FISHERIES ENGINEERING AND TECHNOLOGY; FISHING FLEET OPERATION AND ECONOMICAL CONSIDERATIONS

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Keywords: Fisheries Engineering; Technology; Fishing fleet operation; Fishing equipment; Fishing vessels; Fishing gear; Fish conservation and processing; Fishing fleets; Fishing power; Fishing efficiency; Fishing capacity; Fishing effort; Fishing productivity; Fishing fleet productivity; Multipurpose vessels; Operations cost; Investment; Investment opportunities; Alternative fishing methods; Fishing technique selection; Selective fishing; Monitoring and control of the fishing operations; Impact of fishing operations; Safety; Working conditions; Waste generated by fishing vessels; Resources needed for different fishing techniques; Sustainable development; Developed country; Developing country; Artisanal fisheries; Industrial fisheries

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Summary

Over recent years, the evolution of fisheries engineering has been very fast. Changes regarding fishing technology and equipment is reviewed here, as well as progress regarding the effectiveness of individual fishing units.

Remarkable improvements have been made in the design of fishing vessels and the installation of equipment on board. Substantial progress has also been observed in the field of fish navigation and very promising progress exists in the field of fish detection and identification as well as sea bottom detection.

Fishing gear is more effective with increased dimensions, improved design, and new synthetic fibers. Because of advances in our knowledge of fish behavior, we also know more about the reaction of fish species vis-à-vis fishing gear and so can fish more selectively (targeting certain species and/or sizes) using specific selection devices. Fishing operations have benefited from the development of fish aggregating devices and remarkable progress has been observed with regard to equipment for controlling the fishing gear during operation. At the same time, research is being carried out to assess the impact of fishing operations on the ecosystem and environment (which is now recognized as a very important issue). Hence, much attention is now paid to fish conservation on board fishing vessels, the quality of fish and, in a number of cases, opportunities for value-addition to fish before landing.

The identification of fleets by typology analysis based on fishing vessel characteristics, fishing operations, strategy of operations, fishing periods exploited, and targeted fish products is reviewed here. The main types of fishing fleet and operation are described in relation to technological and economical considerations according to the fishing gear in

use, targeted resources/species, the scale of the fisheries, and vessel autonomy (including multipurpose vessels).

The fishing fleet productivity is reviewed according to the productivity of individual vessels, that of the fishing gear and equipment used as well as the human factors involved. Important aspects such as fishing power, efficiency, costs of operation, value of the catch, and capacity, are also considered. The evolution of fishing fleet effectiveness, now focusing on rational and economically profitable exploitation of limited resources, is observed, while recommendations for investment in fishing units and equipment are reviewed. The risks in this respect are briefly analyzed, as well as ways to minimize them.

Alternative methods for the exploitation of aquatic resources are presented with consideration given to the species being fished, fishing depth, the characteristics of the sea bed (for benthic and demersal species) and economic aspects of the operation, including the value of catch and potential markets.

The conditions for fishing operations and the context for the development of fishing fleets, opportunities, are changing. In recent years, several international initiatives have been taken, which severely affect fishery industries and are highlighting the relevance of advancing or new fishing technology.

In this respect, the main elements of the agreement on the International Code of Conduct for Responsible Fisheries and the concept of precautionary approach are reviewed here.

The following are considered in particular:

- Selective fishing. The responsibility given to states, with the active participation of fishermen, for the protection of the aquatic environment and the prevention of any damage to it. This includes the development and the implementation of technology and operational measures which reduce the catch of non-target species, waste, discards, as well as reduce the threat to endangered species and which even increase the rate of escaping fish. These measures also seek to minimize the loss of fishing gear and ghost fishing effects as well.
- Monitoring and control of fishing operations. This includes the proper marking of fishing vessels and gear
- Careful evaluation of fishing power and the effort and impact of fishing operations. This involves the safety and working conditions of fishing operations
- Reduction of the waste generated by fishing vessels in general.

Finally, the new context for the development of fishing fleets is summarized including, in particular: the overexploitation of most resources; increased difficulties for access to fishing grounds (restriction on licenses in national waters); increased fishing fees; more competition for fishing rights; conflicts among fisheries; and the need for policies aiming at reducing fishing capacity.

Over recent years, the evolution of fisheries engineering has been very fast, with the main objective being increasing the catch rates. In the past, traditionally fished stocks brought in good/satisfactory catches, multipurpose fishing activities and the changing of fishing grounds kept productivity high. The conditions are changing now.

1. Evolution Regarding Fishing Technology and Equipment; the Effectiveness of an Individual Fishing Unit

1.1 Fishing Vessels

Remarkable improvements have been made in the design of fishing vessels and the installation of equipment on board. Building techniques have changed. For hull construction in particular, the use of polyester has meant great improvements for small and medium units (now larger vessels, up to 30–35 m long, are made from FRP, e.g. purse seiners for the Mediterrannean Sea). New forms have been introduced, e.g. catamarans, and, in some cases, hulls have been adapted for sail propulsion.

More fishing gear/methods can now be put into operation on board smaller vessels (purse seining for small pelagic fish or tuna longlining on board vessels of approximately 15m long).

More and more advanced equipment has been installed on smaller boats, making it possible today for medium size vessels to work like large ones, i.e. fish far offshore and in rough weather conditions (the trawl of a 20m trawler can stay on the bottom even if there is a wind of 10 to 11 Beaufort).

Small stern trawlers with sheltered working decks are equipped with powerful winches and use bottom trawls for very deep fishing, up to almost 2000m depth. Small purse seiners with advanced equipment manoeuvre large nets (now for small pelagics only, in the near future, possibly for tuna as well). Small longliners, 15–20 m, catch and process top quality tuna.

The large fishing companies are now operating trawlers or “tuna boats” with a large capacity and a large range of operations able to exploit the various resources of the world.

Multi-purpose vessels are more and more common, i.e. the possibility of operating several types of fishing gear according to fishing opportunities is becoming more and more frequent (large seiner/trawlers are very common in Norway and the UK, while, in developing countries, smaller vessels can use trawls, longlines, or gillnets, alternatively). An example of another type of multi-purpose activity is the use of several models of trawl to fish either on or close to the bottom, or in midwater.
The power of the engine, particularly aboard trawlers, has been increasing for years. In many cases, the engine effectiveness has increased with the use of better propellers (propellers that are larger and that at times necessitate modification to the back of the hull, or variable pitch propeller), the use of an optimal reduction rate or the addition of a propeller nozzle, the addition of a fuel consumption counter (which allows an instant

evaluation of fuel consumption at different pitches during various phases of fishing operations), or the total or partial use of heavy fuel (tuna purse seiners, beam trawlers).

In addition, progress has been made in electricity production on board by generators and the recuperation of exhaust gas for heating or fish refrigeration.

More effective fishing gear manoeuvring largely results from the generalization of "hydraulics" for auxiliary equipment, even on small vessels while, in the wheelhouse, more and more advanced equipment for navigation and fish detection is installed.

With respect to fish navigation, it has been observed that, using positioning equipment such as GPS and other satellite navigation systems, which are less and less expensive and also more compact (for installation on board smaller vessels), it is now possible to trawl next to rough bottom/reefs, between wrecks, near ice-packs, to operate handlines, or to set longlines on or around "pick" or reefs, as well as to retrieve Fish Aggregating Devices set offshore, etc.

Regarding charts, electronic charts are used more and more for navigation; these are regularly and automatically updated. More and more fishing charts are available to fishermen, including information on the nature of the bottom, main species likely to be met, wrecks or very hard bottoms which may damage fishing gear, etc.

For detection of fish and sea bottom, echo-sounders and sonar (horizontal/oblique echo-sounders) are much more effective than before. It is worth mentioning in particular progress concerning bottom expansion, stabilized images, panoramic images, color echo-sounders, and the general detection of fish around fishing gear (i.e. trawls) during fishing operations. Further progress is still expected in the field of fish detection in the cases of (a) the more accurate detection of fish species which are normally difficult to detect (cephalopods, mackerels, etc.), (b) the identification of fish species on the echo-sounder screen, and (c) the quantity evaluation of the detected fish.

The acoustic perturbations when fishing vessels are passing above fish shoals have to be studied and taken into consideration for the evaluation of fishing opportunities just before setting fishing gear or when doing an acoustic assessment of the fish stock.

1.2 Fishing Gear

For the manufacture of fishing nets, new synthetic fibers are constantly being developed; which have:

- better stability: of particular importance for the meshsize of the codend of a trawl (since, in most fishing areas, there is a recommended minimum meshsize by law)
- better elasticity: useful for cords used for the construction of large mid-water trawls (trawls with very large meshes of 10 to 20m, or cords at the entrance)
- greater breaking strength: synthetic products now replace wire ropes (i.e. kevlar).

1.2.1. Trawl

With regard to the trawl, considerable progress has been made, such as the development of very large trawls with very large mesh or cord. There have been other less important developments, such as new trawl/rigging designs making it possible to "trawl" on a very rough bottom.

In some cases, the adoption of a specific type of trawl or rigging has allowed a great increase in productivity, e.g. pair trawling for fish, twin trawling for shrimp, etc.

Selective devices have been developed, in particular, for shrimp trawling to separate the shrimp from small fish (juveniles). It is worth observing that, in addition to the preservation of living resources, such devices may simplify sorting and allow the capture of good quality fish (excluding debris from the codend).

Research on trawls and trawling techniques will continue in the years to come. The following areas for research can be identified:

- study of trawls capable of increased catches but with reduced drag (thus consuming less energy in traction and allowing use by smaller/less powerful fishing vessels)
- study of trawls or rigging capable of passing over a very hard bottom with a minimum of damage
- utilization of rigging for "twin trawling," which increases the width of the swept area on the bottom
- study of more selective devices, either to select by size or species (e.g. cephalopod trawls, shrimp trawls, etc.).

1.2.2. Purse Seines

The dimensions of purse seines have increased more in depth (almost 300m for some tuna purse seines) than in length. New material is now used for net webbing to make it sink faster and for reduced drag during the pursing as well as for the floats and for the ballast.

Larger meshes are tested for the bottom section of the seine. In certain cases, diamond mesh has been replaced by hexagonal.Some net construction and rigging make it possible to use purse seines to catch demersal fish ("gadoids fish," off Norway). As already mentioned above, purse seines can now be used on board very small vessels (in Asia, in the Mediterranean sea).

1.2.3. Pots or Traps

Pot vessels can now use more pots (stackable or foldable which take up less space). Those used for crab, lobster, or shrimp, are more and more frequently made entirely or partially from plastic (more expensive than wooden pots but practically everlasting).

Research could bring about:

- a design of rack simpler to build or less cumbersome on deck
- pots better adapted to the behaviour of various shellfish
- development of techniques to capture new species (i.e. shrimp, cephalopods, fish in midwater, etc.)
- tests on the effectiveness of lures which, in some fisheries, could replace natural bait.

1.2.4. Hooks and Lines

As far as hooks and lines are concerned, progress has been made concerning new material for lines (in particular for longlines: monolines for mid-water fishing for tuna or swordfish; floating lines for demersal longlining). New shapes of hooks have also been introduced very successfully (i.e. circle hooks).

Supply of bait often constitutes a problem (purchased ashore or caught by the lines themselves). Research work is being carried out on artificial bait and promising results have been observed.

As a result of technological improvement, longlines have proved effective for catching a wide range of species, some of them previously caught only by other methods. Handlining (in particular when using automatic reels) has also been recognized, in many cases, as an efficient and profitable method.

1.2.5. Gillnets

Gillnets are widely used for small and medium-scale fisheries for a very broad variety of species (fish, shellfish, cephalopods, etc.)

The design of an effective gillnet is a rather complex technology. Research work on the textiles used, as well as on the mounting of the nets or riggings, has resulted in substantially increased effectiveness. However, progress can still be expected, for instance concerning, among other things, shrimp gillnets or riggings allowing the gillnets to be set on a very rough bottom.

An entangling net is a kind of gillnet very commonly used. Strictly speaking, the difference it bears to a gillnet is that the fish is caught in the net webbing by entangling more than by gilling. The entangling net often catches several species at the same time (including even some endangered/protected species). In general, there is room for progress concerning the selectivity of the method, in order that certain species and/or size only are caught.

1.2.6. Dredge

Dredges have also been made more effective; an example is the progress made on dredges used for scallops, which are equipped with teeth assembled on springs or harnessed four in parallel (thus raking a bottom area 7 to 8m wide). Dredges could be made still more selective; improvements should be made, in particular, to decrease the number of shells broken by the dredge which remain on the bottom.

1.2.7. Related Research

One can thus say that currently a lot of fishing gear now in use is really effective. Research aims today at, on the one hand, still improving its performance to make fishing more profitable and, on the other hand, to develop more selective techniques which require a proper understanding of the mechanisms of selection by species and size. Towards these objectives, as a priority, efforts are being dedicated to studies regarding the behavior of the fishing gear in operation (the shape of towed trawl and of seine at various phases of the manoeuvres, etc.) and the reaction of fish (species or sizes of fish) vis-à-vis fishing gear.

In this field, much research has already been carried out and significant results have been obtained. It is, however, always difficult to carry out: in the techniques to be implemented—in particular techniques of visualization underwater—equipment is generally heavy and expensive and the interpretation of the data collected is always somewhat subjective.

The impact of fisheries on the ecosystem and environment, in general is now recognized as a very important issue. There are various aspects to this: research is under way concerning biology, ecology, etc., while, as far as fishing gear is concerned, the direct impact on the seabed of towed fishing gear, such as bottom trawls and dredges, is now given attention. The immediate and medium term effect of wearing the bottom is being carefully studied.

1.3. Equipment and Auxiliaries for Fishing Gear Operation

Remarkable progress has been observed with regard to fishing gear—in particular, trawls—but perhaps the more significant progress has been with regard to auxiliary equipment (the hydraulics installed on fishing vessels, even the smallest vessel). These include towing or hauling systems; trawling winches with, in some cases, towing warps equilibrated according to their tension, spinning, and turning of automatic machinery; additional winches for “twin trawling” operations; winches of seine with more flexible disengaging and braking for the various phases of operation, the effectiveness of which greatly depends on the speed; powerful line or gillnet haulers (making deep fishing more feasible, even from small boats); power-blocks of all types to raise, even from rather small boats, seines and other surrounding nets (less than one hour is necessary for hauling more than one kilometer of net); power-grips; etc.

Among other auxiliaries now commonly in use in the fishing industry, it is worth mentioning the following:

- Trawl drum: this is necessary for hauling a very large/long trawl on board a small trawler. It is used, for instance, when a trawler 15–20m long uses a 150–200m long trawl. Also associated here are the gillnet and seine drums (very common in the USA), as well as longline drums now commonly used on board small tuna longliners in the Pacific or Indian Ocean, or for demersal fisheries off Norway;

- Baiting machine for longlines: 100 to 200 hooks per minute (by hand, a properly trained crew member can put bait on at almost 4 hooks per minute).
- With respect to longlining or handlining, it is worth mentioning that all manoeuvres can now be fully mechanized, including on board small boats with space limitations (longliners of less than 20m, more or less automated, can use today several tens of kilometers of lines carrying 10 to 30 000 hooks).
- Fish pumps for industrial fisheries using trawls or seines for small pelagics (fish, mesopelagic or crustacea: krill).

Other auxiliaries available and widely in use for operating are as follows:

- Purse seines: speed boats, helicopters, firecrackers for preventing escapement of the fish, artificial fish attraction devices
- Trawls: receptors for electronic fishing and forecasting charts (for instance, for fishing near an ice-pack)
- Passive fishing gear (lines, gillnets, pots, or traps): improved marking with light, radio
- Satellite emitters: continuing fish detection near the fishing gear, attraction devices.

The importance of this last development must be stressed. For fisheries of large pelagic fish, Fish Aggregating Devices (FAD) are very commonly used by the developed industrial fleets, as well as the small-scale fisheries sector (a practice which has led to changes in the species and size composition of the catch, and possible impact on resources). Here, small lights are installed on the longlines next to the hooks for attracting swordfish, etc. For the attraction of fish or cephalopods with light, a series of more and more powerful lamps are used (which has required the establishment of a limitation by law).

It is worth listing the equipment now available for controlling the fishing gear during operation and even, in certain cases, for controlling the fish around the fishing gear and their reaction to it. Such equipment is more and more in use, in particular, when trawling or purse seining (control is exerted upon the opening of the trawl and the sinking depth of the purse seine calculated against the concentrations of fish).

Fishing gear manoeuvring mechanization allows the utilization of larger fishing gear (seines, trawls), or a greater amount of it (kilometers of longlines or more gillnets units) and the capacity to fish in deeper waters (for instance longlines or trawls).

In this connection, as a result of the above-mentioned technical developments, more deep sea fishing is carried out, for instance, by trawlers and longliners.

As far as small-scale fisheries are concerned, changes are also observed, such as a greater number of offshore activities (related to increased motorization), more fishing gear used, and, in many cases, an increased quality of fish products (resulting, for instance, from the installation of insulated fish boxes or, merely through using ice; see 1.1.4).

Such a list would be very long and, anyway, incomplete. As a conclusion, it is clear that the technology available for fishing is now very effective.

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Biographical Sketch

Joel Prado is a FAO Fishing Technologist based at the FAO Headquarters in Rome. Before joining this Organization, fifteen years ago, he was working for the National Fisheries Research Institute, in France, studying fishing gear and operations in that country, including, in particular, bottom and midwater trawling, tuna purse seine design and operation, lining. From 1992 to 1994, he was based in Malaysia assisting an inter-governmental regional fishery organization to set up a Fishing Technology Advisory Service for fishery industries in Asia. Within FAO he has gained a wide experience in all fishing technologies, both in developed and developing countries, through many travels all over the world, and has participated in and organized for FAO many international Conferences and Workshops. For several years now his work has focussed on responsible fishing practices in general and, in particular, on the development and promotion of the use of sustainable technologies, including assessment of the impact of

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