelagics range from about 25 to 115 m in length, and can carry up to 3000 tonnes of frozen fish, but most such vessels targeting the two principal species caught by this fishery, skipjack and yellowfin tuna, average about 75 m and 1200 tonnes (**Figure 9**). These vessels are capable of fishing all the oceans of the world and staying at sea for several months. Many carry helicopters for locating fish and directing the vessel while the net is being set, and are also equipped with sophisticated electronic devices such as specialized radar for detecting flocks of birds at great distances, current meters, satellite communication gear for receiving data on weather and ocean conditions, global positioning systems, and a variety of sonars for detecting schools of fish underwater. Purse seiners make three types of sets: on free-swimming schools of tuna, on schools associated with flotsam such as parts of trees, and on schools associated with marine mammals, mostly dolphins. Because the amount of flotsam is limited, fishermen

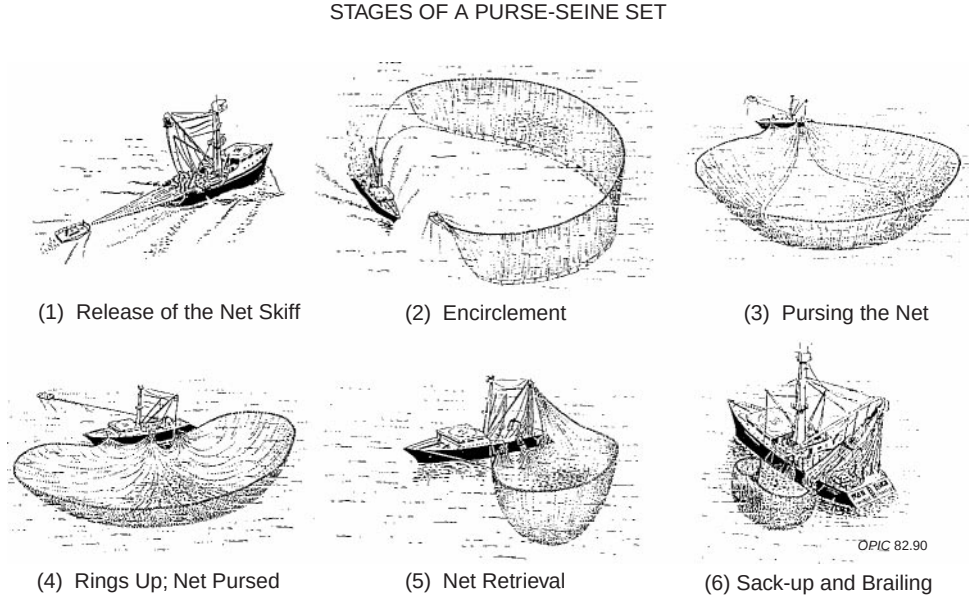

Figure 8 Setting a purse-seine tuna net. (Reproduced with permission from Stequert and Marsac, 1991.)

Figure 9 A modern purse-seine vessel of 1200 tonnes capacity; note the helicopter on board (courtesy of Dave Bratten, Inter-American Tropical Tuna Commission).

build and deploy fish-aggregating devices (FADs) to attract fish. FADs are usually fitted with electronic transmitters which allow the vessel to locate them easily.

Trawls A trawl is a conical net, towed through the water by a trawler vessel, with the apex, or bag end, at the rear. The forward end of the net is held open, and long reaches of net, or arms, serve to guide the fish toward the bag end. Most trawls are used to fish on or near the seabed, but recently pelagic trawls have been used to fish for tuna, primarily albacore.

Catches

The annual world landings of marine fish is about 85 Mt (million tonnes). Of this, approximately 4 Mt are large pelagics (**Figure 10**). The principal market species of tuna – skipjack, yellowfin, bigeye, albacore, and bluefin – account for about 3 Mt, but their economic value is out of all proportion to the volume of their landings. In fact, some species of tuna are among the most valuable fish: a single 300-kg bluefin tuna can sell for over US$ 75 000 in the Japanese *sashimi* market.

About 65% of the world landings of all large pelagic species is taken from the Pacific Ocean, 20% from the Indian Ocean, and 15% from the Atlantic Ocean. Skipjack represents the greatest proportion in all three oceans, constituting about 50% of the total landings of the principal market species of tuna; yellowfin accounts for nearly 35%, and bigeye, albacore, and bluefin make up the rest.

The largest fishery for tuna in the world is in the western Pacific, which produces about 35% of the

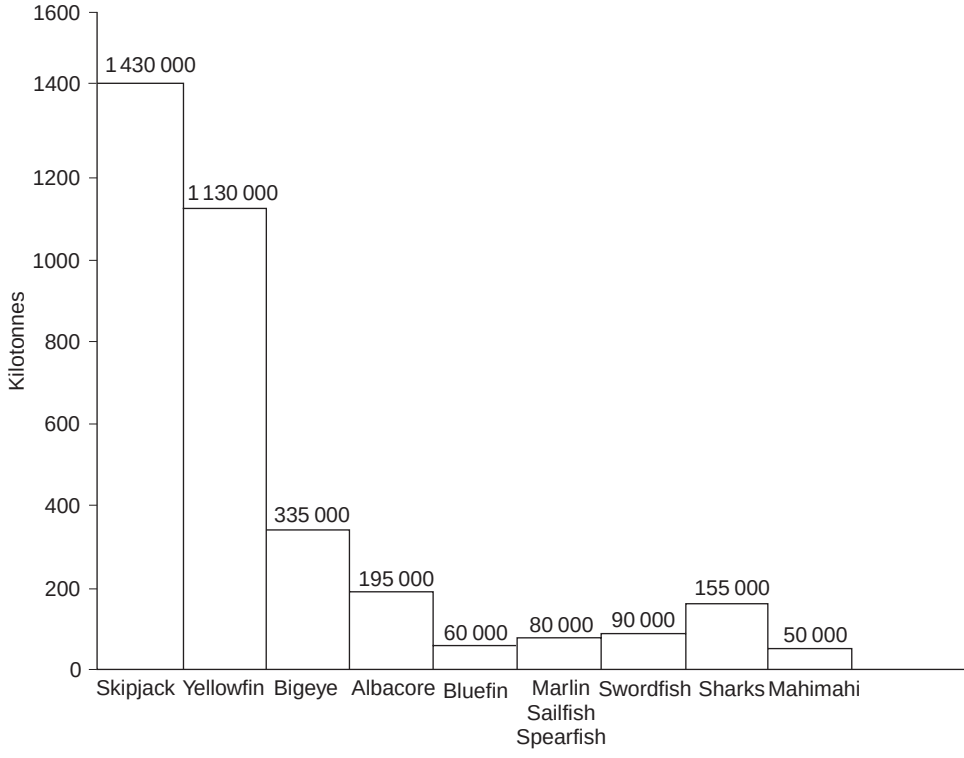

Figure 10 Recent world landings of certain large pelagic species. (Data modified from the 1996 and 1997 FAO Yearbooks of Fishery Statistics.)

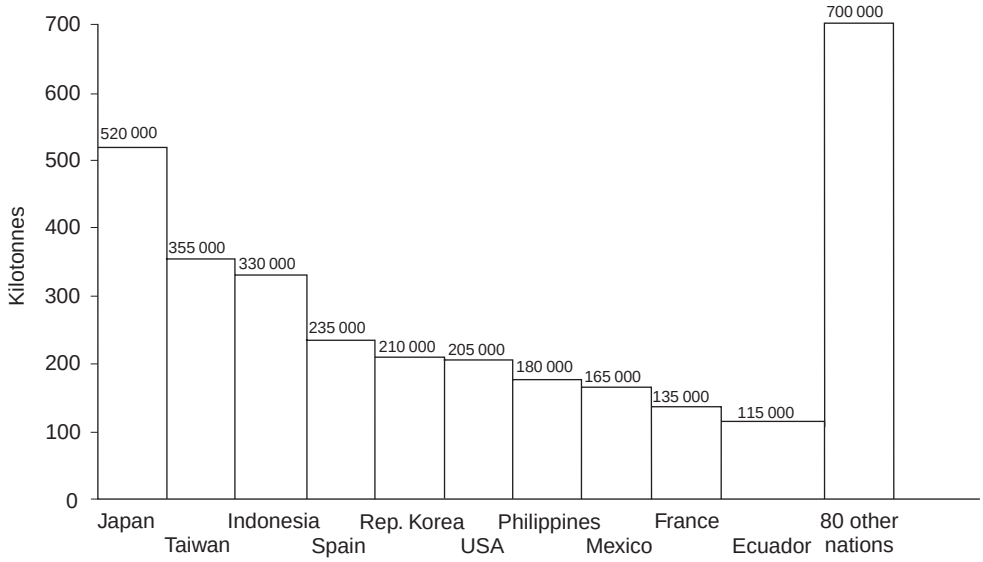

Figure 11 Recent world landings of principal market species of tunas, ranked by country of capture. (Data modified from the 1996 and 1997 FAO Yearbooks of Fishery Statistics.)

world landings, mostly skipjack and yellowfin. Other large fisheries are in the eastern Pacific, the western Indian Ocean, and the eastern Atlantic. In all of these fisheries vessels of many nations fish side by side, using all types of fishing gear. Prior to about 1975 most tuna-fishing vessels were longliners or baitboats, but now purse seiners predominate.

In terms of landings, Japan is the leader, with 20% of the world total, followed by Taiwan, Indonesia, Spain, South Korea, the United States, the Philippines, Mexico, France, and Ecuador (**Figure 11**). These ten nations account for 80% of the total landings, the remainder being shared by about 80 other nations. Japan is also the principal consumer of large pelagics, accounting for about 30% of the world total, followed by Western Europe with about 25% and the United States with about 20%.

In recent years the annual landings of billfish have been about 170 000 tonnes, about half of it swordfish. About 160 000 tonnes of sharks are landed annually, but of this total probably less than 20% are pelagic species. The actual catches are almost certainly higher, but many sharks (mostly blue sharks, *Prionace glauca*) are caught only for their fins and are not reflected in world catch statistics. Japan, once again, accounts for the highest landings of billfish and, with the exception of swordfish, also consumes most of the billfish caught. Both the catch and consumption of sharks are widespread among many nations. The annual commercial landings of the common dolphinfish (*Coryphaena hippurus*) are less than 50 000 tons.

Utilization

Although tuna was first canned in Europe in the mid-1800s, prior to the twentieth century nearly all tuna and other large pelagics were eaten either fresh, salted or dried, or used to make sauce. In 1903 tuna canning was introduced to the United States in San Pedro, California. The canned product was well received by American consumers, increasing the demand for fish and ushering in the modern tuna industry. Since then the consumption of tuna has steadily increased, and today about 60% of the world landings, nearly all caught by purse seiners, is canned, yielding some 150 million cases annually. The United States consumes almost 50 million cases, Western Europe just over 50 million cases, and the remainder is consumed mostly in Asia and Latin America. Second in importance is fresh tuna, for consumption either raw, as *sashimi*, mostly in Japan, or grilled. *Katsuobushi*, lightly fermented, smoked and dried skipjack tuna, used as a condiment in Japanese cuisine, is another important use of tuna.

Of the billfishes, swordfish is consumed mostly as steaks, whereas blue marlin (*Makaira* spp.) and striped marlin (*Tetrapturus audax*) are frequently consumed fresh or smoked. Much of the catch of spearfish (*Tetrapturus* spp.) and sailfish (*Istiophorus platypterus*) is processed into imitation shrimp and crab, and other products.

With the exception of a few species, sharks are generally held in lower esteem as a food fish, and command much lower prices than tunas and some of the billfish. In many cases only the fins, which fetch high prices in Asian markets as an ingredient for soup, are utilized, the remainder of the animal being discarded.

Prior to World War II some species of sharks were heavily fished because their livers were high in certain vitamins, but with the development of synthetic vitamins this use of sharks has declined. Currently, the demand for some sharks is increasing because of the purported curative properties of their cartilage.

Most of the dolphinfish landed is consumed in the United States, fresh or fresh/frozen.

Mariculture

Propagation of freshwater fish has been practiced for centuries, but it is only in recent times that the culture of marine fish (mariculture) has become important on a commercial scale. Over the last few years mariculture has contributed about 10% to the total annual landings of all marine fishes. The pelagic habitat, migratory nature, and large size of pelagic species make rearing them in captivity difficult, and only recently have scientists been able to spawn and rear tunas artificially. In Japan there has been limited success in spawning bluefin tuna in captivity, hatching the eggs, and rearing the young. At the Inter-American Tropical Tuna Commission's Achotines Laboratory in Panama, scientists have been able to spawn yellowfin tuna held in captivity in onshore tanks on a regular basis, and have also successfully reared the hatched eggs to the juvenile stage. It is anticipated that this research will eventually make it possible to complete the life cycle of yellowfin tuna in captivity, an essential precondition to rearing tuna commercially. In the meantime, attempts at what is known as bluefin ranching are being increasingly successful. This involves catching adult bluefin tuna and transporting them to pens in inshore areas, where they are held and fed until reaching a marketable size and condition. Because of the high value of bluefin in the *sashimi* market, ranching is a growing enterprise in many countries, including Australia, Croatia, Japan, Mexico and Spain.

Recreational Fishing

Recreational fishing for large pelagics has been important since the early 1900s, and became more so after it was popularized by writers such as Zane Gray and Ernest Hemingway. The most sought-after species are the larger ones, like marlins, sailfish, and bluefin and yellowfin tuna. It was originally mostly a sport for the wealthy, because of the high cost of fishing boats and access to areas where these species abound. More recently, however, fleets of charter vessels and party vessels, which take groups of recreational fishers for extended trips on the high seas in pursuit of large pelagic species at a reasonable cost, have become available. This, coupled with the lower cost of air travel, has brought big-game fishing within the grasp of many people, and recreational fishing has become an important component of the economy of a number of nations. However, this expansion of recreational fishing has brought it into conflict with commercial fishers, due primarily to competition for the same species, particularly marlins and bluefin tuna. Although there are no accurate estimates of how many fish the recreational fisheries take, the catches are small in comparison to commercial fisheries, but both the catches and the amount of money spent to make them are increasing.

Conservation of the Resource

Large pelagics are a renewable resource whose abundance can be profoundly influenced by human activities, particularly fishing. These activities have been steadily increasing as the demand for food and recreation from the sea increases, and landings of tunas and related species have increased tenfold since 1945. These increases have resulted in overfishing of some species, particularly bluefin tuna, swordfish, and some sharks. Many of the other species of large pelagics, with the notable exception of skipjack tuna, are currently fully, or nearly fully exploited, and sustained increased landings cannot be expected. Many of these other species are in urgent need of conservation if they are to be protected from overexploitation. Widespread concern over the status of some of these stocks has led to action by coalitions of chefs throughout the United States to boycott the use of swordfish in their restaurants, and attempts by public interest groups to include sharks and bluefin tuna as species covered by the Convention on International Trade in Endangered Species (CITES). This increased fishing has also caused problems for other marine species taken incidentally as by-catch with the species targeted by the fishery. These by-catch species are often of no value to the fishers, and are thrown back to the sea, dead. By-catches occur in most fisheries for large pelagic species, and it is important to determine their impact on the populations from which they are

taken and on the ecosystem to which they belong. A similar problem in some purse-seine fisheries for tuna, especially in the eastern Pacific, is the capture of dolphins. Many dolphins were killed in purse-seine nets between the inception of this type of fishing in the late 1950s and the early 1990s, but in recent years, thanks to the joint efforts of environmental organizations, the fishing industry, and governments, the mortality of dolphins caused by tuna fishing has been reduced to very low levels.

Populations of pelagic sharks, in addition to being heavily exploited for their flesh and/or fins, are also taken in large quantities as a by-catch in some fisheries. Because many species of sharks have low fecundity, are slow growing and later maturing, they are vulnerable to severe overexploitation which could lead to the collapse of some populations.

Because tunas and other large pelagic species are highly migratory, the vessels that fish for them roam the oceans of the world, and many nations are involved in their harvest, international cooperation is essential for effective conservation of these species. Article 64 of the United Nations Convention on the Law of the Sea calls on nations to work jointly through appropriate international bodies to manage and conserve such highly migratory species. There are currently four such bodies, the Inter-American Tropical Tuna Commission, the International Commission for the Conservation of Atlantic Tunas, the Commission for the Conservation of Southern Bluefin Tuna, and the Indian Ocean Tuna Commission, and negotiations for creating a similar body for the western and central Pacific are near completion. These bodies are responsible for coordinating and conducting scientific research and, on the basis of that research, making recommendations to governments for the conservation of the tunas and tuna-like species. As a result of their efforts conservation measures are in effect for many of the large pelagic species. Such measures can take a variety of forms, including catch quotas that limit the amount of fish that can be caught or landed, closed areas and seasons, limits on the size of fish that can be landed, and restrictions on the types and amounts of gear that can be used to catch fish. As fishing pressure continues to increase, there will be a need to expand such measures to other areas and species.

See also

Dynamics of Exploited Marine Fish Populations. Fishery Manipulation Through Stock Enhancement or Restoration. Marine Fishery Resources, Global State of. Pelagic Fishes.

Further Reading

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