2 Fish Capture Devices in Industrial and Artisanal Fisheries and their Influence on Management

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2.1 INTRODUCTION

Modern fishing has grown out of the methods and systems still used in artisanal fisheries. A 120-metre pelagic trawler operating out of Killybegs, Ireland, is different from its predecessors by virtue of the technology that has been applied to increase the ship's catching power and to reduce the number of people required to run it. In reality there is a continuum between the most primitive and most advanced fishing equipment and this chapter will illustrate this development. The elaboration of fishing gear from early times is outlined by Smith (Chapter 4, this volume), and this development through time is paralleled by the spatial changes observed between fleets using a large technological input and those using almost none. The new technology has clearly introduced new problems to be coped with by fisheries managers and we will spend some time in this chapter outlining the particular management problems attached to industrialized and artisanal fisheries. Along the way we will describe the equipment used in the various fisheries and how it is used.

In this chapter we focus on the main fishing techniques operated by industrialized fleets taking the bulk of the catch in oceanic fisheries, and on the techniques employed by artisanal fishermen in lakes and coastal waters in Third World countries. The basic principles for these methods is generally the same whether they are operated by industrialized fleets or artisanal fishermen, but the size of the gear, of the tools for gear handling, of the vessels, equipment for navigation and fish finding, of the catches taken and the costs involved are so different that separate considerations are necessary.

2.2 MAIN FISH CAPTURE TECHNIQUES

2.2.1 Introduction

The main fishing gears have distinct constructions and methods of operation (Fig. 2.1). Purse seines capture fish shoals by surrounding them with a huge net. Trawls filter water masses at a speed higher than the fish's sustainable swimming speed. In long lining fish are attracted by the odour of baits that they swallow and get hooked. Gill-nets form invisible net walls that fish swim into and get gilled or become entangled.

The fishing vessels from which the respective gears are operated generally differ in their construction and equipment with respect to size, engine power and gear handling devices. Gill-netters haul the gear over a roller at the rail (Fig. 2.2). Behind the net hauler that is mounted to the deck, fish are removed from the net by hand, and the net is cleared and stacked in a net bin manually or by automatic net clearers, ready to be set again over the stern. The principle for handling long lines is much the same – hauling over a roller at the rail – but the fish are removed before the line goes around the line hauler (Fig. 2.2). The line is then passed through a tube and back to a room with stor-

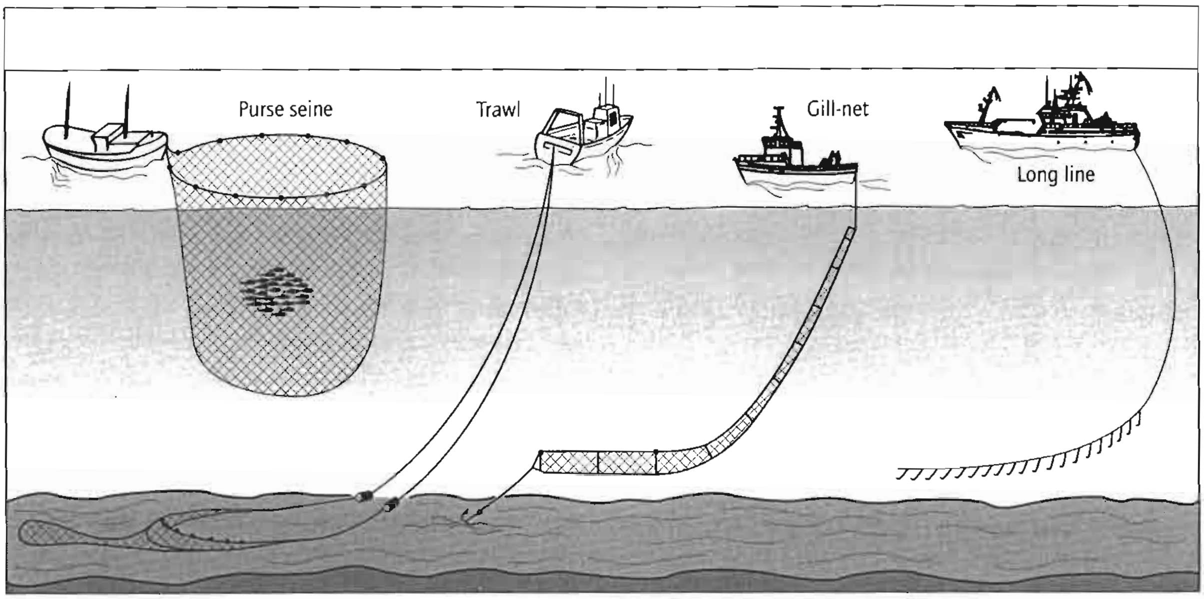

Fig. 2.1 Main fishing capture techniques. From left to right: surrounding of fish shoals by purse seine; filtration of water masses by trawl at a higher speed than the fish are able to endure; gilling of fish that move into a net; attraction and hooking of fish by baited long line.

ing magazines or onto a storing drum. The line is set over the stern through a machine that automatically baits the hooks, or else branch lines with baited hooks are clipped on manually. Large long liners have refrigerated and/or freezer holds for the bait and the catch, and also fish processing machines for heading, splitting and fillet production (Sainsbury 1986; Bjordal and Løkkeborg 1996; Bach et al. 1999a). A purse seiner has two powerful winches to pull in the purse line and thereby close the net up along the side of the vessel (Fig. 2.2). The net is then hauled on board by the net winch, pulled backwards through a net tube or slide by the net crane that also stacks the net in the bin at the stern of the vessel. The catch will finally be concentrated along the side of the vessel in the bag of the purse seine and pumped or brailed onboard with a scoop made of net and into tanks with refrigerated sea water (RSW) at −1.5 °C. This preserves the catch at the best quality. A bottom trawler has two powerful winches for towing and hauling the trawl gear with 5–50 tonnes pulling capacity, and the trawl warp passes through towing blocks at the stern where the trawl doors hang when not in use (Fig. 2.2). The trawl is hauled and shot through the stern ramp, and hauling and shooting are controlled by the sweep winches in the bow. The bottom gear is hauled into a set of trawl lanes (there are usually two such sets on modern vessels) and the trawl net and the bag are pulled in by aid of the gilson winches on the boat deck. A pelagic trawler has no gilson or sweep winches: the trawl net is therefore wound up onto a powerful net drum with 5–50 tonnes pulling capacity.

Modern industrialized fisheries are very effective. Strict regulations through the setting of Total Allowable Catches (TACs) and technical measures like minimum mesh size and closed areas, as well as effort limitations and control of catches and landings, are therefore needed to prevent the collapses of many economically important stocks. A generally important technical measure for fishing gears is the size selectivity, which is defined as the proportion of fish retained related to the length of the fish (Anon. 1996). A selection curve for trawl gears is mostly sigmoid (see Sparre and Hart,

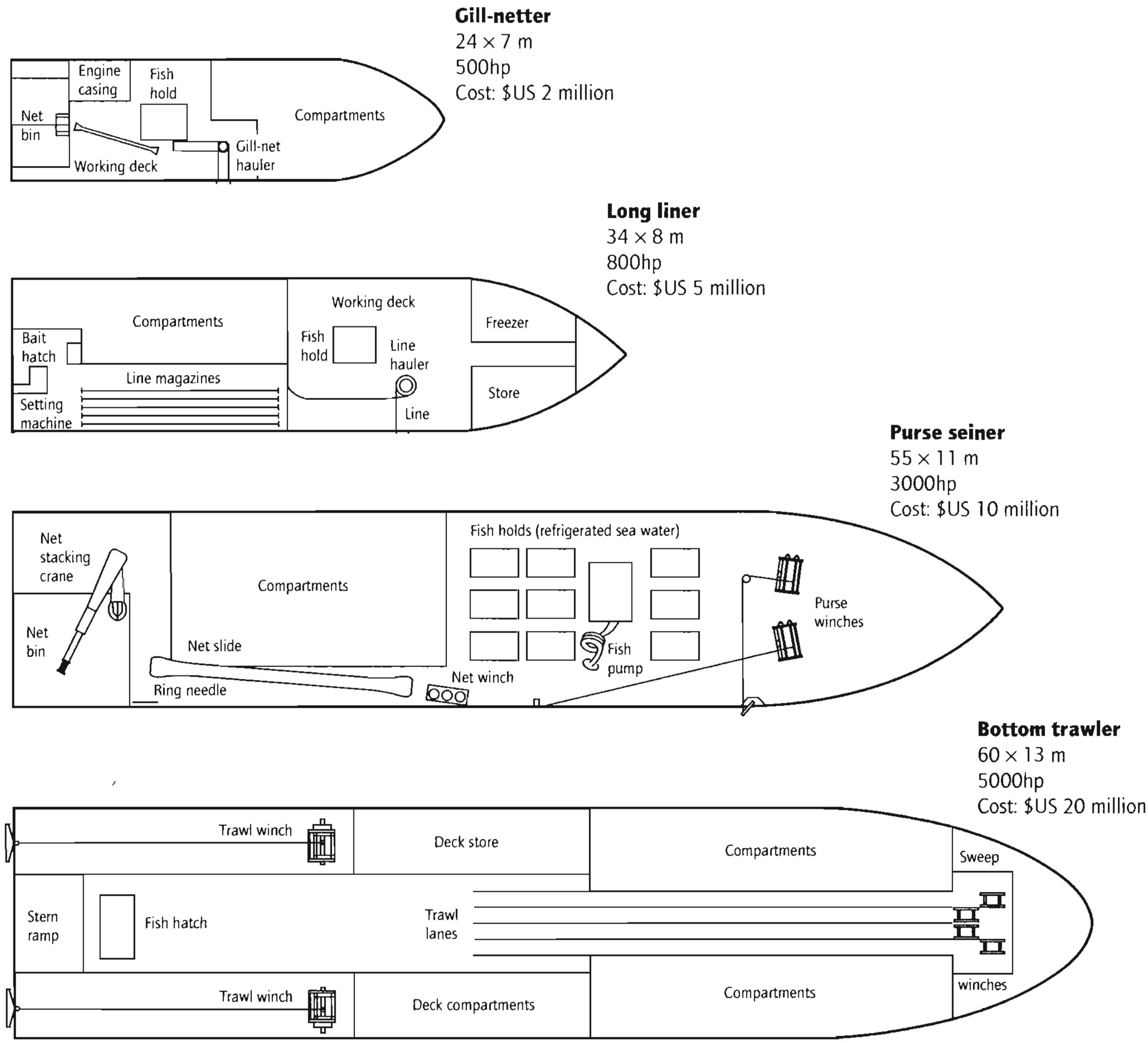

Fig. 2.2 Principal deck layout of main types of fishing vessels (provisional vessel size, engine power and building costs are indicated).

Chapter 13, this volume, equation 13.11), but bell-shaped curves can be the case for gill-nets and hooking gears. Important selectivity measures are L_{50}, defined as the fish length where 50% of the fish is retained by the gear, and the selection factor defined as L_{50} divided by mesh size in centimetres. In addition to the selection range which is defined as $L_{75} - L_{25}$ (L_{75} is fish length where 75% of the fish is retained, and L_{25} is fish length where 25% of the fish is retained), these parametres describe the size selection characteristics of fishing gears.

2.2.2 *Purse seining*

The principle of purse seining is to surround fish shoals by a large net that can be closed so that the fish cannot escape (Ben Yami 1990). When the net is hauled back, the fish will become concentrated in a bag ready for brailing or pumping onboard. The first purse seines were developed by Rhode Island fishermen in the USA for catching menhaden (*Brevoortia patronus*) in the 1860s.

The purse seine is kept floating by a line of floats at the surface, and the lower part of the net sinks by the force of a heavy leadline. The net will thus be stretched out as a circular wall surrounding the fish shoal (Fig. 2.1). The mesh size is so small that the net wall acts as an impenetrable fence preventing escape. When the purse seine has been set out and allowed to sink for some minutes, so that it reaches deeper than the depth of the target fish shoals, it can be closed by hauling the purse line. The lower part of the purse seine will be confined and pulled to the surface. When this operation is finished it is impossible for fish shoals to escape, as long as the net is not torn. However, flying fishes (Exocoetidae) or mullets (Mugilidae) can still jump over the floatline.

The size of the purse seine depends upon the behaviour of the fish to be captured and the size of the vessel from which it is operated. For catching fast-swimming fish shoals at depth, purse seines must be long, deep, have a high hanging ratio and be heavily leaded. The hanging ratio is defined as the length of the stretched net divided by the length of the line on which it is mounted. For catching slower-swimming fish shoals distributed near the surface, purse seines can be shorter, shallower, and have a low hanging ratio. The relationships between fish species, vessel size and purse seine characteristics are given in Fig. 2.3.

Modern purse seining is mostly dependent on detection and location of fish shoals by hydroacoustic instruments (Misund 1997). Larger purse seiners (>40 m) have a low-frequency, low-resolution sonar (18–34 kHz) for detecting fish shoals at long range, and a high-frequency, high-resolution sonar (120–180 kHz) for more detailed mapping of shoal size and fish behaviour in relation to the vessel and the net.

Purse seining is conducted on fish aggregated in dense shoals (Pitcher 1983), or on fish occurring in distinct schools, in which the density is much higher than in shoals. Normally, purse seining on shoals takes place in darkness during night-time, while fishing on schools is limited to the daylight hours. In some fisheries, the fish are available to profitable purse seining both when schooling during daytime and when shoaling at night. For example, this is usually the case during the winter fishery for capelin (*Mallotus villosus*) off the coast of northern Norway, and on the spawning grounds of Norwegian spring-spawning herring off the coast of western Norway in winter. Other purse seine fisheries are profitable only when the fish is shoaling at night or when schooling during daytime. An example of the former is the once-large Chilean fishery for Chilean jack mackerel (*Trachurus murphyi*), which normally is conducted when the fish occur in dense shoals near the surface at night (Hancock et al. 1995). Most of the purse seine fisheries for herring and mackerel in the North Sea in summertime are conducted when the fish are schooling during the daylight hours.

The fishing capacity of purse seiners is normally proportional to vessel size. In the Chilean jack mackerel fishery where there were no limitations set by fishing quotas in the mid-1990s, the total annual catch of purse seiners was related to the hold capacity of the vessel through the equation: total annual catch (tonnes) = 33.3 × hold capacity (m^3) + 18.2 (Hancock et al. 1995). In the 1992 season, a purse seiner with a hold capacity of 1350 m^3 was able to land about 65 000 tonnes of Chilean jack mackerel!

In some regions, artificial light is used to attract fish at night. When sufficient fish have aggregated near the light source, they are caught by purse seining (Ben-Yami 1971). This technique is probably of greatest importance for purse seine fisheries in Asian countries, where it is used offshore. The technique is also common in the Mediterranean, the Black Sea, and in the Russian and African lakes. In other regions, the technique is mostly used inshore, as during the sprat (*sprattus sprattus*), herring (*Clupea harengus*) and saithe (*Pollachius virens*) fisheries in the fjords of southern Norway.

Tuna purse seining is conducted by large vessels (mostly > 60 m) with large nets (Fig. 2.3) in

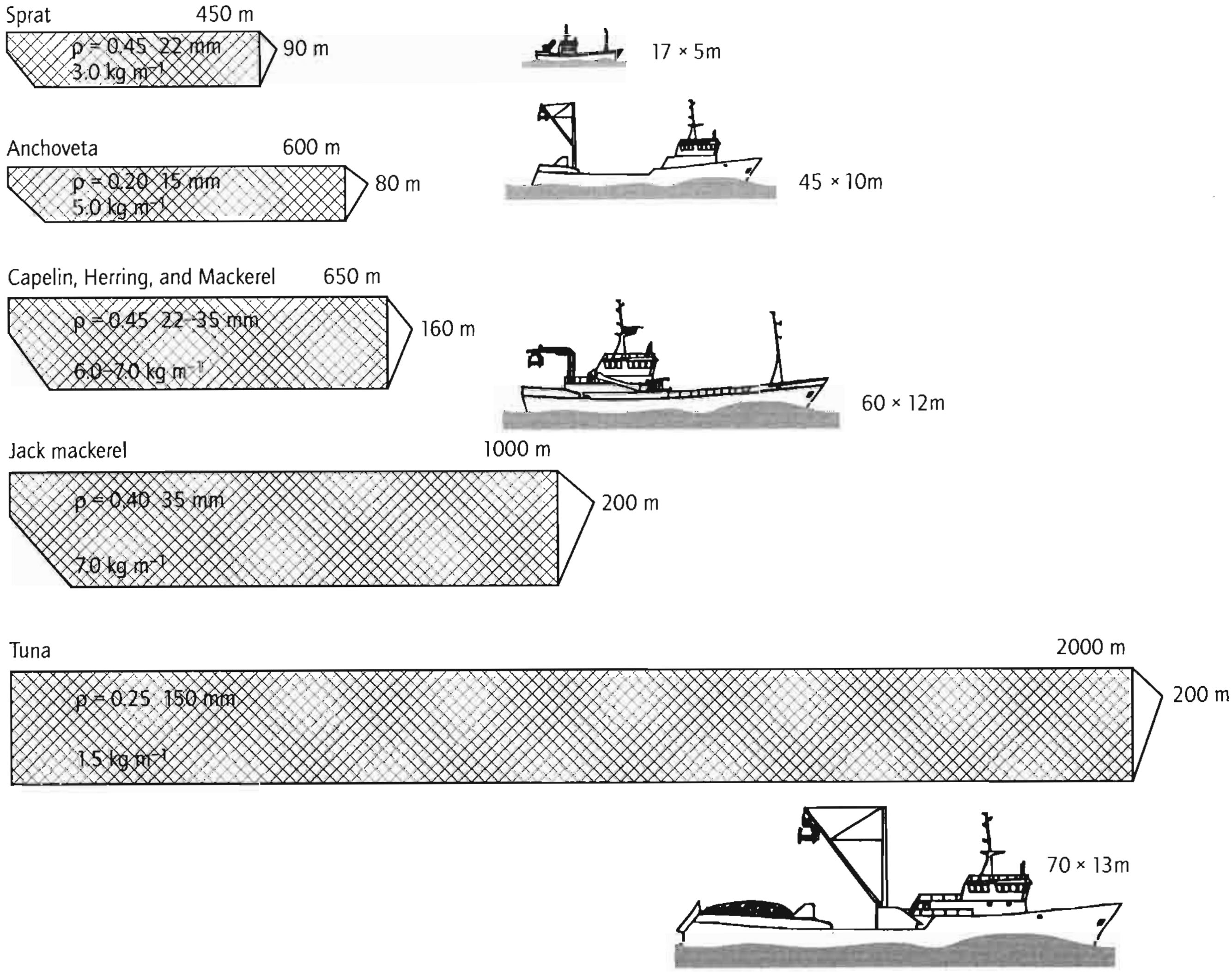

Fig. 2.3 Relationships between fish species, vessel size and purse seine characteristics (length, depth, hanging ratio (ρ), mesh size in mm and lead weight on ground rope are indicated).

tropical/subtropical regions in the Atlantic, Indian Ocean, particularly in the Mozambique Channel, and around the Seychelles, off Australia, and in the western and eastern Pacific (Fonteneau 1997). In the three oceans, the tuna is caught by sets made on free-swimming schools or by sets made on fish associated with floating objects of natural or artificial origin, which are mostly trees and branches. In the eastern Pacific, tuna are also caught by sets made on dolphin herds with which the tuna is associated (Anon. 1992; Hall 1998). The dolphin herds are visible on the surface, and rather easy to encircle by the fast-going tuna seiners (see also Kaiser and Jennings, Chapter 16, this volume). Usually, large tuna are present underneath the dolpins. When the purse seine is closed around the encircled dolpins and tuna, the fishers attempt to release the dolphin by the backdown procedure. This causes the floatline of the distant part of the purse seine to submerge so that the dolphins can swim and jump over. However, dolphin frequently become entangled in the purse seine and drown. In total, this amounted to about 60000 killed dolphins due to the tuna purse seine fishery in the eastern Pacific in 1992 (Anon. 1992). The tuna pursers operating in this region have been under pressure to change the fishing strategy or fishing operation to eliminate the accidental killing of dolphins (Kaiser and Jennings, Chapter 16, this volume).

2.2.3 *Trawling*

In principle, trawling is filtration of water masses inhabited by fish at a higher speed than the target fish species are able to swim sustainably. The filtration is done by towing a net bag horizontally through the water masses, either in the pelagic zone (pelagic trawling) or along the bottom (bottom trawling).

Bottom trawling

A bottom trawl is usually rather heavy, with two steel doors to open the trawl and with enough weight to keep the trawl in contact with the bottom during towing (Fig. 2.1). The doors, which can be up to 2 m high and 4 m long and weigh up to 7 tonnes, are connected to the vessel by the trawl warp, usually a wire up to 32 mm in diameter on the largest trawlers. The trawl bag is connected to the doors by a set of one to three bridles on each side, and in the mouth of the trawl there is a ground gear with steel or rubber bobbins or rollers that enable the gear to be operated on rough and stony grounds without being torn or hooked. The first proper bottom trawls, with wooden otter boards and rollers on the ground line, were constructed in Scotland in the 1890s (Smith, Chapter 4, this volume). A long time before that, however, fishermen on sailing ships in the North Sea and in the English Channel had been towing a trawl bag on soft or sandy bottom that was kept open by a wooden boom.

Bottom trawling is conducted in depths as shallow as about 20 m when trawling for industrial species such as the sand lance (*Ammodytes* sp.) in the North Sea, at intermediate depths of about 250 m when trawling for cod and haddock (*Melanogrammus aeglefinus*) in the Barents Sea, in deep waters from 400 m to 800 m for Arctic shrimps (*Pandalus borealis*) and orange roughy (*Hoplostethus atlanticus*) off Namibia, and in depths from 1000 to 2000 m for deep-water species such as grenadier (Macrouridae) in the slopes of the deep-water basin of the Atlantic and hoki (*Macruronus novaezelandiae*) and orange roughy in New Zealand and Australian waters. The ratio of warp length-to-bottom depth decreases from about 10 : 1 in shallow waters to 3 : 1 at intermediate depths, and further down to 1.8 : 1 when towing at great depths.

The construction of bottom trawls reflects the type of species targeted and the bottom type to be operated on. Trawls used on sandy bottoms or soft sediments, such as industrial trawling in the North Sea or shrimp trawling in Arctic waters, often have no rollers on the ground gear. On such trawls the ground gear is just a wire wound with rope. On the other hand, trawls to be operated on hard bottoms with stones, sponges and hard corals are equipped with heavy ground gear with steel or rubber bobbins. During the last decades heavy rock-hopper gear with rubber discs have become popular in the fleets of white-fish trawlers operating in North Atlantic waters. With this ground gear trawlers are able to fish on hard bottom substrates with obstacles such as stones and rocks without damaging the gear or suffering snags on bottom obstacles.

In the southern North Sea beam trawls are commonly used for catching flatfishes such as sole (*Solea solea*) and plaice (*Pleuronectes platessa*). These trawls are kept open by an iron boom up to about 10 m wide that runs on iron shoes on each side so that the boom is kept about 60 cm above the bottom during towing. The beamers can operate one trawl on each side of the vessel. A beam connected to the bow mast, which can be turned at 90° to the side of the vessel, is used to handle the boom and the attached trawl net. The beamers are usually powerful vessels with up to 4500 hp available, and can be up to 50 m in length. They can tow the gear at a speed up to 6 knots.

With an otter trawl, fish entering between the trawl doors tend to be guided by the bridles towards the mouth of the trawl, where they turn and try to swim in front of the rolling ground gear. Small fish and species with poor swimming capacity like plaice are less herded than larger and faster fish. As fish get exhausted they turn back and enter into the trawl bag, but in the net section leading to the bag or in the bag itself, the optomotoric response causes the fish to turn forward and try to swim along with the moving mesh wall. Fish finally panic when in the bag and swim towards, and try to escape through, the meshes. The selectivity of the trawl bag then occurs as small fish pass through the meshes while a greater proportion of the larger fish are physically unable to do so.

In most bottom trawl fisheries there are regulations on minimum mesh size in the bag of the trawl, also called the cod-end, to enable proper selectivity of target species. Trawl selectivity is also affected by the number of meshes in the circumference of the trawl bag, the length of the extension, the length of selvage ropes relative to trawl bag and extension, twine thickness, catch size, and mesh geometry. In the North Sea whitefish fishery trawl selectivity can be enhanced by changing the geometry of the meshes in the cod-end from rhombic to square (Robertson and Stewart 1988; van Marlen 2000), while in other areas use of such a mesh configuration did not improve selectivity because of clogging by redfish (*Sebastes* spp.) (Isaksen and Valdemarsen 1989) or catch size-dependent selectivity (Suuronen et al. 1991). Use of rigid sorting grids, made of steel or aluminium, inserted into the net, gives a sharper and more efficient selection than mesh selection alone (Larsen and Isaksen 1993). Fishers in the Barents Sea whitefish trawl fishery have been required by regulation to use grids since 1997.

In the relatively fine-meshed shrimp trawls, bycatch has been a substantial problem. There are estimates of bycatch to shrimp catch ratios of 5 : 1 in temperate waters and up to about 20 : 1 in tropical waters (Pender et al. 1992; Alverson and Hughes 1996; Ye et al. 2000). To reduce bycatch in shrimp trawls, the Nordmore grid was made mandatory in the Barents Sea in 1990 (Isaksen et al. 1992). The name 'Nordmore' derives from Nordmøre, a northern district in Norway where the idea for the sorting grid originated. Other bycatch reduction devices (mesh or grid constructions) have been developed for tropical shrimp trawling, such as in the northern prawn fishery off Australia (Broadhurst et al. 1997; Brewer et al. 1998; Salini et al. 2000).

In recent years considerable focus has been given to the physical impact of bottom trawl gears on the bottom fauna and topography (Kaiser and Jennings, Chapter 16, this volume). On sandy bottoms, tracks of heavy beam trawls were shown to have faded completely after 37 hours (Fonteyne 2000). On other bottom types with more fragile fauna the impact can be more permanent. In the southern North Sea several benthic species have decreased in abundance and even disappeared from certain regions (Bergman and van Santbrink 2000). Some regions of deep-water coral reefs (*Lophelia* sp.) off western Norway have been 'clear cut' with heavy rock-hopper trawl gears (Fosså et al. 2000).

Pelagic trawling

Pelagic species are also caught in large quantities by pelagic trawling, both with single boats and by pair trawling. In the Atlantic, capelin (*Mallotus villosus*), herring, horse mackerel, mackerel, sardines and sprat are caught by pelagic trawling. Off Ireland there is a large pelagic trawl fishery for blue whiting (*Micromesistius poutassou*), which aggregate for spawning during winter and spring. In the northern Pacific, there is a large pelagic trawl fishery for Alaska pollock (*Theragra challcogramma*).

Single-boat pelagic trawling was mainly developed after the Second World War, and is one of the most sophisticated fishing techniques, which sets specific demands for the size, power, equipment and operation of the vessels. In the Netherlands, there has been the development of a fleet of supertrawlers of up to about 125 m in length, and with a carrying capacity of up to 7000 tonnes of frozen pelagic fish. These vessels are operated both in the northern and southern Atlantic, fishing a variety of species such as horse mackerel, mackerel, herring and sardine. During the last decade a substantial fleet of pelagic trawlers, which are often also rigged for purse seining, has been built in Northern Europe (Ireland, Norway, Scotland). These vessels are 60–80 m long, with main engines from 5000 to 12 000 hp, and a carrying capacity of 1500–2500 tonnes of fish in refrigerated seawater (RSW) tanks.

In principle, a pelagic trawl is a net bag, towed behind a single vessel or between two vessels operating together. During pair trawling, the two boats both pull the trawl, and open it horizontally by going parallel to each other, but some distance apart (500–1000 m). A single-boat trawl is kept open by the lateral forces of two large trawl doors (5–15 m^2) in front of the trawl. The doors are attached to the warps from the vessel, and the trawl is connected to the doors via a pair of two or more sweeps. The length of the sweeps depends on the vertical opening of the trawl, and is about 180 m for a 30 m high trawl. A pair of weights (50–2000 kg) attached to the lower wings and the weight of the doors pull the trawl downwards. The fishing depth of the trawl is adjusted by the warp length, the towing speed and the vertical inclination of the doors. At a towing speed of about 6 m s^{-1} (3.5 knots), a warp length of about 500 m gives a fishing depth of about 200 m for a trawl with 30 m vertical opening, 1000 kg weights on the lower wings, and with the doors weighting about 3300 kg (Valdemarsen and Misund 1995). In most cases there are also floats or kites attached to the headline to give the trawl an upward pull. On single boats, using pelagic trawls designed to catch small pelagic fish such as capelin, which are about 15 cm in length, there can be a pair of extra doors attached to the upper wings to give the trawl a proper opening. Such trawls are towed at a low speed of about 3 m s^{-1}, and the lateral pull of just two doors will be too little to give the trawl the intended opening. According to the size, the vertical opening of a pelagic trawl varies by about an order of magnitude, from about 15 to 150 m. The horizontal opening is usually about equal to the vertical, and the total area of the opening of pelagic trawls thus varies by about two orders of magnitude, from about 200 to 20 000 m^2.

Pelagic trawls are constructed according to specific combinations of mesh size, twine, tapering and panel depth. Normally, the trawls are constructed of two or four panels that are joined in the selvage or laced together. The size of the trawl is given as the circumference of the trawl opening. This is calculated as the number of meshes in the trawl opening, minus the number of meshes in the selvage, multiplied by the stretched mesh size. The mesh size of pelagic trawls can be up to tens of metres in the front part, but decreases gradually to a few centimetres in the bag. The meshes in the front part of the trawl must herd the target fish into the centre of the trawl opening. If these meshes are too large, the target fish can escape, and the catching efficiency of the trawl decreases. The meshes in the cod-end must be so small that it is physically impossible for the target fish to escape.

Pelagic trawling is conducted mainly on fish occurring in large shoals, extended aggregations and layers. The fish can be recorded by sonar or acoustically, and the trawl opening is normally monitored by a cable-connected net sonde or a trawl sonar. These instruments provide information on the opening of the trawl, and the presence of fish inside or outside the trawl opening. There are also acoustic sensors to monitor the door spread, the headline height and depth, and catch sensors that are activated when there is catch in the cod-end.

2.2.4 *Long lining*

A longline is made up of a mainline to which branch lines with baited hooks are attached at regular intervals (Fig. 2.1). The mainline can be anchored to the bottom, and is sustained by vertical float lines equipped with instrumented buoys with light, radar reflector and radio beacon. The total extended length of the gear varies from a few hundred metres to more than 150 km and is made of several subunits called skates or baskets (Yamaguchi 1989a; Bjordal and Løkkeborg 1996). Three main types of longline can be identified (see Table 2.1), according to their position in the water column, the type of filament used in the mainline, hook spacing and the shape of the hook, which can be J-, wide gape, circle or EZ baiter (which has an intermediate shape between the circle hook and the J-hook and the name implies the ease with which the bait can be attached):

- bottom longline, which is subdivided into demersal and semipelagic;
- pelagic or drifting longline.

The rigging of longlines varies according to the target species, fishing conditions and countries. A de-

Table 2.1 Main characteristics of the different types of longlines.

Gear category	Mainline	Hook spacing (m)	Hook type
Bottom			
Demersal	Multifilament	1.2 to 1.8	EZ baiter
Semipelagic	Monofilament	2 to 3	J- or wide gap
Pelagic	Multifilament then monofilament	30 to 100	J- or circle hook

mersal longline is usually made of a multifilament mainline of 4–11 mm in diameter, more resistant to chafing than the monofilament lines. The line lays on the sea bed with an anchor. The branches, which are also called snoods, are made either from multifilament or monofilament, and are sometimes ended with steel wire or chain to prevent cutting by predators such as sharks. Semipelagic longlines are also anchored but the mainline is maintained above the bottom by alternate floats and sinkers set at regular intervals. Modern pelagic longlines are usually made of a synthetic, monofilament mainline of 3–4 mm in diameter. For tuna fishing, monofilament branch lines of about 20 m length and 2 mm diameter are attached to the mainline by metallic snaps. The rigging of the branches can be made more sophisticated by the use of swivels, aimed to limit twisting and chafing, and a combination of monofilament, multifilament and coated steel wires (Cook 1989; Yamaguchi 1989a,b; Bach et al. 1999a).

Catch distribution

Demersal long lining occurs mainly in the north Atlantic, targeting cod (*Gadus morhua*), haddock, tusk (*Brosme brosme*) and hake (*Merluccius* sp.) and in the northeastern Pacific where it targets essentially cod (*G. macrocephalus*) and halibut (*Hippoglossus stenolepis*). The common depth of exploited ground varies from 100 to 800 m, but can be deeper as in the case of the Patagonian toothfish (*Dissostichus eleginoides*), exploited up to 2500 m depth in Antarctic waters (Bjordal and Løkkeborg 1996).

Pelagic long lining targets tunas world wide (Fonteneau 1997). Bigeye (*Thunnus obesus*) and yellowfin (*T. albacares*) tuna are mainly caught along the whole intertropical areas of all oceans plus in the northern part (from 20° to 40° N) of the Pacific Ocean for bigeye only. Albacore (*T. alalunga*) is primarily caught in the northern (25° to 35° N) and southern (10° to 40° S) part of the oceans while bluefin tuna (*T. thynnus*) are mainly exploited in the southern hemisphere (20° to 50°) on each side of the African continent and around Australia and New Zealand (Yamaguchi 1989c; Fonteneau 1997; Carocci and Majkowski 1998). Subsurface longlines target swordfish (*Xiphias gladius*) in warm waters.

Bait and baiting

A variety of bait types are used by demersal long lining, such as small pelagic fish, saithe, shrimp, crab, octopus, mussels, whelks and lugworms. In pelagic long lining only the thawed saury (*Cololabis saira*) was used until recent years, but the bait tends nowadays to be more diversified (sardine, squid, etc.). The bait is usually dead, whole or cut in pieces. Artificial bait are currently being tested but are not commonly used at present. Chemical light sticks are sometimes added to the gear in the swordfish fishery. Baiting is done manually before setting, either onshore or on board, or by a baiting machine during the setting process. Automated baiting can be subdivided into precise baiting, where a piece of bait fish is automatically cut and hooked, and random baiting where the longline passes through a container with a mixture of precut bait and water. In tuna long lining, prebaited branch lines are stored in tubs or boxes and are attached to the mainline during setting. The use of baiting machines is common on board bottom long liners larger than 30 m as these require the baiting of up to several tens of thousands of hooks. Manual baiting is common in coastal and artisanal fisheries.

Setting and hauling

Setting the longline is normally done from the stern of the vessel. The time of setting depends on the target species but also on the feeding habits of bait scavengers. The end marker buoy and floats are dropped first at low speed, followed by the buoy line and the anchor in the case of bottom longlines. Then the vessel speeds up for setting the rest of the gear. Pre-baited bottom lines can be set at speeds of up to 10 knots since only the different skates need to be linked. When snoods are snapped on the line, a timer secures an even hook spacing. Three to five men are employed during the shooting.

Hauling is usually performed from the side of the vessel, starting by the marked buoy and the anchor for bottom longlines. When intermediate buoys and sinkers are used, they must be detached from the mainline. In tuna long lining, snoods are also detached when they arrive on board.

The importance of fish behaviour

The capture process of long lining is based on the feeding behaviour of the fish (see Juanes et al., Chapter 12, Volume 1). The bait is regarded by the fish as a food item, detected at long distance by the odour trail that is dispersed by the water current. The chemical senses of olfaction and taste are therefore essential and allow detection from several hundred metres. Vision can only detect objects from a few metres. Fish are able to locate the bait by swimming upstream. The current intensity and direction play a major role in the shape and extension of the so-called odour plume released by the bait. The rate of release of attractants, which are amino acids, in the water decreases rapidly with time so that strength has been reduced to one half after one hour, and therefore fishing time usually ranges from 10 to a maximum of 24 hours and can be reduced to only 2–3 hours when hooked fish can be attacked by large predators. Vision is an important sense at short range, especially in midwater, and explains why some species attack the bait mainly during the phase of deployment or hauling of the gear. Vision also explains the higher catching rate of monofilament lines, which are less visible than multifilament ones, and the attraction of some species, such as swordfish, to light sticks (Boggs 1992; Bjordal and Løkkeborg 1996; Bach et al. 1999b).

The success of long lining largely depends on fish behavioural aspects: level of hunger, diel foraging habits, prey attack, abundance and patchiness of the natural prey in the habitat. In French Polynesia, for instance, bigeye tuna catch rate is, as expected, positively correlated to the large-scale abundance of the micronekton. Nevertheless within relatively rich areas this correlation is negative at the much smaller scale of the longline where the micronekton distribution is patchy. This is interpreted by a competition between natural prey and baits (Bertrand 1999).

Species and size selectivity

More than 30 pelagic species can be caught by pelagic longlines and the question of untargeted species mortality by hooking is a major concern, mostly for shark species. Selectivity of longlines depends first on the match between the fish habitat and the place where the gear operates, both in the horizontal and vertical plane. Second, the type of bait used favours some species or sizes over others due to preference for food items (Juanes et al., Chapter 12, Volume 1). Finally, the size and type of hook affects the species composition, because of differences in feeding behaviour. The bait size, and to a lesser extent the hook size, are positively correlated with the fish size (Bjordal and Løkkeborg 1996), as expected from typical predator–prey size correlations (Juanes et al., Chapter 12, Volume 1). However, bottom longlines seem to catch about the same size range of cod as bottom trawls with 135 mm mesh size, and smaller fish than those caught by gill-nets (Huse et al. 2000). For Greenland halibut (*Reinhardtius hippoglossoides*), longlines catch a size range larger than that caught by bottom trawls, but smaller than by gill-nets (Huse et al. 1999).

Impact on sea birds

Impacts of fisheries on sea birds are reviewed by

Kaiser and Jenings (Chapter 16, this volume). We therefore do not go into the details here, except to reiterate the scale of the problem and methods of reducing mortality. Up to 70% of the baits can be taken by birds during longline setting. Estimated values of the number of birds killed per 1000 hooks range from 0.36 to 0.44 depending on both longline area and bird species, which results in the killing of several thousands of birds per year (Ryan and Boix-Hinzen 1998). Moloney et al. (1994) used an age-structured model to simulate population trends of albatross (*Diomedea exulans*). The simulation results portray a population decreasing at a rate of 2.3% per year, presumed to be a result of deaths caused by longline fishing vessels on this long-lived species.

To limit bird mortality, different methods are used such as shooting lines during the night, which mainly reduces the capture of albatross but is less effective for petrel. It is also possible to fit lines with lead weights, aimed to obtain a faster sinking, or to scare the bird away from the line. The two most efficient methods consist in either using a setting tunnel or trailing a 'bird scarer' made of a line with pendants parallel to the longline (Løkkeborg 1998).

Commercial aspects

Longlines mostly target highly priced species like tuna and demersal species (Table 2.2), which are very important economically and a significant source of food (Bjordal and Løkkeborg 1996; Nambiar and Sudari Pawiro 1998). In Japan, some tuna species like bluefin and bigeye are traditionally eaten raw ('sashimi' and 'sushi') and regarded as a delicacy. The wholesale price paid at landing for top sashimi-quality tuna can reach more than US$200 per kilogram. However, only very small quantities sell at these high prices and tuna used for canning can be sold for less than US$1 per kilogram (Carocci and Majkowski 1998).

Long lining is a cost-effective way of catching fish because it does not require a lot of energy, nor a large crew. This is especially so in coastal fishing that does not involve long travel distances. Nevertheless the gear is relatively expensive, as is the bait and the baiting process, which is either labour-intensive when manual or needs costly investment in baiting machines. The advantages of longlines over other fishing gears are: the quality of the fish which are often alive when caught; no or little impact on the sea bed; little 'ghost fishing' by lost equipment; little fish dumping; a relatively good size selectivity, limiting juvenile catches and the possibility to reduce unexpected mortality by using an adapted fishing strategy (Bjordal and Løkkeborg 1996; Bach et al. 1999c).

2.2.5 Gill-netting

Hand-knitted nets of natural fibres like cotton are among the oldest and most widespread fishing gears. Gill-netting is still amongst the most impor-

Table 2.2 Characteristics of the main longline fisheries.

Gear category	Common range of boat size (m)	Main target species	Yearly catches during the 1990s (million tonnes)	Main fishing countries
Bottom	8–55	Cod, hake, haddock, tusk, halibut, Patagonian toothfish	0.5	Norway, Iceland, Russia, Spain, Argentina
Pelagic	25–60	Bigeye, yellowfin and bluefin tuna, albacore	0.4	Japan, Taiwan, South Korea

tant fishing methods, and is used to harvest a variety of species worldwide. The nets are now made of synthetic fibres like polyamide forming monofilament or multifilament twines of which the net is knitted. There are several types of twine: twisted multifilament, monofilament, monotwine and multimono. The webbing of gill-nets should be as transparent and invisible as possible because gill-nets are passive gears, the fish itself moving into the net webbing head on, and trying to push through the mesh opening. Small fish pass through, but the larger ones with a maximum circumference just bigger than the girth of the mesh opening become gilled. The very large fish can entangle themselves or escape capture.

To keep it standing as a rectangular net wall in the sea, the net is mounted under a floatline with positive buoyancy and a groundline with negative buoyancy. The floatline can be made of a floating material like polypropylene, and may have synthetic floats embedded in it or solid floats formed as rings or rectangular pieces can be mounted on it. The groundline can have solid lead pieces mounted externally, or small lead pieces can be embedded in the groundline itself. For pelagic drifting gill-nets the positive buoyancy of the floatline is larger than the negative buoyancy of the groundline, while the opposite is the case for bottom-set gill-nets. At each end the gill-net webbing is mounted to a breast line joining the float and groundline. Gill-nets are normally joined together to form fleets that can consist of 10–100 units. Important parametres determining the size of fish to be captured are the mesh size and the hanging ratio of the gill-net webbing. Gill-nets are usually rather selective, but bycatch of sea birds and marine mammals can be substantial in some fisheries. Trammel nets, which have two large-meshed and a small-meshed net webbing in between have low selectivity. This is because such nets capture fish by entangling.

The visual stimulus of the net is a key factor determining whether or not fish detect the net (Cui et al. 1991), and at a certain light threshold gill-nets become invisible, depending on colour, net material and turbidity (Dickson 1989b). Gill-nets are therefore normally set to operate when the fish are actively moving around, either searching for food or migrating, and they function best at night when the fish do not see the webbing. Multifilament nets are less efficient than monofilament nets (Washington 1973; Hylen and Jackobsen 1979). Experiments have shown that attaching baits to gill-nets may increase catches of gadoids such as tusk and ling (*Molva molva*) (Engås et al. 2000). In areas with a high density of gill-nets, such as during spawning aggregations of cod in Lofoten, Norway, in winter, a satiation effect can occur so that there will be a decreasing catch rate with an increasing number of nets (Angelsen and Olsen 1987). Currents can reduce net height and change the shape of the webbing and thereby affect the efficiency substantially (Stewart and Ferro 1985). A model of how various factors influence catch rates of bottom-set gill-nets for cod has been developed (Dickson 1989a).

Fish caught in gill-nets can be gilled, wedged or entangled. In hard and stiff monofilament nets cod are mainly gilled, while in soft multifilament nets cod are mainly entangled (Stewart 1987). Despite this, gill-nets are very size-selective; few fish are caught differing from optimum length by more than 20% (Hamley 1975). The optimum girth for capture is about 1.25 times the mesh perimeter and the optimum length for capture increase approximately in proportion to mesh size (Engås and Løkkeborg 1994). A loosely hung net catches fish over a much wider size range than a more tightly hung net.

In recent years there has been much focus on 'ghost fishing' by lost gill-nets. (Kaiser and Jennings, Chapter 16, this volume). This is because synthetic gill-nets can continue to fish for several years after the nets have been lost. In Norway there is an official programme to dredge for lost gill-nets in areas where fishermen report loss of nets or where it is known that there is much gill-netting. Also, bycatch of sea mammals such as dolphins, harbour porpoise or seals take place in gill-nets (Tregenza 2000; Kaiser and Jennings, Chapter 16, this volume).

2.3 ARTISANAL FISHERIES

There is no standard, or even clear definition of small-scale artisanal fisheries (Panayotou 1982; Ben Yami 1989; Bâcle and Cecil 1989; Durand et al. 1991) other than perhaps 'scale' and 'artisanal', where the latter means a craftsman relying on his skill by himself, or with the help of family members or a few companions. Generally, artisanal fisheries can be seen as an integrated informal way of living within a geographically limited community and intrinsically dependent on local resources, rather than a formal occupation with a broad spectrum of options in terms of fishing grounds, markets and alternative investment opportunities (Thomson 1980; Panayotou 1982; Bâcle and Cecil 1989).

2.3.1 *Diversity of methods*

The modern large-scale fishing techniques that have been described so far have all developed from small-scale equivalents, and given the evolution in power, mobility and technical solutions of fishing vessels, the congruent evolution in commercial capture techniques have mainly been in terms of size, refinement and power requirements, with an ensuing increasing dependency on modern port facilities. Thus, small-scale artisanal capture techniques comprise all the categories and combinations of fishing methods already described (von Brandt 1959, 1984; Nédélec 1975; Nédélec and Prado 1990) but are different by being less capital-, vessel-, and fuel-intensive than modern industrialized fishing methods (Fig. 2.4). Many do not require vessels or energy-consuming accessories at all but can be operated from the shore, and many have remained virtually unchanged for centuries. Others are in rapid technological development, like the Senegalese pelagic canoe fisheries (WWF 1998), and may only be distinguished as 'artisanal' by the scale of the fishing units, and their still limited range. As a consequence a further distinction between commercial- and subsistence-artisanal fisheries has therefore sometimes been used (Kesteven 1976; Smith 1979). An important characteristic, however, of small-scale artisanal fisheries are their numerous actors (Fig. 2.4), resulting in an extraordinary variety in terms of specialized capture solutions to different resources, environments and seasons, with many being only seasonal in combination with agriculture, still small-scale fisheries are highly dynamic and diverse in terms of fishing techniques within each exploited ecosystem (e.g. Gerlotto and Stéquert 1978).

Apart from the purely technical classification of capture devices (see von Brandt 1959, 1984; Nédélec 1975; Nédélec and Prado 1990), small-scale fishing gear can be grouped into appliance or development categories (Ben-Yami 1989):

1 Traditional, 'primitive' fishing implements and installations characteristic for artisanal subsistence fisheries in developing countries. These are locally produced and operated from small canoes and rafts, and by wading or diving fishers. Barriers, weirs, traps, pots, spears, tongs, harpoons, gill-nets, dip-nets, small beach seines, and simple hook-and-line gear are included in this group.

2 Modern, 'sophisticated' equipment used almost exclusively in industrialized countries. For example dredges, automated haulers and jiggers, hydroacoustic and electronic equipment, and various auxiliary labour-saving devices.

3 Intermediate equipment used by small-scale fishermen in both industrialized and developing countries. This group consists of most fishing nets such as gill-nets, seines, and lift nets and much of the hook-and-line gear, almost all of which are factory produced and made of synthetic materials. Modern accessories, however, such as mechanized net and line haulers, light lures, and echo sounders are increasingly used in developing countries, and particularly by the small-scale enterprises which expand into harvesting previously underutilized pelagic species in lakes, reservoirs and coastal fisheries.

2.3.2 *Research problems in artisanal fisheries*

One of the first striking problems in artisanal fisheries is the lack of data and scientific literature. About 25–30% of the world total output of fish, or

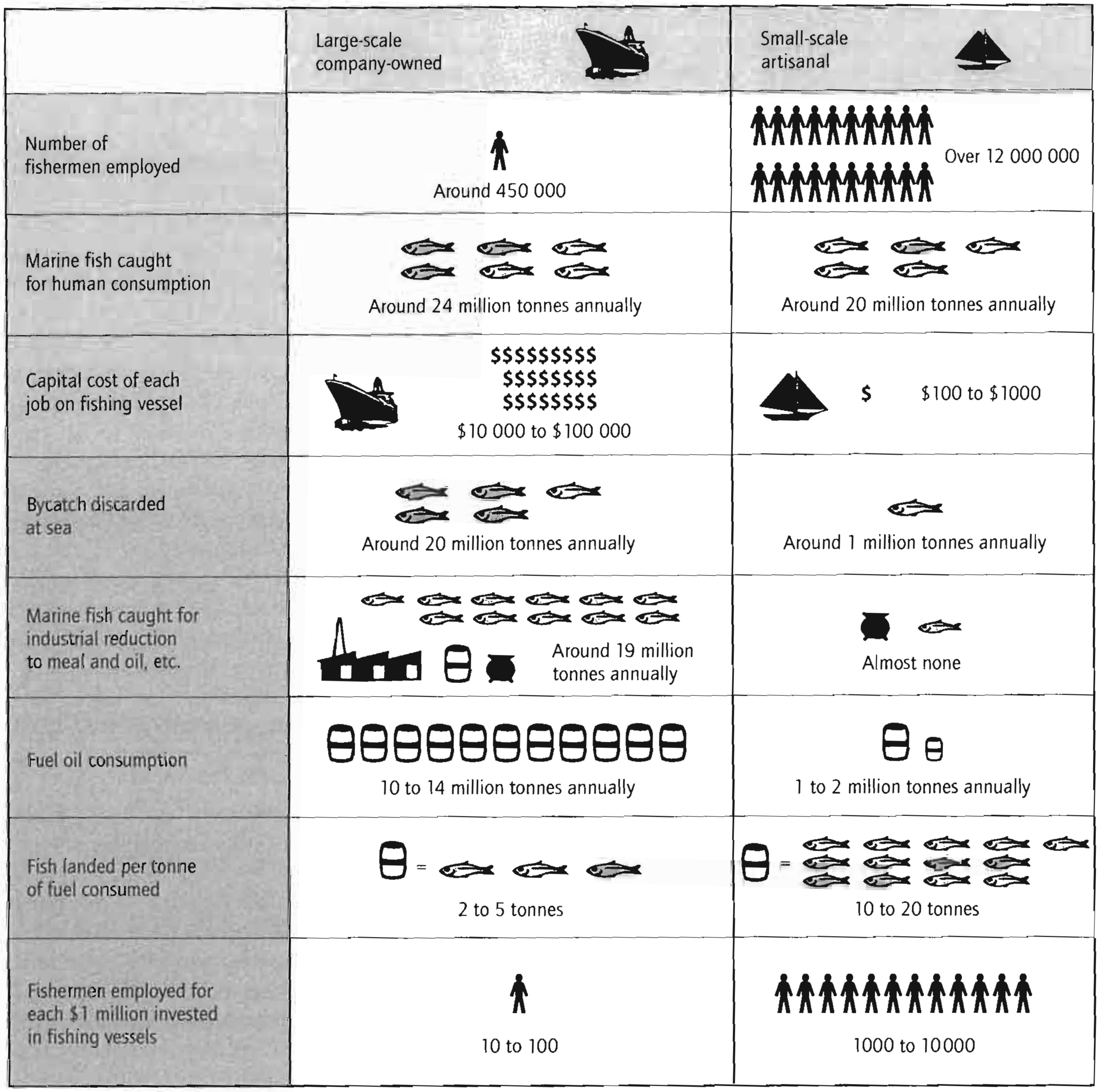

Fig. 2.4 Comparison of large-scale commercial fisheries with small-scale artisanal fisheries. (Source: modified from Thomson 1980.)

nearly half of the landings for consumption (Panayotou 1982; Fitzpatrick 1989; Allsopp 1989), come from small-scale fisheries, which engage 80–90% of all fishermen, estimated at between 12 and 15 million people (Smith 1979; Alsopp 1989; Platteau 1989). Considering the magnitude of this sector, the relative dearth of literature compared with industrial fisheries is astounding and severe. Moreover, most literature on artisanal fisheries is (semi)-anthropological or socioeconomic and gives, if anything, only descriptive accounts of capture devices and species compositions (e.g. Durand et al. 1991). The lack of quantitative data is a particularly acute problem for making meaningful suggestions for research and management (Larkin 1982), but this may also be one of the reasons for the many unsolicited notions that exist around artisanal fisheries. It may be fair to state that small-scale fisheries have received only scant attention during the past few decades of national and international development, with the exception of some agencies specialized in research in developed countries, such as the Institute of Research for Development (IRD, formerly ORSTOM), the International Center for Living Aquatic Resources Management (ICLARM), and Food and Agriculture Organization (FAO).

Many aquatic ecosystems are exploited by artisanal fisheries only. Coastal lagoons, tidal flats, shallow shores, estuaries and coral reefs on the marine side, as well as most freshwater fisheries such as lakes, reservoirs, rivers and floodplains, are by their size, depth, topography or inaccessibility only suited for small-scale enterprises and are exploited in a wide variety of ways. Other coastal areas, except for uninhabited coastlines such as those found off Namibia, are mostly exploited by both artisanal fisheries inshore and industrial fisheries offshore. In many of these there is persistent competition and conflicts between the two types and, with few exceptions, the artisanal fisheries are struggling to survive against the pressures of modernized capture techniques and overexploitation (Crean and Symes 1996).

In Senegal, the artisanal pelagic fishery has been landing over 200000 tonnes of fish per year since the beginning of the 1990s and competes seriously with the industrial fishery (Fréon et al. 1978; Samb and Samb 1995). The bulk of the catch is made up of sardines (*Sardinella aurita* and *S. maderensis*) caught by small purse seines which are typically 250 × 30 m and surrounding gillnets of 200 m × 9 m. (Sech 1980); 14–16 m length wooden canoes, motorized with outboard engines, transport these gears. All the fishing operations are performed manually by a crew of 12 to 18 people. In the case of the purse seine fishery, a second canoe, often up to 20 m length, is used to carry the catch (Fréon and Weber 1983). Similar artisanal fisheries occur along the coast of West Africa (Bard and Koranteg 1995), particularly in Ghana and Côte d'Ivoire. The Ghanaian canoe fleet has over 8000 units, of which more than 2000 are purse-seining, but the yield is lower than in Senegal (around 70000 tonnes per year) due to lower fish density.

In Venezuela the pelagic artisanal fishery is also well developed and targets mainly *S. aurita* using encircling nets operated by up to five canoes. In contrast with the conventional purse seine, which was commonly used until recently, this net does not close at the bottom. The fish school is encircled and then the net is pulled to the shore where its bottom part is in contact with the sea floor. The net is then secured by anchors and buoys, and left for up to a week for a larger vessel to extract the fish still alive and transport them to canneries and fishmeal plants. The landings commonly reach 140000 tonnes per year in recent years (Fréon and Mendoza, in press).

The common limitation of artisanal fisheries is the range of operation. In Senegal two new ways of exploiting resources located far from the landing sites have developed from the 1970s. The first one, called 'marée pirgoque', consists in using large canoes loaded with ice and food that travel up to 800 km from their landing site for a period of 10 to 30 days. The second consists of loading up to 45 open canoes on board a large vessel that transports them to the fishing grounds where they are released for line fishing over several days. The mother vessel provides them with food and water and stores the catches. This mode of exploitation resembles the 'Dory' fishery for cod in the northwest Atlantic during of the nineteenth and early twentieth centuries (Charles-Dominique and Mbaye 1999).

These fisheries are all based on traditional wooden canoes that have been modified by the addition of an outboard engine, a synthetic hull, storage and conservation of the fish, and for the use of modern gear. This shows the high potential for adaptation and evolution of this traditional fishing vessel. Nevertheless the design of the canoes themselves, which dates back many hundreds of years in response to local constraints imposed by the sea and by the coastline where they are built and stored, tends to remain the same and often fishermen resist changes in design. In most of these fisheries, a large part of the catch is processed to fishmeal, the price of which is largely dependent on the global market of soya and fishmeal (Durand 1995). Therefore some crises observed in the artisanal fishery can find their origin on the global market (Fréon and Weber 1983).

For coral reef fisheries the main gears used are nets, hook and line, and spearing or traps for finfish (Medley et al. 1993). Nets are usually set just off the reef and fish are driven to them. Hooks and spearing are more effective for larger teleost predators. Traps are the least selective, taking a variety of fish and crustaceans depending on their construction. An important form of exploitation is gathering, often combined with diving, for the more sedentary organisms. Unfortunately, a number of reef-destroying fishing methods are in increasing use worldwide, often stimulated by the aquarium trade (Rubec 1986). Many poisons, such as bleach or sodium cyanide, as well as explosives, used mainly on schooling species, not only kill the target fish, but also the corals (McManus et al. 1997). Muro-ami is another destructive method where boulders are dropped on the corals to scare and drive fish out of the reef crevices and into nets. Such methods are giving rise to much international concern and inevitably create a negative impression of the whole artisanal sector.

Freshwater fisheries, which account for about 10% of the world total capture, are predominantly artisanal and these are as diverse as the freshwater habitats. Gill-nets, seines, traps, hooks and lines are generally used in most lakes and reservoirs all over the world for inshore and demersal species. However, in most freshwater fisheries of the Western world the traditional methods are slowly phasing out in favour of recreational fisheries for economic and social-political reasons. Important artisanal freshwater fisheries are therefore mainly found in the tropical and subtropical hemisphere, which produce at least 90% of the inland fisheries' yield. Africa is the only continent with large natural tropical lakes. The reported inland fish production south of the Sahel was about 1.3 million tonnes in 1987 (Vanden Bossche and Bernacsek 1990), which constituted a bit more than 40% of the total world production. Still, the reported inland production may only be about half the estimated potential. The three largest lakes, Victoria, Tanganyika and Malawi, alone cover a combined area of 132 500 km^2 and give an annual yield of more than 300 000 tonnes of fish (Kolding 1994). The traditional artisanal inshore fisheries of these and other lakes or reservoirs have over the past three decades mainly expanded and evolved towards the productive offshore resources, consisting of small barbus and clupeid species with a very high biological overturn. With the subsequent technological development of a highly specialized night fishery using larger vessels, light attraction and various encircling seine techniques or large winch-operated dip-nets, some of these fisheries are now rapidly crossing the border between subsistence fishing and small-scale commercial, or even semi-industrial, enterprises.

Rivers and floodplain fisheries are among the most diverse in the world and may still be categorized as belonging mainly within the subsistence sector of artisanal fisheries. In Bangladesh, Indonesia and Thailand, for example, each river may commonly be fished by 20 or more different gears (MRAG 1994; Hoggarth et al. 1999a,b). In the Mekong Delta, producing around 1.2 million tonnes annually, at least 62 different fishing techniques have been classified (Claridge et al. 1997), under 19 general headings ranging from scoop-, cast-, lift- and gill-nets, over a variety of traps, baskets, enclosures, fences and weirs, to spears, guns, poison and explosives. A similar diversity is found in Africa and Latin America. This general picture of a wide variety in fishing gears enables the capture of the many different fish species and sizes, in the many different habitats and during the various changing seasons. As a result floodplain fisheries are in general highly productive, where yields may reach more than 100 $kg\,ha^{-1}\,yr^{-1}$ without signs of biological overfishing (Kolding et al. 1996; Hoggarth et al. 1999a).

2.3.3 *Myths and misconceptions related to artisanal fisheries*

Due to the increased marginalization of small-scale fisheries in the industrial world, or their conversion into semi-industrial or recreational activities, artisanal fisheries are more and more associated with developing countries, and are often perceived as a traditional or even antiquated, poorly equipped subsidence activity (Dioury 1985; Bâcle and Cecil 1989; Platteau 1989). By their informal, free and liberal position they are habitually looked upon as unruly members of a society, which are difficult to manage. Moreover, many of the attempts to 'modernize' these fisheries have failed due to the very fact that the desired changes from 'traditional' practices have encountered formidable obstacles because such changes also affect the social structures which are entrenched in a community (Allsopp 1989; Durand et al. 1991). Africa, for example, is 'littered' with scrambled trawlers and abandoned ice plants/cold stores (Bataille Benguigui 1989; Bernascek 1989) as a result of well-meant, but poorly planned development programmes and the lack of clearly defined government policies and commitments. However, improving the standard of living of small-scale fishermen is but one of the objectives in fisheries policy. Competing, and often more important, objectives are employment creation, and increased production for consumption, export and, not least, national revenue (Smith 1979; Panayotou 1982; Dioury 1985; Chauveau and Samba 1989; Platteau 1989). Consequently, as other economic sectors are 'advancing', many small-scale fisheries are left behind with an increasingly negative image of being persistently poor, ignorant, ancestral, and often resource-depleting or ecosystem-destructive (Panayotou 1982; Bâcle and Cecil 1989; Amar et al. 1996), although the latter may be a direct consequence of the unfair competition they are exposed to (Thomson 1980). This picture, however, is not uniform and there is an increasing attention to the importance of this sector and a growing awareness of the need to conserve these communities. Several studies show that smaller-scale technologies are more socially and economically rational and efficient (Thomson 1980; Fréon and Weber 1983; Dioury 1985; Durand et al. 1991) and that they may reconcile high returns on capital, low investments, labour-intensiveness and high added value (Fig. 2.4). Finally, they constitute a prerequisite for the new paradigm for community-based resource management (Verdeaux 1980). Many are not declining but advancing, renewing equipment, transforming their boats and gear, and taking advantage of market changes (Durand et al. 1991). Still, the overwhelming opinion among many actors in the fisheries sector, particularly among assessment biologists, economists and policy makers, is that small-scale fisheries in developing countries employ inefficient, wasteful and indiscriminate fishing practices (Chou et al. 1991), ignore gear regulations and legislation (Panayotou 1982; Gulland 1982), are subject to open-access 'Malthusian overfishing' (Pauly 1994; Amar et al. 1996), and therefore need to be managed and controlled one way or the other. Are these notions true, or are they myths and misconceptions? As this chapter is dealing with capture devices, we will discuss here only the rationality of prohibiting non-selective fishing methods which is occurring in most artisanal fisheries.

2.3.4 *From gear to management*

Capture devices are intrinsically associated with selectivity, and selectivity, or the impact of fishing on an ecosystem, is an essential component of a management programme (Pauly and Christensen, Chapter 10, this volume). Consequently, much effort is devoted to investigations of the efficiency and selectivity of active and passive fishing gears (Fitzpatrick 1989). Recent developments have been motivated and promoted by world and market opinion, leading to devices that allow turtles to escape from shrimp trawls,that reduce entanglement of mammals in drift-nets and purse seines, and that decrease the large volumes of by-catch in the shrimp- and other specialized fisheries (see the purse seine and trawling sections above and Kaiser and Jennings, Chapter 16, this volume).

The importance of selectivity is therefore rooted in most researchers and managers, and any non-selective capture method automatically carries the connotation of being harmful, bad or destructive, or will at least lead to growth-overfishing, seen from the traditional single-species perspective (Shepherd and Pope, Chapter 7, this volume).

Mesh size- and gear restrictions are among the most easily applied and widely used management regulations. Consequently most nations have imposed legislation, which bans certain gears and mesh sizes, with the aim of protecting the resource (Gulland 1982). Although many of these regulations have originated from the problems associated with the large-scale fisheries, they are often uniformly applied on all sectors. However, selectivity seems much more a problem for industrialized fisheries, which on average dump about 45% of their catch, while small-scale artisanal fisheries discard on average only 5% (Bernacsek 1989), despite the fact that they mostly operate in more multispecies environments. Although numerous authors have already pointed to the problems of defining the 'right' mesh size in a multispecies fishery, the notion of regulations on selectivity still persists. In addition, small-scale fisheries often use a variety of gears, both traditional and intermediately modern. Many of these gears, and particularly the traditional ones such as seines, small mesh sizes, drive- or beat fishing, barriers, weirs, are often classified as illegal under the pretext of being non-selective with assumed negative impacts on the fish populations. However, the actual impact of these methods is rarely investigated and the true aim of the regulation may be to protect for political or social reasons the position in a fishery of another less efficient gear (Panayotou 1982). In the few instances where the actual impact of non-selective illegal gear used in small-scale fisheries has been studied, it is in reality an open question how 'detrimental' these fishing methods are. Two such case studies are from the floodplain fisheries in Zambia (Kolding et al. 1996; Chanda 1998), and the artisanal beach seine fishery on the Cape coast in South Africa (Bennett 1993; Clark et al. 1994a,b; Lamberth et al. 1995a,b,c).

In fact, non-selective harvesting patterns are in principle ecosystem conserving. All species are preyed upon at various rates during their lifespan, and for teleosts the highest mortality is usually during the early life history phase (Myers, Chapter 6, Hutchings, Chapter 7, both Volume 1). Thus theoretically, the 'utopian' but optimal exploitation pattern, by which an ecosystem could be maintained in balance, is fishing each trophic level and fish population in proportion to the rate of natural mortality (M_i) it is subjected to (Caddy and Sharp 1986; Kolding 1994). However, as all fishing gears are more or less species- and/or size-selective, such non-selective 'utopian' exploitation patterns can be achieved only by employing a multitude of gears simultaneously. The multigear, multi-species artisanal floodplain fisheries often seem to be producing an overall species, abundance, and size composition that closely matches the ambient ecosystem structure (MRAG 1994; Kolding et al. 1996; Claridge et al. 1997; Chanda 1998; Hoggarth et al. 1999a,b). On the ecosystem level such an exploitation pattern may be considered unselective across the species diversity range, and floodplain fisheries, particularly in Asia, seem to have persisted, with the only change coming from natural fluctuations, despite a very high fishing effort. Judgement on this is limited by the length of the data series we have.

In other words, the multi-gear, which is generally unselective, fishing pattern employed in many small-scale fisheries, combined with the ability of fishermen to change their target species within a single trip (Laloë and Samba 1990), is the closest example of the optimal exploitation pattern that exists. Therefore, the established fishing practices versus legal frameworks may easily become not only an infinite tug of war, as seen in most instances where small-scale fisheries have resisted the implementation of gear-restrictive regulations, but also a completely futile tug of war, as seen from the perspective of ecosystem conservation.

2.3.5 Can we manage small-scale fisheries?

The survival of traditional management systems, or perhaps more commonly, the persistence of small-scale fisheries under unmanaged conditions, is challenged and often overwhelmed by the tendencies of modernization, accumulation and concentration in which increased capital investment and the creation of global markets affect the means of production. Accelerating technological sophistication in capture methods, as well as subsequent increasing conflicts between commercial and small-scale fisheries, may be seen as the capitalistic way of delaying the economic consequences of declining resources (Crean and Symes 1996), as evidenced by the growth of advanced gear technology and distant water fishing fleets (Alverson and Larkin 1994). The universal solution to these conflicts seems to be characterized by the intervention of the state in terms of technocratic regulation systems based on mesh and gear restrictions, TACs and quotas (Beverton 1994). However, when both artisanal and industrial fishermen are exploiting the same resource, a total quota is certain to favour the large-scale fisheries, which have greater catching capacity. Unavoidably, the livelihood of the small-scale fishery will be reduced while no economic surplus would be generated in the fishery as a whole (Panayotou 1982). Unfortunately, science is used (and shaped?) to legitimate the implementation of these regulation systems and thus shield the policy makers from confronting the basic sociological objectives of fisheries management. By focusing on single-species TACs, quotas, and enhanced selective harvesting strategies and gear development, the mainstream research is better suited for those having the equipment and vessel technology to make a quick kill on targeted species, than for the small-scale fishermen working outside the global markets. Incidentally, the dominating scientific paradigms thus protect and favour the interests of the corporate structures and do little to investigate the truth behind the possible myths and misconceptions related to small-scale artisanal fisheries, as evidenced by the relative absence of scientific literature on this sector. On the contrary, the independent, and often technically 'illegal' response, by small-scale fisheries to increased regulations in order to safeguard their traditions and livelihoods, is used to brace and support the views on this group as being backwards, indiscriminate and destructive in their fishing patterns. Nevertheless this sector proves that it is still capable of reacting and innovating at the level of its organization.

2.4 CONCLUSIONS

The gear used in industrial fisheries is characterized by changes brought about by technological innovation. This, coupled with the intense competition between fishers to catch their share of the catch, has led to larger boats, nets and electronic fish-finding equipment. The emphasis in the past has been on improving the catching power and efficiency of vessels and fishing gear. The increasing demands of management are now leading to the use of technology to improve the selectivity of fishing, with devices such as the sorting grid, inserted into the trawl tunnel, helping to reduce bycatch. Further devices, such as satellites, will be increasingly used to monitor fishing effort spatially and temporarily, so making it easier to ensure that fishers are following the regulations,

There is an urgent need to remedy the lack of quantitative information on small-scale fisheries. In terms of capture devices there is a particularly important need to establish the selectivity of the various gears individually and in combination in order to evaluate their impact on the ecosystem. Faced with the complexity and heterogeneity of the operating conditions of small-scale fisheries, the present national and international efforts in small-scale fisheries seem concentrated on management implementations. However, without the necessary fundamental research, these implementations will be based on the reiterated dogma and may face the same failures as the many previous attempts to 'modernize' these fisheries.

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