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Technological trends in capture fisheries

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Abstract

Technological developments were a major cause for the increased landings from capture fisheries in the second half of the last century. The fishing vessels were made more powerful, combined with the development of better fishing gears partly as a consequence of the introduction of synthetic fibres in gears like trawls, purse seines and gill nets. Development of gear handling devices and electronic instruments to locate fish aggregations and control gear operation were equally important factors in this development. Such important developments of fleet and fishing methods are briefly reviewed in this article. Besides technical developments aimed to increase fishing efficiency, recent developments have also included technologies and fishing practice, which reduces the environmental impact including improved selective performance of some fishing gears resulting in reduced bycatch and discards. The article briefly provide an outlook of possible future developments of capture fisheries and it concludes that increased landings can be achieved if organisms lower in the food chain are exploited more intensively with proper developed technology, and that environmental concerns will force the industry to make more use of responsible fishing gears and practices. © 2001 Elsevier Science Ltd. All rights reserved.

1. Introduction

The global landings from capture fisheries (inland and marine) have increased dramatically during the second half of the 20th century. The landings rose to 64 million tonnes in 1970 from about 19 million tonnes in 1950. Since 1990, the catches have stabilized around 85–90 million tonnes [1] (see more about the development of catches in the chapter on trends in biological resources, this volume).

This growth of capture fisheries has been achieved through a combination of two major factors. First of all, the number of people occupied with fishing has increased, together with an increase in the number of vessels and their sizes. Another important

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explanation for the increased catches is the dramatic improvement of the efficiency of fishing operations during the second half of the 20th century.

The most significant examples of technological innovation have been seen in the larger sized industrial fishing fleets. Particularly, in the 1960s and early 1970s powerful new fleets were built which could operate far from the base, using highly efficient gear such as the pelagic trawl and the purse seine, and in some cases with onboard processing of the catch. Then, in the 1980s came the general extension of fishing limits following the United Nations Conference on the Law of the Sea (UNCLOS), which greatly reduced the fishing opportunities for distant water fleets and the focus was turned to middle distance fisheries within national limits.

Technology has also had some impact on the small-scale artisanal fisheries. However, innovations in this sector have been relatively simple. For example, nets made from synthetic fibres are more efficient and last longer. Outboard or inboard motors allow fishers to get further afield more quickly, or to surround pelagic schools rapidly with their nets.

This chapter reviews major trends on how the global fishing fleet has developed during the most recent years. This is followed by highlighting some of the developments in catching techniques that has had a major influence on the increases in capture fisheries during the second half of the 20th century.

2. The world fishing fleet

In 1995, the world fishing fleet numbered about 3.8 million vessels. About one-third of these were decked vessels, the remaining were undecked, generally less than 10 m in length. While almost all decked vessels are motorized, only about one-third of the undecked are equipped with an engine [1,2].

A major part of the world's decked fishing vessels is operating in Asia (Fig. 1). Following two decades of rapid growth in the numbers of decked vessels, they have changed a little since 1990. In fact, if it was not for the increase of decked fishing vessels in China from 60 000 in 1980 to 460 000 in 1997, which partly was a result of privatization of the fishing sector, the number of decked vessels in the world would have remained stable between 1980 and 1995. Figs. 2 and 3 illustrate the development in numbers and tonnage of the same fleet by the type of fishing. Gillnetters and vessels fishing with lines account for a considerable proportion of the world fleet of decked vessels. Trawlers tend to be larger and more powerful vessels and they dominate in terms of tonnage, amounting to about 40% of the aggregate GT (Gross Tonnage) of the fleet.

Fishing vessels larger than 100 GT (or larger than 24 m) amounted to 37 000 vessels in 1995. Approximately, 40% of these vessels belonged to China, while no other country had more than 10% of this fleet. This size of the vessel is generally capable of fishing on the high seas, but it is estimated that at least half of this fleet never does so. Lloyds Maritime Information Services (LMIS), which obtains data under exclusive licence from Lloyds Register of Shipping, maintains detailed information on individual vessels in this category. A recent study, undertaken by

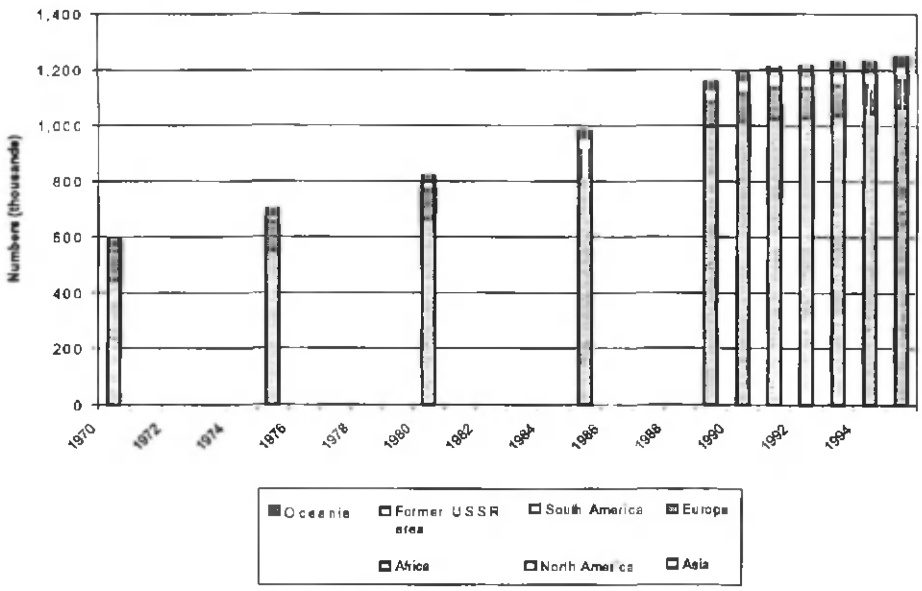

Fig. 1. Number of decked fishing vessels by continent (FAO).

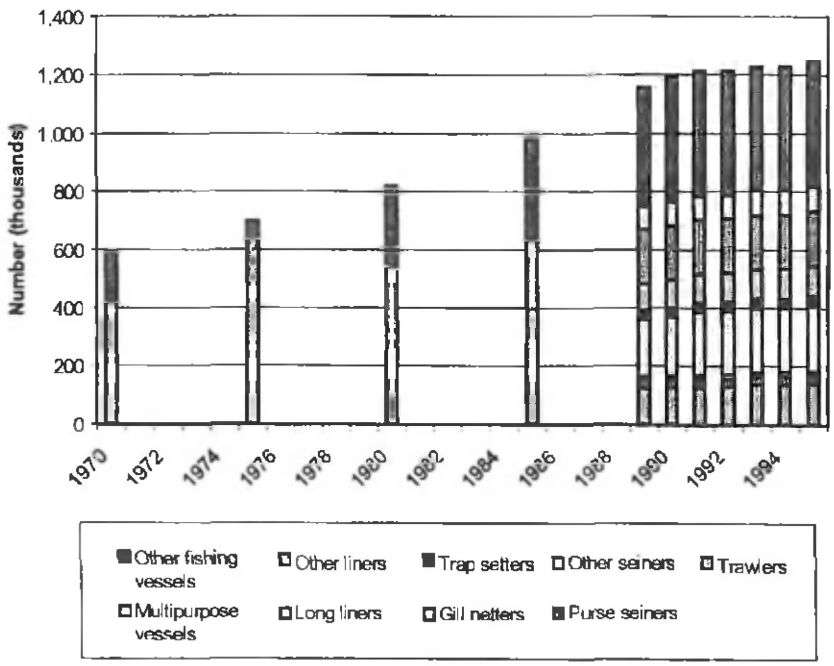

Fig. 2. Number of vessels by type in the world fleet of decked fishing vessels (FAO).

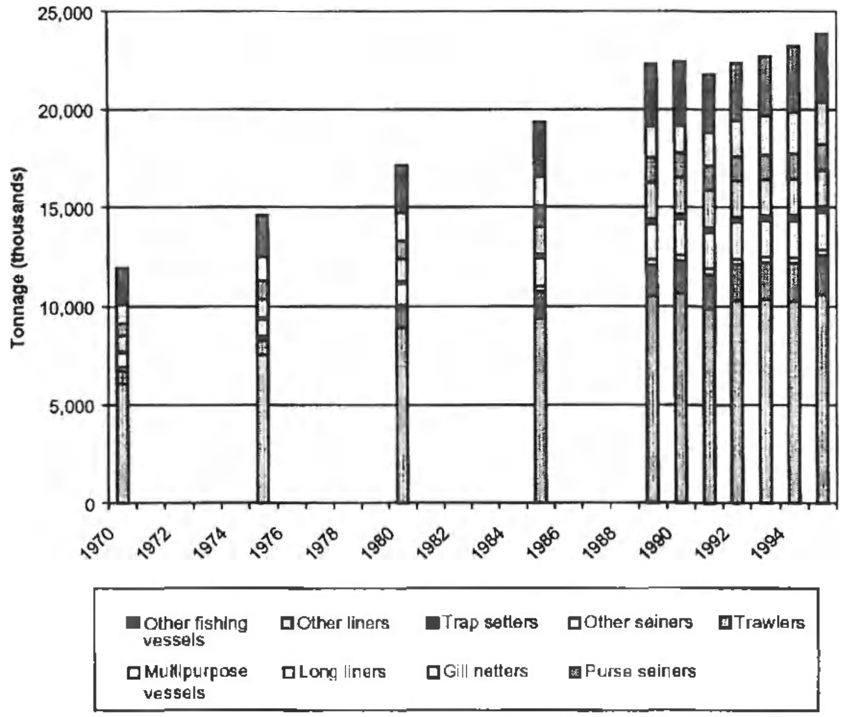

Fig. 3. Tonnage by vessel type in the world fleet of decked fishing vessels (FAO).

FAO, of vessels contained in this register provides some interesting insight into the development of this fleet during the past few years [2].

In 1997, fishing vessels in the Lloyds register of Shipping numbered 22 668. However, the LMIS database contains virtually no information on vessels registered in China, the Democratic People's Republic of Korea or Taiwan, Province of China. For the remaining countries, LMIS contains approximately 80% of vessels reported to FAO by member countries.

The trend in the number of larger fishing vessel can be seen from Fig. 4. Between 1985 and 1991 there was a gradual increase in the number of these vessels and after 1991 there has been a significant reduction. This reduction certainly reflects the overfishing problems experienced in recent years when governments have imposed licence regulations and programmes to reduce fishing fleets. The present age profile of the larger vessels shown in Fig. 5 is also an indication that a further reduction can be expected in this fleet segment in the coming years, as vessels older than 20–25 years can be scrapped or are decommissioned.

The development of vessel sizes and engine power is not obvious from the data set. There have been developments in various directions, depending on the fishing method and the fish targeted and not least because of variable fuel prices experienced during the last quarter of the century. Fuel is an important running cost for several

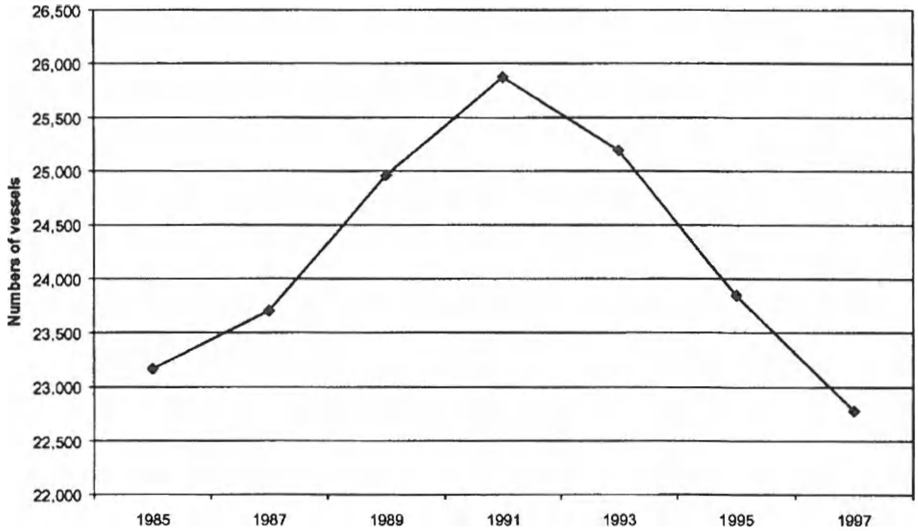

Fig. 4. Number of fishing vessels over 100 tonnage (Lloyds database).

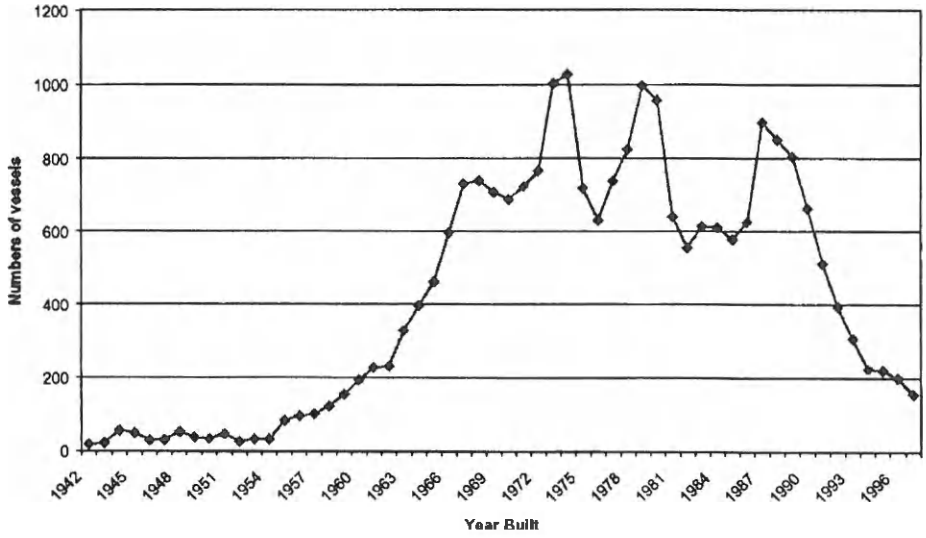

Fig. 5. Year of building of vessels in the 1997 dataset (Lloyds).

fishing methods, and has therefore been an important factor to consider when engine sizes had to be selected for new vessels. The global data, however, cannot identify such variations, but a general trend was that the far distant fleet, built in the 1960s and 1970s, mainly by the then eastern-block countries, typically consisted of many larger vessels for operating pelagic trawls in particular. The average horsepower of vessels in the Lloyds database is shown in Fig. 6. This figure illustrates to some extent that more powerful vessels have been built in recent years. This coincides with relatively low fuel prices experienced over the last 10–15 years compared to the situation following the international fuel crisis after the wars in the Middle East in the early 1970s. Another explanation for increased horsepower in recently built vessels is the expansion of the fleet of vessels operating large pelagic trawls, as has been seen in the Alaska pollack fishery and for mackerel, blue whiting and redfish in the northeast Atlantic.

3. Fishing vessels

The design and equipment of fishing vessels have changed considerably during the 20th century consistent with the development of the entire industry, increased competition on resources, and the need to travel further to find fish. Wood remains the most commonly used material for the construction of fishing vessels, though in developed countries (and to a small extent in developing countries) fibreglass reinforced polyester (FRP) has replaced the use of wood in vessels up to about 18 m, while steel is the preferred choice on larger fishing vessels. Developments in non-marine industries have influenced fishing vessels through developments in diesel engines, hydraulics, electronics and refrigeration. In developed countries, virtually, all classes of fishing vessels are equipped with navigational and fish finding aids,

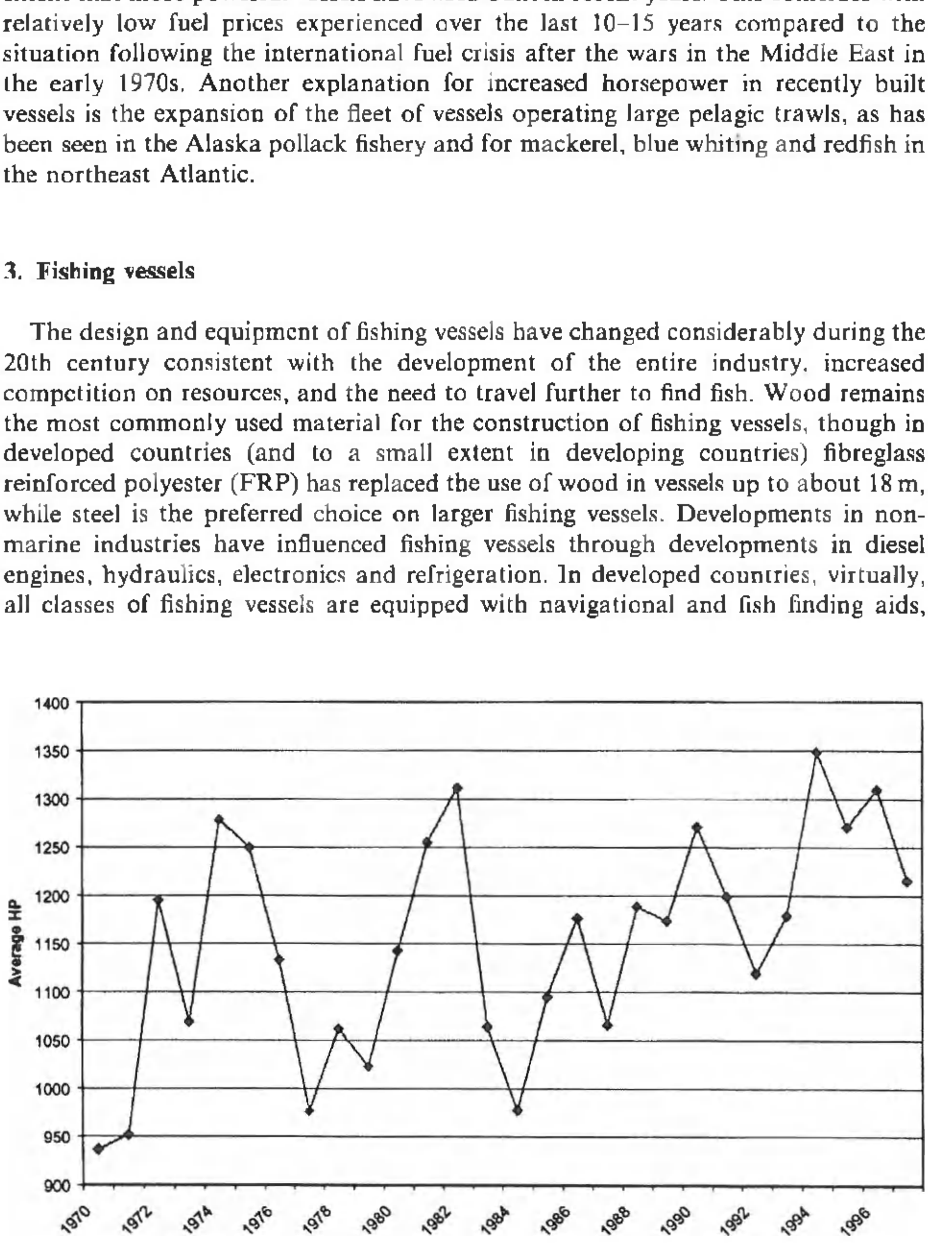

Fig. 6. Average HP of the present fishing fleet by date of construction (Lloyds).

hydraulic or electrical equipment for handling the gear and various means for preserving the catch. The safety of larger fishing vessels has been positively influenced by the implementation of Global Maritime Distress and Safety System (GMDSS) and the introduction of satellite based vessel position monitoring schemes, but still there remains no international legal instrument covering the safety of fishing vessels. In developing countries, the issue of safety of vessels and their crews is largely neglected as a result of inadequate regulation and enforcement. As the equipment of a vessel is often related to the fishing method, more specific developments are mentioned under the description of each of the major fishing methods below.

4. Fishing methods

Fishing methods have continuously evolved throughout the recorded history. Fishers are innovative people, who effectivley have made use of new technical developments and modified it to suit their purpose of catching more fish. The opportunities for innovation have been especially good in recent decades with advances in fibre technology, naval architecture, navigation aids, computer processing, gear design and acoustic fish detection, to mention only a few of the major technologies.

When reviewing the outgoing century for events, that have had substantial impact on the development of fishing technologies and practices besides the large scale motorization of the fleet, it is difficult to find anything that overshadows the introduction of synthetic fibres in fishing gears, which can be dated to around 1950. It can certainly be argued that the innovation of the power block in 1953 was a perquisite for the development of modern off-shore and large-scale purse seining, but this technology was only made possible because of the stronger netting material made available from synthetic fibres. Pelagic trawling can also been considered as a major development in this century, but neither development would have been possible without the strong synthetic fibres.

The following is a closer look at major developments of important fishing methods, such as bottom trawling, pelagic trawling, purse seining, gillnetting, longlining and a few others, with particular emphasis on technological developments related to the efficiency and environmental issues.

4.1. *Bottom trawling*

Modern bottom trawling techniques, using otter boards to spread the gear horizontally, were developed by an Irish fisherman between 1860 and 1870. Its commercial use dates back to the end of the last century [3,4]. Since then, it has developed to become the most important fishing method to exploit high value fish and shrimp resources living on or in the vicinity of the bottom. The gear has gone through significant development steps over time and is typically specialized for the targeted catch. A major feature of a trawl is that it needs to be towed through water and therefore its resistance to movement (drag) is of importance. Another factor is that such a gear has to be towed across bottoms that are not always even and smooth. A third issue of increasing concern is that a trawl may catch most of the organisms that come into its path, resulting in bycatch and discarding practices.

Introduction of synthetic fibres in trawls in the 1950s and the 1960s was a major step to increase the size of the trawl without increasing its drag. Since the synthetic fibres like polyamide, polyester, polyethylene and polypropylene were introduced, no major improvements of such fibres occurred before the late 1980s, when a super-strong carbon-based aramid fibre was developed (Dynemea). This fibre has 4–5 times the breaking strength of the traditional synthetic fibres, but because of its high cost it is presently not widely used as netting material in bottom trawls. Its potential, however, is obvious and increased use is to be expected particularly if the price of the material is reduced.

An important and relatively recent (10–20 years ago) development of bottom trawling technique is the use of several parallel trawls rigged between two trawl doors. This is a technique that increases the horizontal fishing area substantially, particularly to catch non-reacting organisms like shrimps more efficiently. The twin/double/multi-trawl rigging is now common, used both by larger deepwater shrimp trawlers in northern waters, and by shallow water outrigger shrimp trawlers in tropical fisheries, which may use two trawls on either side towed from outrigger beams. The technique is also becoming popular in various flatfish fisheries, and even trawling for some roundfish species has been successful. Twin trawls can be rigged with a bridle arrangement attached in front of the otter boards as one option, but many vessels operate with three parallel trawl wires handled by separate winches. On an experimental basis, three parallel trawls have been successfully rigged behind two trawl doors. Further developments and use of multi-trawl riggings can thus be expected in the future.

Bottom conditions where trawling occurs are often variable, from smooth sandy bottom to a rocky, uneven surface, where the risk of the fishing gear becoming entangled on rocks or wreckage and possible gear damage is high. The trend in recent years has been towards fishing in worse and worse bottom conditions as well as going into deeper and deeper waters, where bottom conditions often are known to be fairly rough. Trawling in such areas has been made possible not least with the development of rougher bottom gears for protection of the more sensitive netting parts, first through the use of gears with large rollers and later with the development of the so-called rock-hopper gear. The latter gear allows trawling in areas where stones of up to 2 m diameter might occur.

Trawling in deep waters down to 1500–2000 m was developed in the 1980s targeting particularly the valuable orange roughy, mainly in South Pacific waters. Fishermen from New Zealand primarily developed this fishery, but other countries soon became involved. Fisheries for orange roughy have now spread to many other areas where new resources of this species are located. Trawling in such deep waters requires powerful deck machinery and not least instrumentation to locate the fish aggregations, to provide accurate navigation and to monitor the gear during fishing.

Instruments for acoustic fish detection were developed for fishery purposes in the 1940s as a result of successful transfer of a naval technology originally designed to detect submarines. This is without doubt the non-gear development that has influenced the efficiency of fishing operation most. The major instruments are the echo sounder and sonar, which both have been significantly improved during recent years [5]. Changing from paper recording of echoes to the colour screen display was a major development during the late 1970s and the computerized processing of echoes was a major development of the late 1980s, a process which is still ongoing.

Instruments which monitor gear performance have undoubtedly been useful in the process of developing efficient trawling in deep waters and in difficult weather conditions as well as for the monitoring of more complicated gear riggings. The cableless transmission of signals from the gear monitoring sensors, attached to the trawl, was a major breakthrough for such instrumentation in the 1980s. The warp tension control was also an important development in the same period, facilitating trawling in bad weather. A very recent development in that respect is a sensor that measures the symmetry of the trawl during towing, further improving the precision whereby a trawl can be adjusted to function optimally while fishing in changing conditions.

The feature of trawl catching and mostly everything in its path has increasingly become a major concern and is one of the main reasons for the generally poor image of trawling as a fishing method. In addition to the target species, a trawl catch might occasionally consists of juvenile fish and other non-target species that are subsequently discarded. Already in the 1950s, larger codend mesh sizes were introduced in the North Sea fisheries to allow smaller individuals to escape from capture. Since then, many countries around the world have legislated minimum codend mesh sizes in their trawl fisheries. Mesh size regulations alone, however, have limitations as a relatively wide range of sizes still might be retained in the codend, which is a particular problem when the target species are of different sizes in the so-called multi-species trawl fisheries [6].

Until 1975, management concern related to trawl fishing was mainly focussed on the capture of juvenile fish, which was, and still is, often considered a practice that gives reduced yield of a fish stock. From around 1975, however, capture of non-target non-fish species became an important issue when environmental groups began to focus on the incidental catch and killing of turtles in the tropical shrimp fisheries, at that time a widespread and expanding fishery. These "green" groups had their origin in the United States, a country that has major fisheries for tropical shrimp in the Gulf of Mexico. Such groups exerted strong political pressure to stop the incidental killing of turtles by shrimp trawlers. During the 1980s technical solutions, such as the TED (turtle excluder devices), were developed and made mandatory in the US tropical shrimp trawl fisheries [7]. Other countries, having shrimp fisheries where incidental catch of turtles could occur, were likewise targeted, and this subsequently resulted in an unilateral US embargo on shrimp import from countries that were not complying with measures to avoid turtle capture while shrimp trawling.

Several other technical solutions to minimize the capture of non-target fish were successfully developed and introduced during the last part of the 20th century. The outstanding star among these developments was the Norwegian designed separator grid, used in the deepwater shrimp fishery, which to a large extent solved the problem of bycatch during fishing, which in many areas is considered a non-sustainable practice [8].

Fish trawls as well have been subject to modifications with respect to size selection of the targeted fish. Such modifications have included the use of more open meshes in the codend achieved by turning the netting 45° until the mesh attains a square configuration during fishing [9,10]. These mesh shapes facilitate the escapement of fish and result in better selective properties. Grids acting as a filter have also proven to be superior to traditional diamond meshes with regard to size-selective performance [11].

4.2. Pelagic trawling

Since pelagic trawling was invented in Denmark in 1948 [12] as a two-vessel operation, the major development has been towards larger gears, one-boat operation and the use of more powerful towing vessels. A modern trawl might have a mouth area of 15 000 m^2, whereas 250 m^2 was typical for the first pelagic trawl designs, a 60 times increase in catching volume. A major step towards increased size of pelagic trawls occurred in the early 1970s when it was found that fish in the trawl mouth reacted by avoiding netting made from much larger meshes than they easily could escape through. This was the start of a development of front parts with 10 m meshes (France) or of parallel ropes (Former DDR), which later have increased further to meshes measuring 64 m in some large pelagic trawls used to catch scattered concentration of redfish in the Irmirger Sea.

The pelagic trawls are most commonly made of a four-panel construction, and typically the front part is now made from buoyant synthetic fibres, which is often a combination of more than one material. The aft part, including the codend, is normally made from nylon material. The Dynema fibre, mentioned earlier, has been used on an experimental basis in various parts of the pelagic trawl to reduce resistance, as thinner twine can be used from this very strong material. The benefit of using such thin and strong netting seems to be the most apparent in the aft belly where a significant proportion of the trawl drag originates. The resistance of the trawl is approximately 90% of the total gear drag. The other 10% originates mainly from the trawl doors, which also have undergone some development during the evolution of this fishing method, particularly with regard to steel material used and handling. The hydrodynamic efficient Süberkrüb door developed in the 1960s is, however, still a model for many of the most recent successful developments of pelagic trawl doors.

Efficient pelagic fishing with trawls relies to a great extent on instruments for localization of fish aggregations and on instrumentation to monitor the gear during fishing operation [13]. Sonar to measure density and to track movement of fish schools ahead of the towing vessel has been improved and is now commonly used in successful pelagic trawling. Instruments to monitor the entrance of fish into the trawl and to monitor the trawl shape during fishing as well as the filling of the codend with catch are standard equipment on modern pelagic trawls.

The pelagic trawl with its recent enlargements and new instrumentation is now undoubtedly the most important gear to exploit the large resources of Alaska Pollack in the North Pacific and blue whiting and redfish in the North Atlantic. Pelagic trawls are also an alternative gear to purse seines for exploiting the many herring, anchovy and mackerel stocks throughout the world. An important development in recent years is also the development of a pelagic trawl fishery for smaller tuna species.

Development of a fishery with large pelagic trawls has been possible, not least because of the mechanized handling of the trawl with large and powerful net drums, introduction of refrigerated sea water (RSW) to store large amounts of fish in bulk and the fish pump, which can rapidly take onboard large quantities of fish from a codend. Catches might often exceed 100 tonne in many fisheries.

4.3. Purse seining

Modern purse seining was a result of the two major developments in the 1950s; introduction of synthetic fibres as netting material and development of the power block [14]. The high efficiency of purse seining was also due to the advances made in fish detection from about the same time and later [15]. Schooling fishes, such as most of the clupeoids, scombroids and carangids, were obvious targets for the purse seiners. The fishing method was so efficient that several important fish stocks were subject to serious overfishing in the 1960s and 1970s. These included the Peruvian anchovy, Japanese sardine, South African sardine, Atlanto-Scandinavian herring and the North Sea herring. After depletion of some of these stocks, their recovery was only possible through strict regulations in fishing effort.

The purse seining technique has developed in different directions, particularly regarding handling of the gear. Three basic principles can be identified in the present purse seine fleets. One is based on the original method using a single block, positioned high above the deck for hauling and stacking of the net. This method demands normally a relatively large crew [15–25] for handling of the net. This technique is still popular and is in use in several major purse seine fisheries, such as for tuna by the US fleet fishing menhaden, the Peruvian fleet fishing for anchovy and a wide range of Asian and African purse seine fisheries. The technique has evolved over time and among recent developments are a rail-mounted roller that facilitate the hauling of heavy nets [4].

Another system has been developed in Norway, the Triplex net hauling device, consisting of three rubber-coated rollers rotating simultaneously in the opposite direction of each other to haul in the net. The purse seine net is threaded between the rollers to create friction, and by this system the net can be operated with large catches and in rough weather conditions. In addition to the Triplex hauler, this system consists of a second transporter block to bring the net to its stacking position on the vessel. As a result of a demand for reduction of the crew on purse seiners in Nordic countries, in particular, the stacking of the net was further mechanized by a manoeuvrable stacking block, and handling of the net now requires only 3–5 crew members on the largest purse seine vessels.

A third system is the drum seining, where a stern drum is used to haul the seine. This technique requires a special purse seine design, where the netting is of the same length as the float and ground ropes. This technology is widely used by smaller seiners catching salmon off the North American West Coast [16].

A major improvement in the purse seine fishery occurred when the vessels were equipped with tanks for RSW for storing the fish. This made it possible to store and transport large quantities of fresh fish. For some purse seine fisheries, freezing is the most common way to preserve fish onboard for longer periods of time.

Another development that significantly facilitated purse seine operation, not least with regard to reduced time for emptying the gear for large catches, was the development of the fish pump [17].

The purse seine fishery is normally regarded as a relatively "clean" fishery where the catch mainly consists of a school of one fish species. There are, however, situations when non-targeted organisms are captured. The outstanding example, similar to the turtle issue in shrimp trawls which has caused major international problems was the incidental capture of dolphins in the tuna purse seine fishery. In the late 1950s, an efficient fishery for yellowfin tuna developed with purse seines, as it was found that a school of dolphins on the surface often was associated with a school of tunas below. Encircling the dolphins thus resulted in a catch of tuna but in addition large quantities of dolphin could be caught, which often entangled in the netting and subsequently drowned. A substantial effort was devoted to solve this bycatch problem. A successful technique using a combination of a modified operation, the "backdown method" and a panel of smaller meshes to reduce entangling, the "Medina panel" was developed and is now mandatory in these tuna fisheries. Both these major developments were a result of ideas and initiatives by active fishermen [18].

Another and more recent development in tuna fishing is to target aggregations of fish associated with floating logs or manmade constructions called fish aggregating devices (FADs) [19]. A problem experienced with this kind of purse seining is that the catch often consists of many small individuals, both of the targeted tuna species and also other non-tuna fishes. At present, a technical solution to mitigate this problem has not been found.

By its nature of operation, a purse seine will normally catch all the encircled fish. To avoid gilling large amounts of fish that eventually will try to escape, particularly when they become densely packed at the final stage of the pursing operation, it is of utmost importance that the mesh size is small compared to the targeted fishes. This non-size selective property of purse seines can sometimes cause problems as when the encircled fish school consists of different sizes and when benefit is only seen in catching the high-valued larger fish. There might also be regulations in places, where it is illegal to catch and discard fish below a certain size. Some recent experiments with size sorting grids in the purse seine have shown that this problem can be solved for some species [20,21]. But the fish handling, before and during escapement, through sorting grids may generate fish injuries and later mortality. More research on the survival of escaping fish through such devices is therefore required before it can be introduced in commercial fisheries.

Avoiding of non-target fish sizes and species can also be achieved if the fishers have information about the school composition before it is encircled. There are ongoing developments of sonar instruments that aim at species recognition of a target school and also to have an indication of fish sizes based on a frequency distribution of the targets. This has to some extent been successfully developed for vertical echo sounders [13,15].

4.4. Gillnetting

The gillnet is one of the predominant and most efficient fishing gears used by all sizes of fishing vessels all over the world, from tropical regions to under-ice fishing in the Arctic region and in marine as well as in fresh water. It has been used from ancient times and is a simple and relatively cheap way of fishing demersal, as well as pelagic, species. It is certainly one of the most energy effective methods in terms of fuel used per kg of fish caught. Before trawling and purse seining, gillnetting was introduced as a result of the motorization of the fleet; gillnetting was, in fact, a very productive way of fishing schooling pelagic resources, such as herring in the North Sea.

As for the other mentioned gears, the synthetic fibre was also very beneficial for improved catching efficiency of gillnets. Particularly, due to the importance of the visibility of gillnets, the introduction of transparent monofilament nylon resulted in significant increases in its catching performance [22]. The synthetic fibre was also much stronger than the previously used natural fibres, and thus made it possible to mechanize the gillnet operation with hydraulic hauling equipment.

The gillnet fishery expanded rapidly during the 1980s particularly in the Pacific Ocean due to the fishing vessels from Japan, Korea and Taiwan, Province of China. These fisheries mainly took place on the high seas and targeted species of tuna, salmon and squid. This fishery became an international issue of concern when it became known that the large fishing effort for these species was a threat to the long term sustainability of such species, and that such a fishing practice represented a serious threat to certain non-target species, particularly some seabird species and marine mammals (whales and seals) [23]. Although the conflict had its roots in the Pacific, where the major fishing grounds were located, the United Nations General Assembly adopted a resolution (44/225) to ban all high-sea driftnetting in December 1990. In recent years, bottom set gillnetting has also been criticized because of its ability to continue to catch fish when the net cannot be retrieved for accidental reasons. The gillnets which are made from synthetic fibres are not biodegradable and will continue to catch fish for a long period of time, the so-called "ghost-fishing".

4.5. Longlining

Using baited hooks on branch lines attached to a main line for fishing started on a larger scale some centuries ago when hooks could be industrially produced at a reasonable cost. In Norway, longlines were known at least since the 16th century. During the 20th century, longlining like the other fishing methods has been significantly developed, both with regard to individual hook efficiency and not least because the mechanization of operation which has greatly increased the number of hooks to be operated by a given crew. In demersal longlining, the automatic baiting machine was developed in the early 1970s and are now commonly used by larger demersal longliners in all oceans. These machines can deploy up to 40 000 hooks per day, an increase of 2–3 times what is possible with manual baiting, which requires a much larger crew.

Pelagic longlining is presently the most widely used fishing method for deeper living oceanic tuna. Except for the hydraulic hauling equipment, which often includes a drum for storing the mainline, most of the operations involved (baiting and attachment of snoods) are still manual [24].

Longlining is mostly regarded as an environmentally friendly fishing method. It is selective as it mainly catches larger individuals, it causes no damage to the bottom habitat and it requires less energy during fishing operation than, e.g., trawling [25].

Recently, growing concern has been expressed about the incidental catch of seabirds during fishing operations, a phenomenon particularly common at higher latitudes, where longlining can coincide with high densities of seabirds. In particular, the longline fishery in the southern oceans was found to take significant amounts of different species of albatrosses and petrels, some of which are considered to be endangered or threatened. During the 1990s, technologies which can reduce the incidental catch of seabirds were developed, and recently (1999) member countries of FAO have adopted an international plan of action to reduce the incidental catch of seabirds in longline fisheries [26,27].

4.6. Jigging

The use of a vertical line with unbaited hooks, where the up and down movement of the hooks combined with "attractive" hooks is a widely used fishing technique both in small- and large-scale fishing. This fishing method was mechanized in the 1970s when electric machines were developed which simulate the jigging movements and haul the line when fish were caught. Such machines are now commonly used in the small-scale fishery for codfishes in northern waters as well as by large ocean going vessels fishing for squids. In fact, jigging to a large extent has replaced gillnetting for large squid, which is now more or less phased out because of the drift net ban imposed by the United Nations.

5. Summary of development during the last 50 years and an outlook

A general conclusion from the trends described for the last 50 years is that the period between 1950 and 1975 was the time for technical innovations in vessel and fishing gear designs and operation, which gave rise to significantly increased production of wild marine resources from 19 million tonnes in 1950 to 62 million tonnes in 1975, an average annual increase of 1.75 million tonnes. Substantial improvement of working conditions for fishers, including safety, was also seen in this period, which made fishing a more attractive occupation both with regard to income opportunities and job status. The 1950–1975 period can therefore be classified as one with major break throughs in *technical innovations* that increased fish production.

The 25 years period after 1975 was first characterized with a continuous growth in production from wild fish stocks till its growth stagnated between 1985 and 2000. On average, the annual global catches from capture fisheries increased by 1 million during the last quarter of the 20th century. In fact, the average increase in landings during the last decade was ~0.5 million tonnes. Although technical developments that increased fish production have been significant in the last quarter of the outgoing century as well, this period have been the time when it became obvious that there is an upper limit to growth in wild fish production. Awareness of possible negative impact on the environment of certain types of fishing has likewise become an important issue. Consequently, more and more of technical developments were directed towards fisheries conservation, e.g. technologies to reduce unwanted bycatch during fishing. As of the situation at the end of the century, still there are many unsolved issues concerning overfishing and negative impact of fishing on the environment, the fourth quarter could probably best be classified as a period when *conservation fishing technologies* were set on the global agenda.

The outlook for the first quarter of the new millennium is, for obvious reasons, difficult to predict. Harvest of wild marine fish cannot be significantly increased unless organisms lower in the food chain are exploited more intensively. Such organisms include small planktonic crustaceans (e.g., krill), meso-pelagic fish and squids. With improvements in catching technologies and increased demand for marine proteins, a possible scenario is that such organisms might be more utilized in the future and thus contribute to an increase in total marine harvest.

Another likely development is that more will be done to add value to the captured fish. The impact of the fishing operation on such a scenario is that preservation of fish onboard will be intensified with improved techniques and more widespread use of existing high quality preservation technologies. A future population that demand more fish protein could probably also result in more use of small pelagic fish for direct human consumption that is presently the case when 30–40% of captured fish is used for animal and fish feed.

Technical developments of the fishing operation as such will continue. The ongoing electronic revolution will undoubtedly have impacts on future ways of fishing. Better equipment to locate and identify sizes and species prior to fishing operation is likely to be developed. Such equipment will help in the decisions to avoid capture of non-target organisms and thus contribute to more responsible resource exploitation. Future communication equipment will most likely to be cheaper than at present and the amount of information to be transferred between any positions is consequently expected to increase significantly in the years to come. One possible scenario of such a development is that more of operational decisions can be taken ashore when managers and experts can have direct access to information about fishing conditions and vessel operational parameters.

The present major methods of fishing are not likely to change dramatically during the first quarter of the 21st century. The focus on sustainable technologies and practices will most likely become even stronger than at present. Trawling will therefore be developed to be more selective with regard to target sizes and species, and the present discarding practice will be reduced significantly. If and when fuel cost increases substantially, it is likely that less energy demanding fishing methods to some extent will replace trawling for certain species. Energy demanding techniques will likewise be modified to have less towing resistance, by applying stronger and thinner twine and to some extent make better use of the behaviour of the targets during the capture process.

With these few ideas of possible developments that might be seen during the next 25 years, a suggested characteristic for the first quarter of the coming century will be one of responsible fishing techniques (let us hope!!!).

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