5

Harvesting Methods and Fisheries Resources of the United States

The United States has one of the most diverse fauna of freshwater fishes and mussels of any temperature region of the world. Its vast freshwater, anadromous, and oceanic fisheries resources historically have supported extremely active commercial and recreational fisheries. Many of these resources have declined in abundance due to the exploitation that has been imposed on them and to changes in the condition of aquatic habitats caused by human land- and water-use activities. A great number of resources are depleted, in some instances to the point of extinction or near extinction, due to a wide variety of direct and indirect human influences.

This chapter provides an overview of harvest methods that have been used in various fisheries, and of the general types of fisheries resources that have been harvested or otherwise affected by humans.

HARVESTING METHODS IN FISHERIES

Most recreational fishing for fishes is accomplished by the use of hook and line or, in a few instances, gears such as dipnets—for example, in rainbow smelt fisheries. Recreational and commercial users of shellfishes may harvest nearshore mussels and clams with rakes or shovels or by hand, and species of crabs with small baited pots or traps. This section will not detail different hook and line or other methods of recreational users. Although traditional harvesting methods used by Native Americans or others in some subsistence fisheries (see Chapter 4), such as throw nets, fish wheels, and other gears, and some commercial methods such as harpooning are significant techniques in some fisheries, they will not be reviewed because they are not widely used. This section will focus on major gear types that are used in particularly large commercial fisheries or are used to harvest a wide variety of different fisheries resources.

Numerous types of gear and harvesting methods have been employed to harvest fisheries resources commercially. Many of these can land extremely large biomasses of fisheries resources within relatively limited amounts of time expended by participants in the fishery (for example, the 60-metric-ton catch of walleye pollock in one net haul of an ocean factory trawler shown in Figure 5.16). In addition, some types of gear harvest a wide variety of fishes and other resources that are not specifically being sought. For example, in the Gulf of Mexico shrimp fishery the biomass of organisms other than shrimp that are killed and discarded—the bycatch, or incidental catch—greatly exceeds the biomass of shrimp that the fishing effort is directed toward—the directed catch. Recreational fisheries can be managed with the expectation that a reasonable percentage of individuals that are returned to the water survive the capture experience. In many commercial fisheries, gears and methods do not allow this to occur. Very often, a captured fish is a dead fish whether it is kept or discarded. Thus the fisheries agency must understand the behavior of gears and the outcome of using particular methods in order to attempt to regulate the interaction between the resource and its user. Such characteristics of gears and methods can greatly influence the effectiveness of management strategies and regulations.

Hook and Line Gear

Hook and line capture is one of the oldest fishing techniques (Everhart et al. 1975). Longlines, also called trotlines or setlines, are left in the water and later retrieved (a passive capture method), whereas handlines, pole and lines, and trolling lines are fished actively under direct control of the harvester.

Longlines. Longline gear consists of baited hooks and leaders, also called gangions, that are attached in series to cables or ropes called mainlines that are left in the water to fish. Longlines used to harvest bottom fishes have an anchor, a buoy line, and float at each end of the mainline. Longlines used to harvest pelagic species—those that dwell in the water column rather than on the bottom—have buoy lines and floats, but these lines generally are not anchored (Everhart et al. 1975). The spacing of the leaders and hooks will vary according to species being sought. Ten-inch leaders may be spaced at 3- to 4-foot intervals in the Pacific sablefish fishery, whereas 3-foot-long leaders may be spaced as much as 30 feet apart in the Pacific halibut fishery (High 1989). The spacing of the gangions is related to the general distance that a baited hook must be from the nearest hooked fish to attract other fishes. Mainlines may stretch for several miles or more in length. After fishing, many longlines are retrieved by power winches. Some longline fisheries have become highly automated, with machines retrieving the mainline, removing fishes from hooks, removing old bait from hooks and then rebaiting them, and untangling twisted gangions.

Many types of marine pelagic and demersal bottom-dwelling fishes are taken in longline fisheries, including tunas, sharks, swordfish, sablefish, Pacific halibut, Pacific cod, reef fishes, and others (Joseph et al. 1988; High 1989; NOAA 1991).

Active Hook and Line Fishing. Handlines are held and retrieved by hand, or they are wound on a hand-turned or power reel. Lines may possess a single baited hook or a series of hooks. Because it is labor intensive, this method is restricted to a relatively small number of valuable, specialty-market fishes such as grouper species in the Gulf of Mexico (High 1989). Pole and line fishing has been used extensively to harvest several tuna species commercially. When a school of tunas is sighted, live bait such as anchovies, sardines, or other small-bodied fishes are thrown overboard, a process called *chumming*, to attract the tuna toward the vessel. Once attracted, they are caught with pole and line using artificial lures with barbless hooks (Joseph et al. 1988).

Baited hooks and artificial lures imitating natural foods are also dragged through the water by moving vessels in a method called *trolling*. Vessels troll multiple mainlines, each one attached to a power or hand-wound reel. Each mainline may hold a single hook or a series of hooks at specific intervals along its length. King and Spanish mackerel of the Atlantic and Gulf coasts, chinook and coho salmon along the northwest Pacific coast, and albacore in the Pacific Ocean have been commercially harvested by trolling (Everhart et al. 1975; Joseph et al. 1988; High 1989; NOAA 1991).

Active Entrapment Gear

Active entrapment methods include gears that are towed or pulled through the water, encircling or trapping fishes or shellfishes during the towing process.

Trawls and Dredges. Trawls are cone-shaped nets, closed at the posterior end, that are towed through the water by vessels (Figure 5.1). As the net is towed, fishes swimming in front of the trawl enter the open mouth and are collected in the bag at the rear end of the net, called the *codend*. Trawls can be fished along the substrate or in the mid-water column. There are two basic trawl designs, the beam trawl and the otter trawl. The mouth of a beam trawl is held open by a rigid frame or a pole attached to the headrope at the top of the net mouth. The footrope along the bottom of the net mouth is often weighted with a chain (Hayes 1983). The beam trawl is awkward to handle because of the rigid mouth of the net (Pitcher and Hart 1982). An otter trawl is held open by otterboards or doors attached to both sides of the net mouth. Ropes leading to the vessel are attached to the anterior edge of each door or to the surface of each door that is facing inward toward the middle of the net mouth. The net is attached to the surface of the boards facing outward. Thus, as the net is pulled forward through the water, the boards spread outward from each other due to water pushing against the inward-facing surface of each board. Floats are attached to the headrope and chains to the footrope in order to spread the net vertically. When bottom trawls are towed over somewhat rough substrates, large rollers may be attached to the footrope to prevent the net from becoming entangled

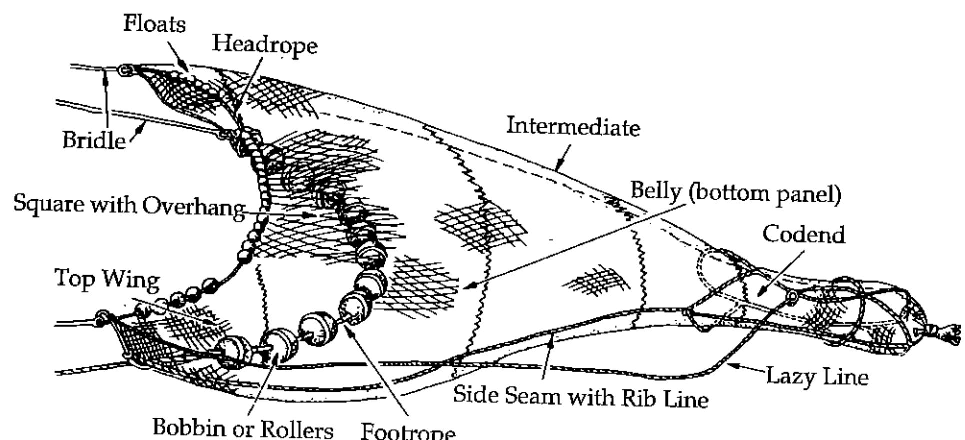

Figure 5.1 An otter trawl. (From Hayes, M. L., 1983. Active fish capture methods. Pages 123–145 in L. A. Nielsen and D. L. Johnson, editors. *Fisheries techniques*. Reprinted by permission of The American Fisheries Society.)

on rocks. The size of net used depends on the power of a vessel needed to tow the trawl through the water and to handle tow cables and otterboards (High 1989). The largest trawls may be as long as 100 meters with a mouth opening of 400 to 500 square meters (Pitcher and Hart 1982). A trawl normally is not towed at speeds fast enough to immediately overtake and capture most fishes in its path. Many fishes swim in advance of the trawl, avoiding its mouth until they tire and are gradually overtaken by the gear.

Trawls are used on both the Atlantic and Pacific coasts. A variety of continental shelf groundfish (bottom-dwelling) species are harvested in the northeast, including ocean perch or Acadian redfish, Atlantic cod, haddock and other members of the cod family (*Gadidae*), and yellowtail and winter flounder, American plaice, and other flatfishes. Gadids such as Pacific whiting, Alaskan walleye pollock, Pacific cod, yellowfin sole and other flatfishes, numerous rockfishes, and other groundfishes are harvested in trawl fisheries along the Pacific coast of the conterminous states and Alaska. Shrimp species are harvested by trawling in the Gulf of Mexico and the Gulf of Alaska and along much of the Atlantic coast of the United States. Pelagic species such as Atlantic and king mackerel, menhaden, long-finned and short-finned squid, drum and seatrout species, and butterfish are harvested by midwater trawling.

Trawls typically capture a variety of organisms other than those that might be targeted for harvest in a fishery. This bycatch can include sublegal-sized fishes of species being sought or nontargeted species. The biomass of bycatch can exceed that of directed or targeted catch in some fisheries. Capture in trawls and handling on board vessels can be extremely stressful to bycatch. In many trawl fisheries, bycatch exhibits high rates of mortality even when returned to the water after the catch is sorted. The reduction of bycatch of finfishes or other taxa such as sea turtles has become a major priority in the management of many fisheries (see Chapter 7).

Bycatch of small fishes can be reduced in some trawl fisheries by the use of large mesh netting in the trawl's codend. The size of the openings in the codend mesh determines the minimum size of fish that will be retained in the trawl rather than passing through it. Small fishes pass through the mesh, whereas higher percentages of fishes of each larger size category are retained within the codend. Retention of small fishes may increase for any specific mesh size as a trawl fills while being fished, because the growing mass of trapped larger individuals may prevent smaller fishes that enter the codend from contacting and passing through the mesh openings. Special devices that deflect small fishes, such as bycatch reduction devices (BRDs), or sea turtles, such as turtle-excluding devices (TEDs), out of an opening anterior to the codend of a trawl are required in some shrimp trawl fisheries (see Chapter 7).

Dredges are rigid framed gears that are dragged over substrates to harvest bivalve shellfish such as scallops, oysters, and clams (Hayes 1983). A scallop dredge has a metal frame with a scraper bar across the bottom of the mouth and a collecting bag constructed of metal rings. The scraper bar or blade drags across the substrate as the dredge is pulled through the water, deflecting scallops into the collecting bag (Figure 5.2). The size of ring openings can function much in the same manner as mesh openings in trawl nets: Bivalves smaller than the ring openings may pass through the collecting bag, whereas larger ones are retained. An oyster dredge will have rakelike teeth on the scraper blade to dislodge the oysters from their attachment point on the substrate (Figure 5.2). Surf clam dredges may have a hydraulic device that washes sediment away and flushes the clams into the collecting basket. Whereas bottom trawls may be equipped with rollers to keep the footrope

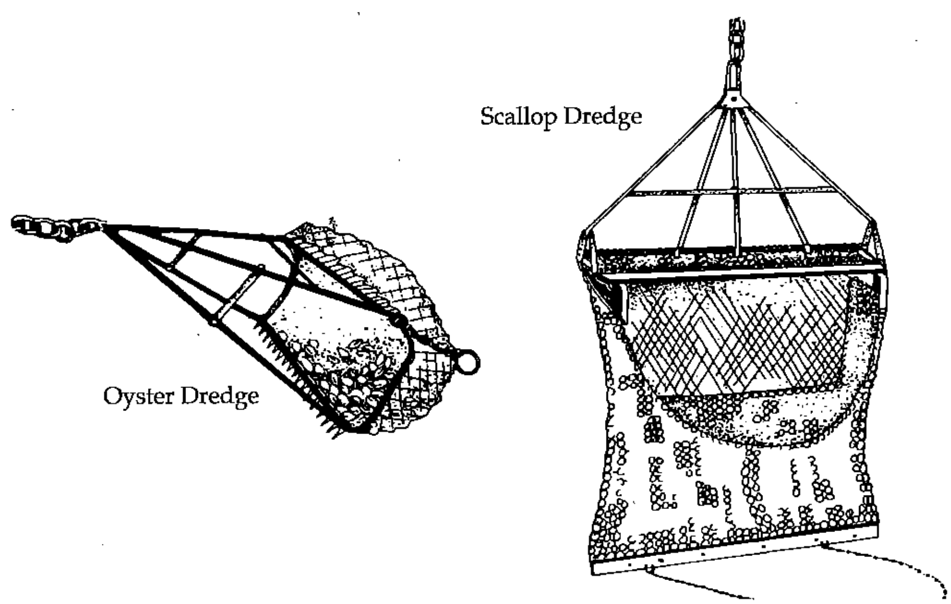

Figure 5.2 Scallop and oyster dredges. (From Hayes, M. L., 1983. Active fish capture methods. Pages 123–145 in L. A. Nielsen and D. L. Johnson, editors. *Fisheries techniques*. Reprinted by permission of The American Fisheries Society.)

from entangling upon objects on the bottom, dredges are constructed to scrape across and into substrates. Such harvesting devices can severely disrupt the surface substrate and the benthic fauna that live on or within it.

Numerous resources pursued in U.S. trawl and dredge fisheries are overfished, particularly principal bottomfishes of the Northeast (discussed elsewhere in this chapter) and sea scallops and other bivalves. Along with other regulations established to protect these depleted resources, groundfish trawl fisheries are often regulated with minimum-mesh size regulations that are intended to reduce the capture of undersized individuals and incidental capture of nontargeted species.

Seines. Seines are small-mesh nets used to encircle fish schools. The top line—called the *floatline*, or *corkline*—supporting the netting typically has floats, and the bottom line—or *leadline*—has weights to keep the netting spread vertically as it is pulled through the water (High 1989).

Beach or haul seines are used in shallow water to entrap fishes along the shoreline of coastal areas, lakes, or large rivers. Large beach seines are typically put into position by a boat, which encircles an area of water adjacent to the shore with the netting and places both ends at the shoreline. Once in place, a seine is hauled to shore by hand or by winches or other power equipment, with workers piling up the netting as both ends are drawn to shore. Striped bass, bluefish, Atlantic mackerel, weakfish, tautog, and other coastal species have been harvested with beach seines, as have freshwater fishes such as the common carp, freshwater drum, channel catfish, and other large lake and river species.

Purse seines are used in offshore deepwater fisheries. This gear consists of a long and relatively deep curtain of netting with a floatline and leadline, the latter having a series of rings attached along its length with a cable running through the rings. Once a school of fishes is found, the fishing vessel draws the seine around the school in a large circle while the free end of the seine is held in position by a small boat (skiff) or sea anchor. Once the seine encircles the school, the vessel retrieves both ends of the ring cable, closing the bottom of the net and ultimately pulling the leadline onto its deck (Figure 5.3). This traps the fishes within a "purse" of netting.

Purse seine fisheries harvest greater total biomasses of fishes than any other commercial gear used in the United States (High 1989). Before the collapse of Pacific sardine stocks in the early 1960s, purse seine fisheries for this species accounted for 25 percent of the entire U.S. commercial finfish harvest (NOAA 1993). Until recently, purse seine fisheries harvesting Gulf of Mexico and Atlantic coast menhaden stocks have accounted for as much as 40 percent of the total U.S. finfish catch (High 1989). Tunas, Pacific salmon species, northern anchovy, king mackerel, and other schooling species have also supported purse seine fisheries.

Standard purse seining operating procedures have caused high mortality rates of dolphins incidentally trapped and drowned in the southeastern Pacific yellowfin tuna purse seine fishery. Nearly 370,000 dolphins were either killed or seriously injured in that fishery in 1972, before procedures were established to reduce incidental capture (Chandler 1988). Under provisions of the Marine Mammal Protection Act, the number of dolphins that can be incidentally killed in the U.S. yellowfin tuna fishery each year is limited to a small fraction of the unregulated incidental take of years previous to regulation (see Chapter 6). A significant reduction in dolphin

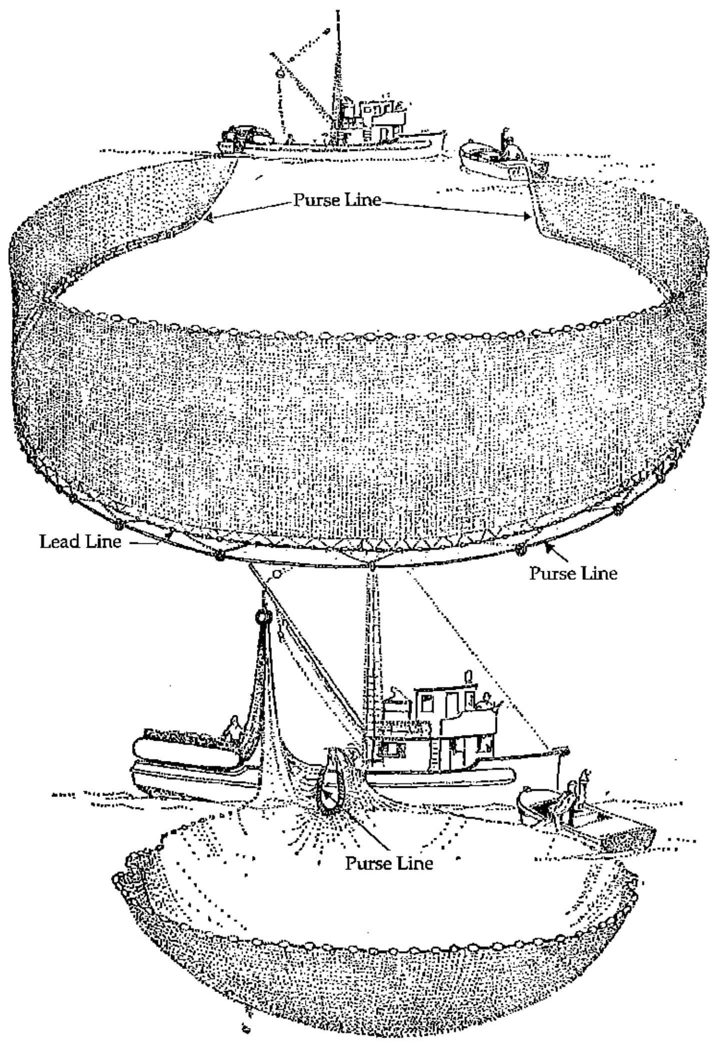

Figure 5.3 Purse seine being deployed and the purseline being drawn. (From: T. Bagenal, *Methods for Assessment of Fish Production in Fresh Waters*, 3/e. Copyright © 1978. Reprinted by permission of Blackwell Science, Ltd.)

mortality has been achieved by use of a procedure called *backing down*, which consists of lowering one edge of the float line below the water's surface after the seine has been pursed. This allows dolphins to escape while retaining most or all of the deeper swimming tuna. U.S. yellowfin purse seine vessels are also required to use a small mesh panel in the part of the net that the dolphins swim over, so that they will not entangle their snouts in the webbing and drown while trying to escape (Chandler 1988).

Many stocks that traditionally supported purse seine fisheries have collapsed or are seriously declining in abundance. Thus the use of purse seines to harvest some schooling pelagic species is regulated or prohibited.

Passive Entrapment Gear

Passive entrapment gears are fixed in position. Thus fishes and shellfishes must contact the gear and become entrapped in order to be captured. Fishes and shellfishes encounter such gear either because it lies in their standard path of movement or because they are attracted to bait housed within the entrapment area (Hubert 1983).

Trap Nets, Pound Nets, and Weirs. Trap nets have an entrapment area consisting of a series of connected funnels (Figure 5.4); the final funnel is tied closed at its posterior end. The opening of the trap generally is anchored off the shoreline with its open end facing shoreward. Long barriers of netting (leads or wings) extend from the trap outward, often toward the shoreline. Fishes that encounter the netting follow it, eventually swimming into the entrapment area. Weirs and pounds are more permanent structures that function similarly to trap nets. Corralling areas and leads in herring weirs of coastal Maine and the Canadian Maritime Provinces consist of stakes driven into the substrate with brush woven through the stakes to create a barrier (Lagler 1978; High 1989).

Trap nets, pound nets, and weirs have been used to harvest salmon species on the Pacific coast; Atlantic herring, Atlantic mackerel, and other schooling species on the Atlantic coast; and species of whitefishes, ciscoes, and other Great Lakes fish-

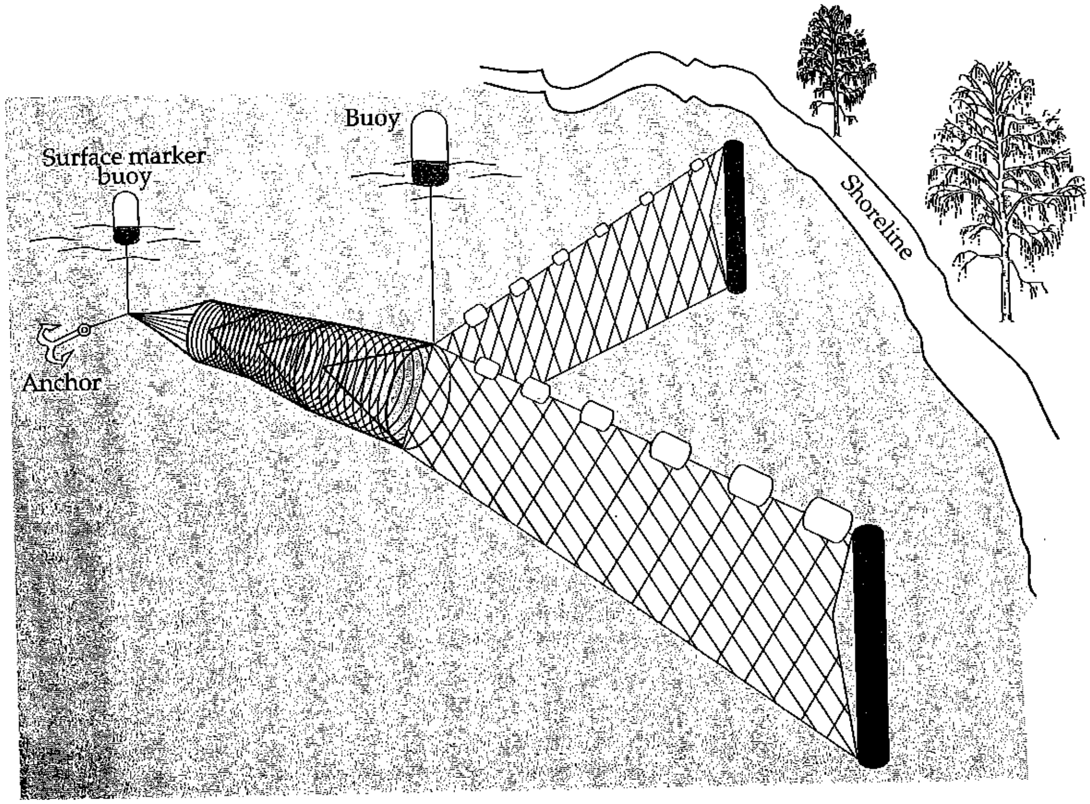

Figure 5.4 Trap net.

es. The potential impact of pound nets and weirs on coastal migratory species was recognized early by the first U.S. Fish Commissioner, Spencer Baird, who recommended prohibiting the use of these gears in New England coastal fisheries in the early 1870s due to the depleted condition of numerous fish stocks (see Chapter 6). The use of large Pacific salmon trap nets was prohibited in Alaska before the 1960s (High 1989). Such devices are now highly restricted or prohibited in many fisheries.

Pots and Traps. Pots and traps are small, portable gears normally consisting of a rigid frame and mesh netting with constricted openings through which fishes or shellfishes pass (Figure 5.5). Devices designed to capture fishes are called *traps*, whereas those designed to capture invertebrates such as crabs or lobsters are called *pots*. Pots and traps are usually set individually, with an anchor to hold them in place and a float tied by line to mark their position. Some are attached in series along a long groundline, as in the sablefish trap fishery of the Pacific coast and the offshore lobster fishery of the Atlantic coast (High 1989). Although some species may enter pots or traps to gain shelter, most are attracted only if the devices are baited with food.

Many types of invertebrates are harvested with pots, including American lobster along much of the Atlantic coast of the United States and Canada, blue crab in the mid-Atlantic states, spiny lobster and stone crab from the southern Atlantic coast and the Gulf of Mexico, king and tanner crabs from Alaska, dungeness crab from California to Alaska, and spiny and slipper lobsters on the Hawaiian Islands. Trap fisheries have focused on species such as the sablefish in Alaskan waters, black sea bass in the mid-Atlantic, American eels in Atlantic coast rivers, and groupers in the south Atlantic states. Traps are now highly restricted in Alaskan sablefish fisheries (High 1989) and are prohibited in Florida grouper fisheries.

Pot fisheries have caused significant declines in some crab and lobster fisheries. American lobster and southeastern U.S. spiny lobster are considered overexploited. Population abundance of the Bering Sea Alaskan king crab stock has declined precipitously since the mid-1970s (NOAA 1993).

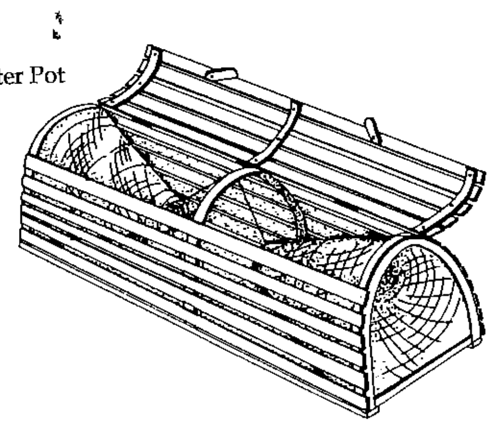

Figure 5.5 An American lobster pot. (From W. A. Hubert, 1983. Active fish capture methods. Pages 123–145 in L. A. Nielsen and D. L. Johnson, editors. *Fisheries techniques*. Reprinted by permission of The American Fisheries Society.)

Entanglement Gear

As with passive entrapment methods, entanglement gears must be encountered by fishes. Fishes encounter and are captured by these devices during normal daily or seasonal activity patterns or migrations.

Gill Nets. The most commonly used entanglement gear, the gill net, is a long wall of large-mesh netting set in a straight line in the water column, with a floatline tied across the top and a leadline along the bottom of the wall of netting (Figure 5.6). Fishes may be captured in gill nets by being (Hubert 1983)

1. Wedged—held by the mesh wrapped tightly around the body
2. Gilled—held by mesh slipping under the opercles or gill covers
3. Tangled—held by teeth, fin spines, or other protrusions without the head or body penetrating the mesh openings

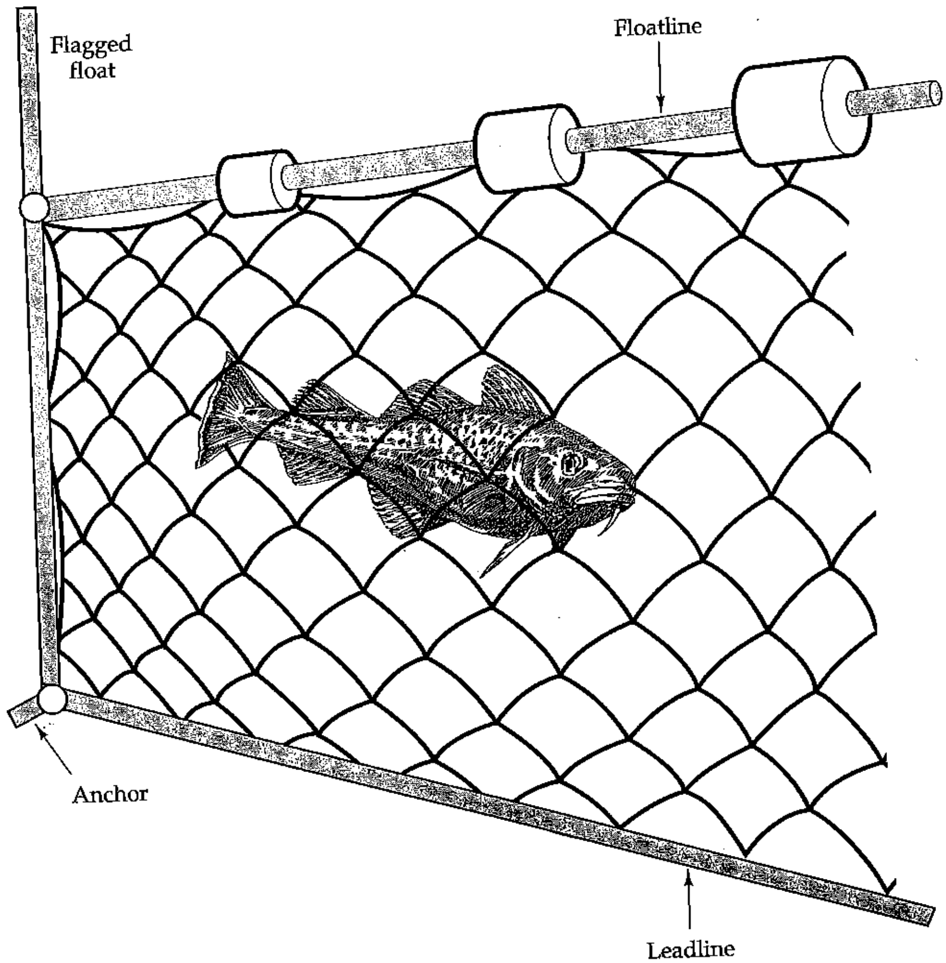

Figure 5.6 Gill net with an entangled Atlantic cod.

Gill nets can be anchored on or near the bottom or suspended in place anywhere within the water column of shallower systems by long anchor ropes attached to the ends. Drift gill nets, which are floated and weighted to remain spread but are not anchored to substrate, are used in rivers or in open ocean areas where anchoring is not possible.

Cotton and linen mesh webbing was used in early gill nets. However, more recently nylon and monofilament twine are most commonly used because they do not deteriorate as rapidly as cotton or linen. Monofilament nets are also markedly less visible to fishes than the other materials. Because wooden or plastic floats and lead weights tend to tangle in the net webbing when folded before or after fishing, foam-core floatlines and lead-core leadlines are commonly used to stretch the net vertically in the water column (Hubert 1983).

Gill nets are used to catch a variety of highly mobile fish species. However, specific gill nets efficiently capture only a narrow size range of fishes, based on the size of the openings of the mesh. For any given mesh size, fishes smaller than the size range of optimum capture efficiency may pass through the webbing, whereas fishes larger than the optimum size bump into the webbing without becoming entangled (Lagler 1978). As with trawls, gill-net size selectivity offers agencies the opportunity to reduce the capture of small fishes in gill-net fisheries by establishing regulations requiring minimum mesh size openings.

Capture efficiency also varies with time of day and length of time the net is fished in the water column. Efficiency may increase during the night, presumably because fishes are less likely to detect the net visually before contacting it. Efficiency also declines with increasing *soak time*—the time that the net is fished—because the frequency of detection and avoidance tends to increase as the net fills with entangled fishes (Hubert 1983).

Gill nets have been used to harvest a number of freshwater, anadromous, and marine fisheries resources. Their use has been restricted or prohibited in many fisheries, as in the Lake Erie walleye and yellow perch fisheries (see Chapter 12). Gill nets produce large biomasses of bycatch. Bycatch of fishes, sea birds, sea turtles, and marine mammals in the drift net fisheries of the Pacific Ocean, which employ gill nets that may stretch for miles, has caused particular concern in recent years (NOAA 1991). In addition, long-lasting monofilament materials, favored by harvesters for their endurance, cause high mortality of a variety of aquatic organisms when lost on fishing grounds. If not recovered from the water, such "ghost" nets can continue to entangle and kill fishes and other vertebrates as well as invertebrates for years (High 1989).

Trammel Nets. A trammel net is composed of three walls of mesh netting lying parallel to each other and spread in the water column by floatlines and leadlines (Hubert 1983). The outer panels of netting are large-meshed, and the inner has small mesh. Fishes are captured in trammel nets when they strike the inner panel of small mesh netting and push it and themselves through an outer, large-mesh panel; this forms a pouch of gathered netting that entangles them. Although these nets are used in some fisheries, such as the California halibut fishery and formerly in the Alaska king crab fishery (High 1989), they are much less commonly employed than are gill nets. Because the middle panel of netting has small mesh openings, trammel nets capture a greater variety of sizes than do gill nets. Fishes and crustaceans can be difficult to remove from trammel nets. Thus fishing with this gear can be very labor intensive, and high mortality rates of bycatch can occur.