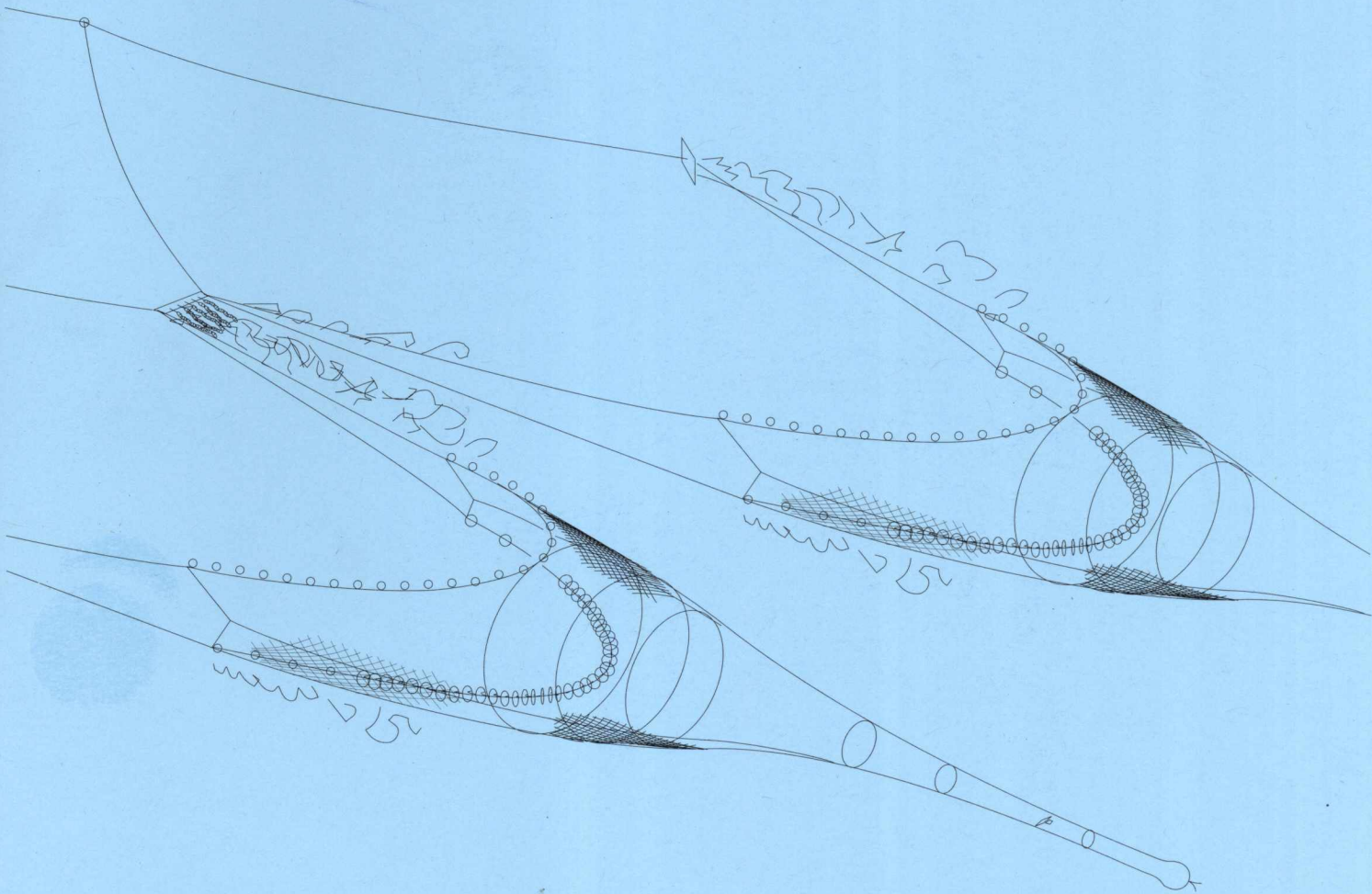


AN ASSESSMENT OF TRAWLING TECHNOLOGY IN CANADA

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Fisheries and Oceans
Canada

Pêches et Océans
Canada

Canada

Published by:

Program Planning and Coordination
Fisheries Management
Fisheries and Oceans Canada
Ottawa, Ontario
K1A 0E6

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Cat. No.Fs23-373/1999E
ISBN: 0-662-28191-8

Également disponible en français



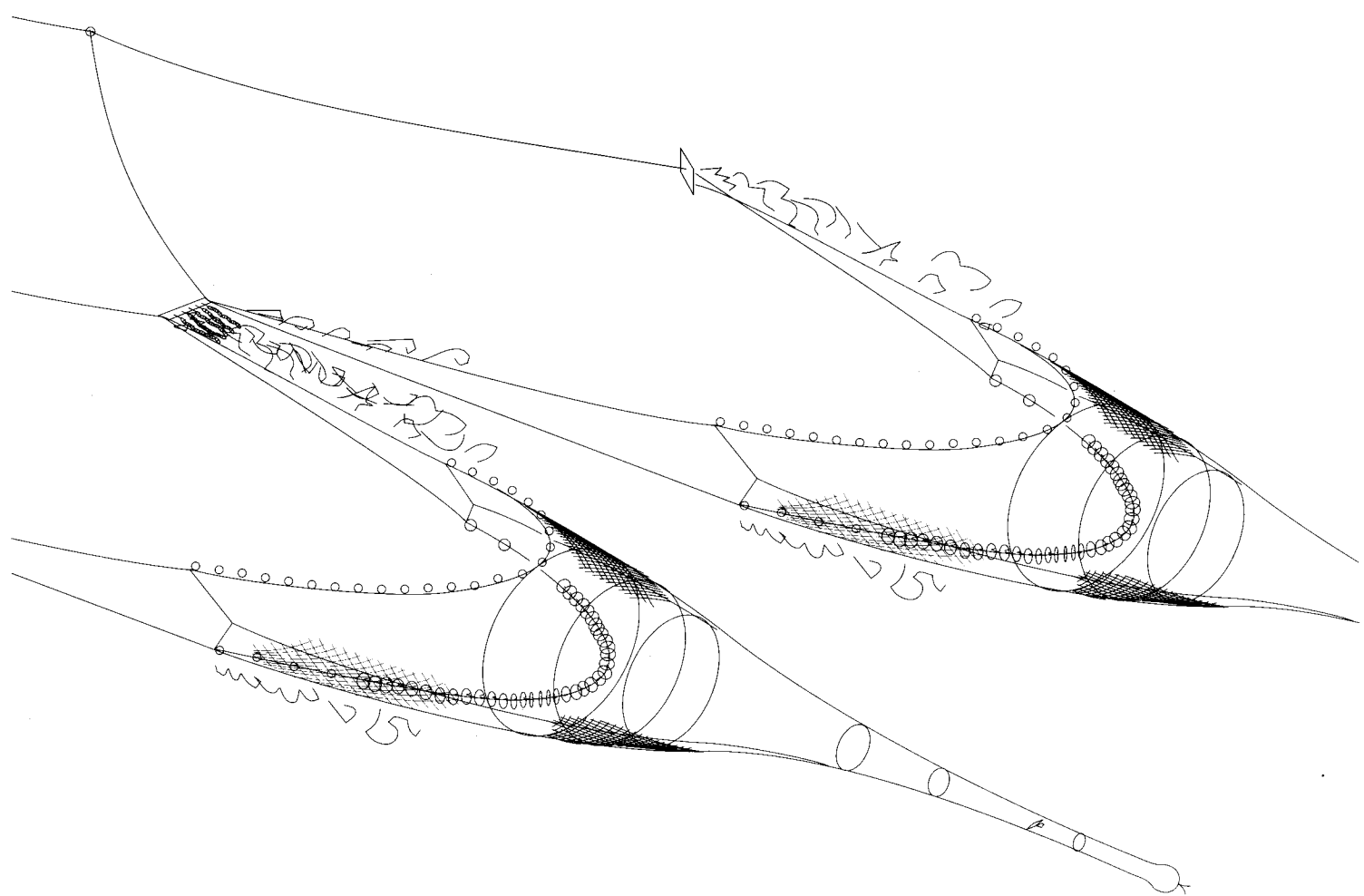
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Executive Summary

Section 1

1.1 PURPOSE OF THIS REPORT

During the past few years there have been various reports in the Canadian and international media relating to the effects of trawling on fisheries resources and the marine environment. Many of these reports have been negative towards trawling, and this type of fishing method has been frequently accused of causing adverse effects to fisheries stocks and the marine environment.

The purpose of this document is to provide a relatively comprehensive review of trawling, including its importance to the fishing industry, as well as its impact on the fisheries resource and the marine environment. The reason why trawlers are used will be explained, as well as the advantages and disadvantages of this type of fishing gear. Recent improvements in the conservation features of this type of gear, and the increasingly responsible way it is being used by Canadian fishermen will also be described.

This report will not deal with other types of towed gear such as scallop rakes and clam dredges. Many believe that these types of fishing gear have a greater impact on the sea bottom than trawls.

1.2 FISHERIES OBJECTIVES

Differences in the desired structure or “vision” of the fisheries vary substantially amongst various fisheries interest groups. As a result, differing views regarding trawlers may be actually based in large part on socio-economic or environmental issues in the fisheries, rather than on truly technical or conservation matters relating to this type of gear. For example:

- One extreme of economic beliefs is based on the support of pure economic rationality, competitiveness, maximization of efficiency and profits, and technology. The other extreme supports values such as maximization of employment, small or cottage scale enterprises, as well as small coastal communities and “rural lifestyles”. Such differing views suggest that ideology may therefore be a more fundamental issue in many fisheries discussions than fishing vessel types or gear technology. Some trawlers can be very small and owned by

individual fishermen, and some trawlers can be quite large and owned by integrated companies. Most trawlers in Atlantic Canada are of moderate size (i.e. in the 20 m length range) and are owned by both independent fishermen and smaller processing companies.

- There are also differences of opinion as to the human use of the marine ecosystem. Studies have shown that trawlers do have an effect on the relatively small part of the sea bottom in which they operate. In general, extensive trawling appears to reduce biodiversity in the marine environment, but does not necessarily reduce overall productivity. Some environmental spokesmen support an unchanged marine environment in which biodiversity is relatively untouched. In contrast, others believe that sustainable productivity of the oceans should be maximized for the benefit of mankind, within a framework of an appropriate oceans use policy.

It should also be noted that many of the conflicts amongst fishermen in various fleet or gear sectors are usually not as much conflicts relating to technical differences of their fishing gears as they are based on simple competition amongst the fleet sectors. For example, some sector spokesmen may be critical of trawlers primarily to rationalize the allocation of a larger share or proportion of the resource to their own fleet sectors.

1.3 WHY TRAWLING IS NEEDED

In 1998, approximately 40% of the Atlantic Canada fisheries landed value of \$1.2 billion was harvested using towed or mobile gear such as trawls. Such landings of finfish and shellfish would have been technically and economically impossible without the use of such gear.

Trawlers are used in our fisheries because of:

- **Technical requirements**

Species such as redfish, flatfish and shrimp, for example, cannot be harvested economically by other types of gear.

Executive Summary—continued

- **Market requirements**

The Canadian harvesting and processing sectors together must be able to produce seafood products which are both quality and price competitive worldwide, and which are supplied on a nearly year-round basis. Otherwise, the industry will not be financially viable. Most of Canada's major seafood competitors are using advanced trawling technology

- **Environmental requirements**

Conditions such as the distance to fishing grounds, the duration of fishing trips, as well as sea and ice environments, are major factors in determining acceptable vessel and gear combination for specific fisheries and areas. One of the key reasons for choosing one type or size of fishing vessel over another, besides the quantity of fish they can land per trip, is the important continuity of supply they can offer year around. Trawling is an active and relatively dependable means to seek out fish throughout the year.

- **Economic requirements**

The incomes of fishermen in Canada, as in most other fishing nations, is generally related to the size and technical sophistication of their vessels, rather than the type of gear used. The fishery is therefore no different than other economic sectors (such as agriculture) where incomes of workers are dependent on the levels of capital investment and productivity.

As well, the higher catch rates of trawlers provide more spin-off benefits in terms of shore based processing jobs supported per crew member. For example, when stocks were abundant, each fisherman on nearshore trawlers in Nova Scotia supported an average of 3.8 person years of shore based employment (i.e. close to eight 6-month jobs).

Finally, an important economic objective for any fishery is to maximize the value of the resource which is harvested, which in turn is related to the size and quality of the landed fish. Although trawlers have been accused of landing smaller and poorer quality fish than other types of fishing vessels, controlled experiments have shown that all types of fishing gear can technically

produce good quality landings. Differences in the past have been primarily due to poor fishing, onboard handling and stowage practices, and not caused by the type of gear used. The performance of trawlers operating under current Conservation Harvesting Plans demonstrates that this technology can provide landings with a size distribution and quality of fish which is as good or better than that provided by other types of fishing technologies.

- **Traditions, expertise and working conditions**

Another important factor which determines the type of gear used relates to local traditions and "fishing culture". Historical or community "attachments" to certain types of fishing gear, as well as the local expertise which this develops, are very important factors. The current limited entry licensing system has, however, removed most of this flexibility.

1.4 FISHERIES MANAGEMENT INITIATIVES

The fisheries management system of the Department of Fisheries and Oceans (DFO) is one of the most comprehensive in the world, and is increasingly effective in protecting the resource. Although the collapse of the Atlantic groundfish stocks has been attributed by some to the mismanagement of the resource by DFO, there is much evidence to indicate that natural environmental changes may also have been a major contributing factor.

In addition to setting Total Allowable Catches for each groundfish stock based on scientific assessments, the Department also:

- Regulates fishing capacity through limited entry licensing systems. In Atlantic Canada, the Department's efforts to reduce excess fleet capacity has been most successful in the groundfish trawling sector as a result of introducing Enterprise Allocation and Individual Transferable Quota Systems (which causes the industry itself to fund and reduce fleet capacity to match resource availability).
- Has extensive groundfish harvesting regulations to ensure sustainable harvesting by trawlers and other types of fishing vessels. These regulations are as comprehensive as those in any other fishing nation.

Executive Summary—continued

The view that various types of fishing gear can be size and species selective is generally reflected in the international fisheries literature. As previously mentioned, the negative impacts resulting from the use of any type of gear are often caused as much by the way that the gear is operated or misused, as by the intrinsic characteristics of the gear itself. In other words, sustainable harvesting operations may be as dependent on “human” behaviour as on “technical” factors.

Regardless of the type of gear, the ingenuity of fishermen and the continued advances of technology can often defeat most regulatory attempts to control fishing effort and impacts. The solution must therefore come from motivating fishermen to assume more personal responsibility for the proper operation of harvesting gear.

In response to this challenge, DFO has been gradually redirecting the management of the Canadian fisheries towards cooperation and partnerships with the industry. Other initiatives aimed at encouraging fishermen to assume more personal responsibility for the conservation of the resource have also included:

- The development of a Canadian **Code of Conduct** for Responsible Fishing Operations.
- The “**professionalization**” of fish harvesters.
- **Training** programs in responsible fishing.

1.5 IMPROVING THE CONSERVATION FEATURES OF TRAWLS

The conservation features of any type of gear can be defined by characteristics such as size selectivity, species selectivity, and limiting the size of catches. Significant design and technology improvements in many of these characteristics have been achieved in trawling gear through the cooperative efforts of DFO and the fishing industry.

For example:

- The introduction of square mesh has resulted in trawls which are as fish size selective as other types of gear.
- The regulatory requirement for rigid selectivity grids in shrimp trawls has reduced the bycatch of demersal species in some areas from over 20% to less than 2%. No other types of gear has better species selectivity.

- Escape panels and electronic catch sensors in trawls can limit catches to levels which can be easily processed onboard to maintain product quality.

It should also be noted that some other major conservation concerns in the fisheries relate primarily to “fixed” types of gears, and **not** trawls. For example:

- The problem of lost nets and the resulting “ghost” fishing is only a problem with gillnets, and not trawl nets.
- Entrapment and mortality of marine mammals such as whales and porpoises occurs primarily in fishing gear such as traps and gillnets.

1.6 EFFECTS OF TRAWLING ON THE SEA BOTTOM

In summary:

- Scientific studies have shown that trawling does have an effect on the bottom. It generally reduces biodiversity but not necessarily overall biological productivity.
- Natural causes such as storms and ice often have a more dramatic effect on the bottom than fishing activity, particularly in more shallow areas.
- Trawling only occurs over a relatively small proportion of the ocean bottom. It occurs most commonly over relatively shallow and smooth parts of the seabed, since fishing in rough bottom areas increases the susceptibility to damage of the trawl gear.
- Some types of trawls such as mid-water trawls do not touch the bottom and therefore have no effect on the seabed.
- Studies show that extensive trawling activities can produce long-term changes in sediment characteristics and bottom community structures. Such effects depend on the intensity of fishing, the type of bottom, the depth of water and other oceanographic variables. For example, the effects of gear take longer to disappear in deeper water where the fauna is less adapted to changes in sediments due to ocean currents, waves, and other natural phenomena such as ice.

Executive Summary—continued

- It is accepted that changes to the seabed, by whatever cause, can affect the fisheries above the beds, however the relationships are still unclear. To what extent this is a factor in observed “fisheries declines”, as compared to other factors such as over fishing a spawning biomass (with any type of gear), or recruitment failures due to natural environmental changes, has not been addressed in the scientific literature.
- Evidence for either positive or negative long-term impacts is hampered by the lack of historical data on bottom communities and the effects of natural perturbations. The only available scientific evidence of this comes from Europe and it suggests that trawling has increased the abundance of some flatfish species.
- The eggs and larvae of most marine finfish species remain in the water column during the first stages of their life. Discussions on possible negative impacts of trawling should therefore be limited to the effects on young ground fish which have settled to the bottom.

To be more specific, the available information on the effects of trawling and dredging clearly demonstrates short-term effects on both the sea bed and bottom-dwelling organisms. Several contradictory observations, however, have emerged from the numerous scientific studies. Some studies have shown fishing disturbances to reduce the abundance, biomass and diversity of some benthic invertebrates, while other studies report increases in the abundance and biomass of other bottom species, notably scavengers.

One of the few general conclusions that can be drawn from the various studies to date, however, is that mobile fishing gear reduces the complexity of plant and animal life on the sea floor. Such effects have been documented in eastern Canada, Europe and in other parts of the world. These result from the tendency of trawling gear to smooth out structures on the bottom, and to remove bottom fauna that contribute to sea floor complexity.

Reduced habitat complexity is expected to reduce shelter for juvenile fish and thus increase their mortality rates due to predation from larger fish. On the other hand, bottom disturbances from trawling often increase the food supply for scavengers, and growth opportunities for certain bottom dwelling organisms. As a general pattern:

- larger, longer lived and more delicate organisms such as molluscs and corals tend to decrease in trawled areas, whereas
- populations of fast reproducing, and opportunistic feeding organisms such as sea stars and polychaete worms are often enhanced.

For example, studies in those parts of the North Sea which have been fished predominantly with beam trawls since the 1920s show molluscs and crustaceans decreased in numbers and diversity, whereas polychaete worms increased. There were indications that this growth in polychaete populations actually resulted in an increase in the productivity of some flatfish populations such as sole.

An Introduction to Trawling

Section 2

2.1 TRAWLING GEAR

This type of fishing gear consists of towed nets which have a cone shaped body, the larger end being extended by "wings" and the smaller end being closed by a bag or "codend". During each fishing operation, these nets are towed with steel cables or "warps" at relatively slow speeds of 2 to 4 knots. After a towing period of several hours or less (depending on catch rates), the trawl net is hauled onboard the vessel with powered winches. The fish are released from the codend, and are then sorted, processed and stored in the hold. This cycle is then repeated.

Three types of trawling systems are used in Canada; bottom or otter trawls (including pair and twin trawls), beam trawls, and mid-water trawls.

- **Bottom or Otter Trawls** - are designed to operate on the bottom, and their horizontal opening is maintained by "otter boards", as illustrated in figure 2-1. The lower leading edge of the net opening consists of a thick "groundrope" which is ballasted with rubber disks, bobbins, chain or wire. The upper part of the net normally has floats on the "headline" to keep it open. The width of most groundfish trawls used by nearshore vessels in Atlantic Canada is in the order of 30 to 45 m (100 to 150 ft.). This gear is used primarily in the groundfish and shrimp fisheries of this country.

Bottom trawls can be towed by either one or two boats (the latter not requiring otter boards), although single boat operation is almost exclusively used in Canada. As well, twin trawl systems allow one vessel to tow two separate trawls, and are used to increase the swept area and volume, as illustrated in figure 5-14. The use of twin trawls has begun in the Atlantic shrimp fishery.

- **Beam Trawls** - are also designed to operate on the bottom. In these trawls, a metal or wood beam is attached between each side of the net to maintain the horizontal opening (i.e. rather than otter boards). These types of trawls are used by smaller boats in the Pacific shrimp fishery, and have been introduced in the expanded shrimp fishery off Newfoundland.
- **Mid-Water Trawls** - are usually much bigger than bottom trawls, and are designed to operate throughout the water column, from near the bottom to the surface. The horizontal net opening is maintained by special types of doors, and the fishing depth is controlled by changing the towing speed. The operating depth of the trawl is usually monitored by electronic net sounders. In Canada, these types of trawls are primarily used in the Pacific hake and the Atlantic redfish fisheries, however in other countries they are often used in fisheries for pelagic species such as mackerel and herring.

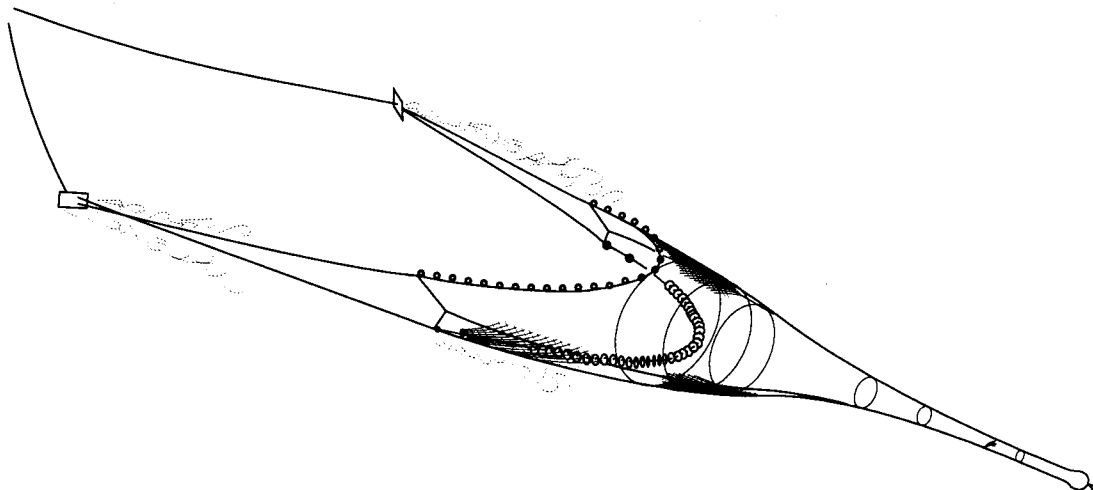


Figure 2-1. A Bottom Trawl

An Introduction to Trawling—continued

2.2 TRAWLING VESSELS

There is an extremely wide variety and size range of trawling vessels in Atlantic Canada.

The smallest trawlers are open deck, inshore vessels which are only 10 to 13 m (35 to 42 ft.) or so in length. They can cost less than \$100,000 new, and usually have a captain/owner and one crew member. These boats usually derive a majority of their income from the lobster fishery, and after that fishery is closed, trawling gear is then installed. These vessels usually target groundfish species such as flatfish during those months when weather permits.

The most common trawlers are nearshore trawlers in the length range of 13.7 to 19.8 m (44' 11" to 64' 11"). These length limits are imposed by the DFO licensing system. Such vessels usually operate in only one fishery such as groundfish or shrimp, however some have dual licenses. They can cost from about \$400,000 to over \$1 million, and are usually operated by 3 to 6 crew members. A smaller 13.7 m (45 ft.) trawler in this class is illustrated in figure 2-2.



Figure 2-2. A 13.7 m (45 ft.) Inshore Trawler

The larger 20 m trawlers in this nearshore class are extremely “beamy” for their length, and many are quite powerful, having engines of up to 1,000 hp. The most common nearshore trawlers in other countries have about the same fishing power, however without such a regulatory length limit, they are usually in the length range of 23 m to 28 m (75 to 90 ft.). This seems to be an optimum size for economical operation and for good sea keeping in heavy seas. Such a vessel size also allows continuity of operations year round in most areas and provides reasonable space for onboard processing and stowage of fish.

The larger, offshore “wetfish” trawlers (i.e. trawlers in which the fish is stored in ice) used in Atlantic Canada are in the range of 36 to 47 m (120 to 155 ft.) in length; cost in the order of \$10 million; and have about 15 crew members. Such vessels can be operated year around in adverse fishing conditions, such as in the ice off Northeast Newfoundland and Labrador.

The largest trawlers are currently the offshore shrimp vessels. Some of these can exceed 60 m (200 ft.) in length; cost in excess of \$20 million; and require over 30 crew members. Such vessels have onboard processing plants where the shrimp is sorted, cooked, packaged and frozen. Some also have onboard factories for processing groundfish and fishmeal. One of these modern vessels is shown in figure 2-3.

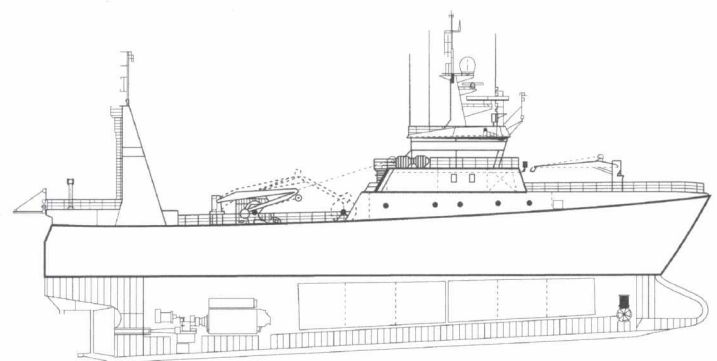


Figure 2-3. An Offshore Shrimp Factory Trawler

Why Trawling is Required

Section 3

3.1 INTRODUCTION

This section will begin with an explanation of why discussions relating to trawling may in large part be actually based on differences in ideology, or differing “visions” as to how the fishing industry should be structured.

This will be followed with a review of why trawling is required due to advantages in technical, economic, environmental and marketing factors.

A relatively detailed analysis of the economics of trawling will then be presented. The Atlantic Canada fisheries will be used for most of the examples, although the same factors would apply in large part on the Pacific coast. An attempt will also be made to explain why this type of fishing gear has the capability to provide reasonable incomes to those in the fisheries and related sectors.

The final section will deal with the important fisheries management issue of maximizing the economic benefits of the resource, particularly as this relates to fish quality control. It is explained how studies have shown that good quality fish can be landed using any type of gear, including trawls. The economic impact of alternative harvesting strategies is also examined.

3.2 SOCIO-ECONOMIC OBJECTIVES IN THE FISHING INDUSTRY

In many Canadian fisheries, annual Total Allowable Catches (TAC) are established for each stock based on scientific advice. In fisheries such as the Atlantic groundfish fishery, the challenge is then to allocate such TACs amongst a various fleet sectors. These sectors are defined or categorized by both:

- The type of gear (e.g. trawls, seines, hook and line, gillnets, etc.), and
- The size range of fishing vessels (e.g. less than 45 ft., 45 to 65 ft., over 100 ft., etc.)

Allocations have been primarily based on historical catch patterns. Given the current depleted state of most groundfish

stocks, as well as the large overcapacity in most fleet sectors, the resulting quotas are usually insufficient to meet the economic needs of each sector. Many sectors therefore attempt to gain a larger share of such TACs, often by accusing other gear sectors of causing adverse effects or destroying fish stocks, even though such claims are usually unsubstantiated.

Many of the conflicts amongst fishermen in various fleet or gear sectors are therefore not as much conflicts relating to technical differences of their fishing gears as they are based on:

- Simple competition amongst the fleet sectors; each sector attempting to gain a larger share or proportion of the resource than previously, and /or
- Differences in ideology or “political” beliefs on how the fishing industry in their area should be structured.

Differences in ideology or “vision” of the fisheries vary substantially amongst the various interest groups related to the fisheries in Canada. These differing view can be characterized by opposing values such as:

Capital intensive	vs	Labour intensive
“Industrial” scale	vs	“Cottage industry” scale
Competitive	vs	Sharing
Larger fishing centres	vs	Many small coastal communities
Efficiency considerations	vs	Social considerations.

One extreme of such beliefs includes the support of pure economic rationality, competitiveness, maximization of efficiency and profits, and technology. The other extreme values maximization of employment, small or cottage scale enterprises, support of small coastal communities and “rural lifestyles”. It is therefore obvious where large trawlers and small “hook and line” vessels fit into this ideological value system.

The view of conventional fisheries economics is that the optimum yield should be extracted from a resource at minimum cost. This usually means replacing labour intensive operations with capital intensive ones. In contrast, the preference of many fishermen for small fixed gear vessels or

Why Trawling is Required—continued

fish traps is very logical given the possible lifestyles which they can provide. The optimum economic balance of capital and labour in the fisheries may therefore vary dramatically depending on whether one is considering the maximization of benefits to the nation, the region, a coastal community or an individual fisherman. This later point is extremely important when considering at which level of government such decisions are to be made.

In summary, although some trawlers can be very small and owned by individual fishermen, many of them are larger and more powerful vessels which are owned by companies. In other words, the ownership structure as well as the relatively large landings of trawlers is often the underlying issue which motivates the criticisms of this type of fishing method.

For example, "hook and line" fishing is often identified with small, inshore vessels whereas "trawling" is often associated with large, company owned vessels. On the other hand, how would a group of inshore, fixed gear fishermen react to fishing alongside either:

- A small, inshore trawler under 40 ft. in length, with a two man crew, which is owned and operated by a local fishermen? or
- A multi-million dollar 200 ft. factory/freezer longliner, which has over 20 crew members, onboard processing and freezing plants, and is owned by a large company?

Accusations that some types of gear are more responsible for decimating fish stocks than other types become even more questionable when considering the fact that natural phenomena may have a larger effect on the fisheries resources than human activity. For example:

- There is increasing evidence that large scale and periodic changes in the ocean environment, such as temperature and salinity, may have as much or more of an impact on resource abundance as mortality from fishing operations, regardless of the gear used.
- Major storms and natural processes such as ice movement often have a more dramatic effect on some parts of the continental shelf bottom than any fishing activity.

3.3 THE REQUIREMENT FOR TRAWLERS

The optimum types of fishing vessels and gear to be used in any fishery cannot be evaluated in isolation from the technical, environmental, market and economic conditions faced by that fishery. As well, these factors and requirements can vary dramatically from fishery to fishery. Some of these factors will be examined in the following subsections.

3.3.1 Technical Requirements

Trawling is the only way of economically harvesting certain fisheries stocks. For example:

- Hook and line gear is ineffective for harvesting most flatfish species.
- Hook and line gear is also ineffective when there is an abundance of feed fish.
- Some other groundfish species such as silver hake and grenadier can only be harvested with trawlers.
- Trawling is the only economic method for harvesting shrimp.
- Mid-water trawls are effective in capturing redfish and other finfish species located off the sea bottom.

3.3.2 Environmental Requirements

Environmentally defined conditions such as the distance to fishing grounds, the duration of fishing trips, sea conditions such as wave heights, and ice conditions are also major factors in determining acceptable vessel and gear combination for certain fisheries and areas.

It must be noted that the ocean environment in Atlantic Canada is one of the most harsh on earth. Frequent storms, particularly in the cold months, result in extreme sea conditions and waves. Working conditions at sea are even uncomfortable in the summer months because of the low water and air temperatures, as well as the incidence of intense and prolonged fogs. As well, Arctic ice moves into most of the Atlantic waters during the winter and its full thrust lasts into the spring. Subzero temperatures can also result in substantial ice build-up, and

Why Trawling is Required—continued

vessel icing is a further serious hazard. The size of the vessel itself rather than the type of gear used, however, is perhaps the most critical factor in protecting against these hazards, with small fishing vessels being most at risk.

There are also basic environmental constraints to the use of certain gear types. For example, Scottish seining is a cost effective and environmentally “friendly” method for harvesting groundfish such as flatfish on relatively smooth ocean bottoms. Such gear, however, is less effective than trawls in areas where currents are substantial; the bottom is relatively rough, or if wave conditions are especially adverse.

One of the key reasons for choosing certain sizes of fishing vessel is the continuity of supply which is required, and the length of their operating seasons. This in turn is dependent on the severity of sea conditions and other environmental conditions such as ice which are encountered in the various fishing areas.

For any area, the average number of fishing days which can be provided by fishing vessels is generally related to their size or length. These operating constraints in various areas of Atlantic Canada have been estimated as shown in figure 3-1.

Vessel Length (ft.)	25-35	35-45	45-65	65-100	100-200	>120 ft.
AVERAGE USE 1						
Scotia Fundy	97	139	160	185	207	213
Gulf	85	100	117	124	136	138
S. Newfoundland	48	75	111	171	203	211
NE. Newfoundland	31	45	66	87	135	174
MAXIMUM USE 2						
Longliner		170	170	250	260	270
Trawler		170	210	260	260	270

Note (1) Based on 24 days available per month, and with allowances for adverse weather, ice, maintenance, and steaming to grounds. Compiled by EYE Marine Architects, Halifax.

Note (2) These figures will be used as absolute maximums that vessels of the given types could be utilized on the Scotian Shelf and Southern Newfoundland waters.

Figure 3-1. Available Fishing Days by Area

3.3.3 Market Requirements

The types of vessels and gear used in any fishery cannot be divorced from the realities of international seafood markets.

This is particularly true at the present time, since the fishery is becoming as “globalized” as most of our other industrial sectors.

The Canadian harvesting and processing sectors together must be able to produce seafood products which are both quality and price competitive worldwide, or the industry will not be financially viable. If competing nations are using advanced fishing technology, the Canadian industry will then be forced to do the same.

It is often said that such large-scale or “industrial types” of fisheries are inappropriate for the socio-economic conditions and cultural history of the Atlantic Canadian fishery. The reality is however, that we cannot isolate ourselves from the international marketplace. Our fishing industry must therefore compete on world markets with seafood produced by other technologically advanced fisheries.

Although at first glance, the Atlantic Canada fishery appears large in terms of the numbers of fishing vessels, processing plants, fishermen and plant workers, it is certainly not dominant in terms of landings and production when compared to many other fishing nations. For example, even before our groundfish stocks collapsed in the early 1990’s, Canada ranked only 18th amongst the major fishing nations in terms of landings (FAO Statistics).

This was recognized in the 1993 report of the Task Force on Incomes and Adjustment in the Atlantic Fishery (the “Kirby” Report), which to quote:

“Looking beyond the impacts human terms and focusing on markets, Canada’s resource crisis is going virtually unnoticed. In our traditional stronghold, the United States, Atlantic cod reigned supreme among groundfish and Canada supplied more than half of all cod. Yet demand and hence price, have dropped notwithstanding the collapse of Canada’s Atlantic groundfish fishery.”

Marketing large volumes of seafood therefore requires:

- Continuity of supply
- Competitive pricing
- Consistent high quality, and
- A wide range of products

Why Trawling is Required—continued

In the retail sector, continuity of supply is absolutely critical. Companies spend substantial sums of money to acquire shelf space in large supermarket chains and invest even more to develop brand identity through advertising and promotion campaigns. When a company fails to supply a product, the retailer invariably makes the shelf space available to a competitor's product.

In many segments of the food services sector, consistence in both quality and supply is equally as important as in the retail sector. Fast food chains such as MacDonald's and Red Lobster build their reputation on the consistent quality of their products. These chains demand year round supply and if this cannot be provided by Canadian producers, they simply source their product from one of many other fishing nations.

The processing and harvesting sectors are therefore closely interrelated, each being dependent on market requirements. For example, the types of vessels and gear used in an area can be very dependent on the characteristics and the target markets of the local fish processing sector. The following two examples display this reality:

- The large inshore longline fleet in southern Nova Scotia is probably appropriate to supply the numerous, small to medium salt fish processing plants in that area. These longliners traditionally targeted large cod, which is by far the most desired and valued species for salt fish. The plants traditionally salted this fish when it was landed in the summer and dried it in the winter, when the furnace driven dryers were most effective (although recent heat-pump technology has reduced this requirement). During this winter period of fish drying and further processing into boneless and other such products, a majority of these local vessels converted to lobster fishing.
- In contrast, the large frozen fish plants in other parts of Atlantic Canada required large amounts of relatively inexpensive groundfish on a year around basis. Offshore trawlers were probably the optimal types of vessels to supply such plants. When fish stocks recover to previous levels, it is unlikely that such plants could be reasonably supplied by a fleet of inshore, fixed-gear vessels.

3.3.4 Economic Requirements

Although the Atlantic Canada fishing industry is internationally competitive in shellfish and higher valued finfish products, it has not been as competitive with lower valued products. For example, there a concern that future markets for some lower quality Canadian cod products may become increasingly difficult to rebuild after fish stocks recover.

In many other fishing nations, the harvesting of high volume or "industrial" types of fisheries (e.g. frozen, commodity type products) are usually carried out by larger, technically advanced trawlers. It is ironic that the lower valued fish products usually require the highest level of technology to compete internationally. Nevertheless, this is a concept that cannot be ignored in the Canadian fishery. As well, when groundfish resources recover, harvesting strategies should change towards maximizing the quality and value of fish landed, rather than simply focusing on volume. Such as shift in strategy may require a different mix of vessel types and sizes.

Productivity in the Canadian economy is a growing issue, and many parts of our fisheries are significantly less productive than that in other developed nations. Economics or profitability is a very significant consideration when comparing fish vessels and gears since harvesting operations will normally cease if unprofitable, no matter how advantageous they are from the resource conservation or environmental point of view. However, the types of vessels and fishing gear necessary to provide a given income for both fishermen and plant workers in a given area can be technically defined.

The incomes of fishermen in Atlantic Canada, as in other fishing nations, are generally related to the size and technical sophistication of the vessels on which they fish. The fishery is therefore no different than other economic sectors (such as agriculture) where incomes are usually dependent on the levels of capital investment and the resulting productivity per worker. The same pattern may not be as applicable in some types of fisheries, such as those for higher valued species such as lobster. Smaller inshore vessels may be the most efficient and appropriate for these fisheries.

Why Trawling is Required—continued

Let us assume, for example, that an economic objective in a given demersal fishery is to achieve average crew earnings of \$30,000 per annum. Since the "lay system" in many fisheries allocates about 50% of the vessel landed value to the crew (the other 50% being required for vessel expenses, etc.), this implies that the average landed value per crew member would have to be about \$60,000 per annum. If the average landed value of the fish was \$0.50 per pound, the average annual productivity of the harvesting operation would have to be about 120,000 pounds per fisherman (i.e. about 60 tons). In most fisheries, the numbers, sizes and types of vessels to provide such income levels can then be estimated quite easily.

In this regard, it has been found that the size of the fishing vessels is a much more important determinant of average incomes than the type of gear which is used. An analysis which demonstrates this in the Atlantic groundfish fishery is included in the following paragraph 3.4.2.

3.3.5 Traditions, Expertise and Working Conditions

Another important factor which determines the type of gear used by a group of fishermen relates to local traditions and "fishing culture". Historical or community "attachments" to certain types of fishing gear, as well as the local expertise which this develops, are very important factors in this regard.

For example, in the southern Nova Scotia groundfish fishery:

- Inshore fishermen from areas of Lunenburg County, such as Tancook Island, tend to use gillnets. Offshore fishermen from the same area work primarily on trawlers.
- Inshore and nearshore fishermen from Shelburne County are strong supporters and operators of longliners.
- Nearshore fishermen in the adjacent Yarmouth and Digby counties operate primarily trawlers, and would probably quit the fishery rather than work on longliners.

Working conditions onboard vessels, as well as crew earnings, are also very visible and personally important factors. The length of fishing trips is usually longer with larger fishing boats (e.g. ranging from less than a day on many inshore boats to more than a month on offshore shrimp trawlers) and this is

an important personal factor in selecting the type of fishery in which to participate. It is generally accepted, however, that crew living conditions are usually better on larger boats.

Although the type of gear used by a fisherman may have been initially chosen because of local traditions and expertise, much of the flexibility to change harvesting methods has been removed in the past several decades by the imposition of limited entry licensing systems.

3.4 ECONOMIC CONSIDERATIONS

3.4.1 The Importance of Trawling in the Atlantic Canada Fishery

Trawling is used in the fisheries on both the Atlantic and Pacific coasts, as well as in the fresh water fisheries of Canada. The importance of this type of gear in just Atlantic Canada, for example, can be illustrated by referring to the landed value of the Atlantic fisheries in 1998 (DFO Statistics):

Atlantic Canada	\$ millions
• Groundfish	\$162.6
• Pelagics	\$71.3
• Shellfish	\$1,027.9
• Other	\$5.2
TOTAL	\$1,267.0

In the shellfish sector, approximately \$400 million of the total was harvested by towed gear. Of this amount, \$274 million came from the shrimp fishery, which is conducted using otter trawls. The remainder came from the scallop and offshore clam fisheries, where harvesting occurs primarily with towing fishing gear such as rakes or dredges on the sea bottom (i.e. mobile gear). It is difficult to determine what proportion of the groundfish catch was harvested by trawlers, however, based on historical pattern, assume 50% or about \$80 million.

Therefore, in Atlantic Canada during 1998, close to \$500 million in landings were caught with mobile, towed gear (note: this excludes purse seining for pelagic species since this "mobile" gear does not involve "towing"). These landings represented close to 40% of the total value in Atlantic Canada, and demonstrates the economic importance of this type of gear. It should also be emphasized that the landings of these important species such as shrimp would not have occurred

Why Trawling is Required—continued

without the use of mobile gear. In this regard, it should be noted that the value of fish landings in Newfoundland are presently at all time highs, despite the depleted state of most groundfish stocks adjacent to that province. This has in large part been due to the development of alternate fisheries such as trawling for shrimp.

The onshore “spin-off” benefits from these mobile fisheries, such as employment in processing plants and the servicing of fishing vessels, has also been a major factor in saving the economic base of many Atlantic Canada communities after the collapse of the groundfish stocks. For example, the shrimp landed by the nearshore trawlers in Newfoundland are cooked, peeled, sorted and packaged in processing plants. As a result, the total Atlantic Canada FOB plant value of the processed seafood resulting from these trawl or towed gear fisheries could be in the order of double the landed (i.e. dockside) value, or close to \$1 billion per year.

It should also be noted that when the Atlantic groundfish fishery was in full operation a decade or so ago, it would have been technically impossible to land the Total Allowable Catches with just fixed gear such as traps, longlines and gillnets. In 1989, for example, the TAC for all groundfish in Atlantic Canada was 825,000 mt, of which approximately 535,000 mt or about 65% was allocated to the mobile gear sector. Given the technical, environmental and seasonal constraints in this fishery, however, much of this resource could not have been harvested without trawlers.

For example:

- Approximately 209,000 mt of this TAC (or about 40%) was for flatfish and redfish, which would have been technically impossible to catch with fixed gear.
- The seasonal and coastal operations of smaller fixed gear boats would not have allowed the full utilization of the remaining TAC for cod, pollock and haddock, due to constraints such as harvesting and plant capacity, seasonal market gluts, etc.

3.4.2 Groundfish Harvesting Economics and Crew Earnings

The incomes of crew members on fishing boats in any fishery can vary significantly depending on the types and sizes of fishing boats on which they are employed.

The potential earnings of fishermen in the Atlantic groundfish (i.e. cod, flatfish, haddock) fishery, for example, can be estimated from historical data on the economic performance of various types of vessels in these fisheries. Such data includes average catch rates, crew sizes and vessel operating costs. This type of information is displayed in figure 3-2 for various types of groundfish harvesting operations in southern Newfoundland waters or the Scotian Shelf.

	Capital Cost (New) 1	Annual Fixed Costs 2	Variable Cost per day 3	Catch Rate MT/Day 4	Crew Size 5
Cod Trap	\$50,000	\$9,300	\$100	1.6	5
Longliners					
12 m (40')	120,000	22,400	400	1.5	3
20 m (65')	900,000	136,000	800	3.3	6
30 m (100')	3,000,000	510,000	1,700	7.0	12
40 m (135')	4,500,000	765,000	1,850	8.4	12
Trawlers					
14 m (45')	500,000	93,300	500	2.3	3
20 m (65')	1,500,000	255,000	1,050	5.4	4
27 m (90')	3,000,000	510,000	1,750	8.2	8
45 m (150')	9,000,000	1,530,000	3,800	14.3	15

Figure 3-2. Costs and Productivity of Various Groundfish Harvesting Methods

Note (1) A Cod Trap operation is assumed to consist of 3 traps @ \$10,000 plus one 8 to 10 m (28 to 32 ft.) trap vessel @ \$20,000. Such traps are assumed to be fished for 6 days per week over an average season of 12 weeks (i.e. an average of 72 days) This can vary significantly however, depending on the area and year.

Note (2) Fixed annual costs assume a depreciated life of 15 years for traps and 12 m (40 ft.) vessels, and 20 yrs. for larger vessels.

Note (3) Variable Costs per day are based on average annual costs for Fuel & Lubricants, Ice, Bait, Food, Gear, Maintenance, etc., as recorded by Canadian vessels.

Note (4) Based on historical groundfish catch rates per sea day in Scotian Shelf and Southern Newfoundland waters. Fixed gear catch rates elsewhere may be significantly less (e.g. approximately one-half during the past decade in the Gulf of St. Lawrence).

Note (5) Crew sizes are based on averages in Scotia Fundy Region. Crews for similar vessels in other Regions of Atlantic Canada are often larger. Cod trap crews and lay systems are based on larger operations in Newfoundland.

Why Trawling is Required—continued

It should also be noted that:

- These estimates are based on averages of actual operating data from several years ago when groundfish stocks were plentiful (DFO Fishing Vessel Performance, Matthews 1990).
- Costs and revenues of the various vessels in a given fleet sector can vary widely. As a result, the following data should be only considered as “representative” for the particular types and sizes of fishing vessels in the Atlantic groundfish fishery (Tavel/FCC 1995).

Based on the above data and the following assumptions, the estimates shown in figure 3-3 can then be derived.

Type of Fishing	Fishing Days	Total Catch mt & \$000	No. of Crew	Catch Per Crew (mt)	Crew Share (%)	Avg. Crew Earnings
Cod Trap	72	115	5	23	50	\$11,5000
Longliners						
12 m (40')	75	115	3	37	50	18,600
20 m (65')	171	564	6	94	30	28,200
30 m (100')	203	1421	12	118	30	35,000
40 m (135')	211	1772	12	148	30	44,400
Trawlers						
14 m (45')	111	255	3	85	50	42,500
20 m (65')	171	923	4	231	30	69,300
27 m (90')	203	1665	8	208	30	62,000
45 m (150')	211	3017	15	201	30	60,000

Figure 3-3. Estimated Crew Earnings in Groundfish Harvesting Enterprises

- Average fishing days per year are as shown in figure 3-1 for southern Newfoundland waters.
- Average catch rates are as shown in figure 3-2, and there are no limits such as ITQs.
- An average dockside value for fish of \$1.00 per kilogram is assumed (i.e. about \$0.45/lb)
- Crew remuneration is based on the lay system, which varies significantly by fleet sector and area, however the percentage crew share usually decreases with larger vessel size.

To simplify the analysis, it will be also assumed that 50% of the landed value is allocated to crew members on smaller vessels, and 30% on the larger ones.

Such analyses and actual experience therefore indicate that:

- Although earnings on trawlers are somewhat higher than on longliners, the key determinant of incomes is more the size of vessel than the gear used.
- For example, productivity in terms of annual catches per crew member can vary dramatically, and without quota restrictions can reach levels of over 200 mt per participant on larger trawlers.
- Earnings of crew members in small inshore enterprises such as traps and longliners are quite modest, being usually less than \$20,000 per annum.
- Earnings on larger vessel can be substantial and can be significantly higher than average incomes in many other Canadian industrial sectors. (i.e. fishermen don't have to be poor, and many are not). Crew members on nearshore and offshore fishing vessels can easily make over \$40 to \$50,000 per annum. This has also been the experience in other fishing nations such as Iceland and Norway.
- Powerful nearshore vessels such as 20 m (65') trawlers may be the most productive on the Atlantic Coast, in terms of both landings per crew member and per unit capital investment. Catch rates of trawlers are dependent on the size of trawl nets which can be towed and this is dependent on the vessel engine power. Recent 20 m trawlers are extremely large and powerful for their length, and have engines of up to 1,000 hp. This is in the same power range as many offshore trawlers several decades ago. As mentioned in Section 2, the optimal length for trawlers of this tonnage and power may be in the 23 to 28 m (75 to 90 ft.) length range (i.e. without DFO length restrictions).
- Catch rates for longliners are proportional to the length of “ground line” or the number of hooks set per day. For the larger longliners, the upper limit is about 30,000 hooks per day.

Why Trawling is Required—continued

- Despite the high catch rates of nearshore vessels, companies may still wish to use larger vessels over 30 m (100 ft.) in length because of their ability to continue fishing in adverse weather conditions and thereby better provide continuity of fish supplies. Companies have always been willing to pay a premium for supply continuity.

3.4.3 Spin-Off Benefits

Trawlers cost significantly more to construct and operate than smaller boats. This implies that most trawlers result in significantly more economic activity and jobs in shipyards and supporting industries than other types of fishing vessels.

Perhaps the most important economic spin-off economic benefit of trawlers, however, are the jobs which they support in the onshore processing sector. Because of their higher productivity, each crew job on a trawler supports significantly more processing or shore base jobs than each crew on a fixed gear vessel. For example, in 1985 when fish was reasonably abundant, each crew member on a 14 to 20 m (45 to 65 ft.) nearshore trawler in the Scotia Fundy Region supported about 3.8 person years of onshore employment. This estimate was based on 10 person years of shore based employment being created per 1 million pounds of groundfish landed. If we assume that each shore job in this nearshore fisheries sector is an average of 6 months duration, this would suggest that each crew member on this type of trawler supported the equivalent of 7.6 seasonal jobs on shore (DFO/CFCL 1994).

For longliners in this region, an average of about one person year of shore based employment was supported per crew member, because of lower catch or productivity rates. This would equate to two shore based jobs of 6 months duration. It should however be noted, however, that the longlining sector supports a significant part of the local bait industry, as well as some onshore baiting jobs.

3.4.4 Fleet Capacity

Prior to the 1980's the offshore trawler fishery was basically a "race for the fish" resulting in unsatisfactory practices and market gluts. The implementation of an Enterprise Allocation (EA) System for the offshore sector then resulted in a more planned and orderly harvest. The EA system has also removed, by definition, the overcapacity problem for the offshore sector.

This is because, given a certain allocation of fish, each company will only use the minimal number of vessels or fishing effort to most efficiently harvest that quota.

This concept was then applied to most of the other trawler fleets in Atlantic Canada through the Individual Transferable Quota system. This has also resulted in a significant reduction in the size of the nearshore trawler fleet. It should also be noted that this fleet reduction was achieved without government funding, since the industry itself paid for quota purchases and consolidated such quotas on fewer vessels. Both ITQs and EAs allow vessel owners to plan their harvesting operations to maximize market returns, rather than simply to compete for a share of the resource.

For example, much of the groundfish landings in southwestern Nova Scotia go to the fresh fish market in New England, and prices on that market fluctuate significantly during the year. As a result, trawler owners attempt to utilize their quotas when market prices are high. When those markets are glutted and prices are low, fishing activity is reduced. Furthermore, since trawler owners and crew members can make reasonable profits and incomes with available resources or quotas, they are not driven to "cheat" or to adverse fishing practices in order to survive financially.

3.5 BEST USE OF THE RESOURCE

3.5.1 The Fish Quality Issue

A basic objective of fisheries management should be to not "waste" the harvested fish. That is, the economic value of fish landings should be maximized as much as possible. This is usually achieved by catching those sizes of fish which are most valuable; landing this fish in top quality condition; and processing it to obtain optimum market prices.

The relative quality and market value of fish landed by vessels using various types of gear is frequently mentioned as a reason to favour one type of gear over another. Care should be taken, however, to distinguish if quality variations are due to:

- The type of fishing gear used, or
- The way in which the gear is operated, as well as how the fish is handled and stored onboard the vessel.

Why Trawling is Required—continued

Trawlers have been blamed in the past for catching excessive amounts of small fish and landing fish of poorer quality. There are **no** technical or intrinsic reasons for this. For example:

- In Section 5 it is explained how trawl gear can be as size and species selective as other types of gear such as longlines.
- The following parts of this section will introduce experimental evidence that trawls can land as good quality fish as other types of gear.

To begin, practically all of the scientific literature on this matter has focused on the handling and storage of fish onboard vessels, rather than on the gear itself. One reference found in the international literature relating to the quality of fish caught by different types of gear was by the Norwegian, Bjordal (1985), who stated that:

“Both methods of capture (i.e. trawling and longlining) may produce fish of high quality. However, big trawl hauls and tows of long duration might lead to reduced quality, both because the fish are exposed to high pressure in the codend, and because it might take too long before the catch is processed.”

In Canada, practically all of the past studies relating to dockside fish quality used the dockside Grade Standards developed by the Department of Fisheries and Oceans. Under this system, quality grades of A, B, C, or Reject were assigned using a combination of factors including texture and handling practices, examination of round or gutted conditions, and examination of cut surfaces.

A report to the Southwest Nova Scotia Groundfish Quality Committee on the 1986 Dockside Grading Program by Tavel Limited indicated the following results (see figure 3-4) of a sampling program of landed fish quality by gear type.

Rather than focus on the somewhat controversial result that the average quality of fish landed by longliners over 14 m (45 ft.) is less than that landed by trawlers of any size, one should note that (with the exception of gillnet caught fish) one could attribute quality as much to the average time held in the fish hold, as to the type of gear used (i.e. larger boats usually take longer fishing trips)

Gear Type	QUALITY AND PERCENT OF CATCH			
	A(%)	B(%)	C(%)	R(%)
Gillnet	54.5	43.6	1.8	0
Handliner	82.9	17.1	0	0
Trawler <14 m (45')	60.1	32.339	7.1	2.1
Trawler 14-20 m (45-64')	49.8	39.55	8.6	0.8
Trawler >20 m (65')	45.6	43.8	9.8	2.9
Longliner <14 m (45')	77.7	18.0	1.4	2.9
Longliner >14 m (45')	32.8	38.7	10.7	17.7
TOTAL	54.0	36.1	7.6	2.3

Exhibit 3-4. Landed Fish Quality by Gear Type

A paper by O'Reilly at the 1988 World Symposium on Fishing Gear dealt with the “Middle Distance” vessels owned by Newfoundland at that time. These 30 meter vessels initially used longline gear, but later changed to gillnets in order to increase catch rates. Quality of landed fish was a priority with this program, and studies showed that the quality of “boxed” gillnet fish was better than the quality of “bulk” stored longline fish. This again demonstrates that gillnet caught fish probably have a poorer quality reputation than longline caught fish because of poor handling and storage practices, rather than an intrinsic characteristic of the gear itself.

In another related paper by Botta and Bonnell at the above mentioned 1988 conference, the results of a DFO study was presented on the causes of quality reduction in Northern Cod landed by offshore trawlers. The conclusion of that study was that the quality of cod caught by trawlers was usually very good when first brought onboard. The reduction in quality was observed to be primarily due to:

- Catching more than 5 tonnes during a single tow
- Having a delay of one hour or more between when the cod were brought onboard and when they were bled and gutted
- Icing cod in pens rather than in boxes, and
- Storing cod in ice for more than 6 days

Why Trawling is Required—continued

In summary, the conclusions of these quality related studies was that any type of gear can provide top quality fish. For example:

- a) The gear should be operated properly. For trawlers, this means that tows should be limited to reasonable lengths of time and the sizes of individual catches should be limited.
- b) After the fish is brought onboard, it should be properly handled, iced and stored, and
- c) Fish should be kept onboard the vessel for a reasonable amount of time when stored in ice.

In other words, numerous studies have repeatedly shown that human or operational factors, rather than the type of fishing gear used are the most important determinant of fish quality.

3.5.2 Optimizing Catch Value

When the cod resource recovers, its economic value will depend on the average size of fish which is harvested, the quality of this fish when it is landed, and the types of cod products which are produced by the processing plants.

To illustrate this, the following analysis (Tavel/FCC 1995) will show how the economic value of fish landings can vary significantly, depending on fish quality and size, as well as the resulting seafood product mix. Although the prices shown below may be somewhat dated, the relative differences are still considered relevant.

Consider the following options:

- a) Processing very small and relatively poor quality cod (i.e. under 17") into skin-on, bone-in fillet layer packs
- b) Processing small cod (i.e. 17-19") of better quality into standard skinless, boneless fillet blocks
- c) Processing medium size cod (19-21") of good quality into skinless, boneless 5 lb. cello packs
- d) Processing large cod (i.e. over 23") of the best quality into primarily IQF loins, tails and centre cuts

The results of the analysis can best be illustrated by comparing the overall results of harvesting and processing 1,000 metric tonnes of cod using these four different strategies. The dramatic differences in the economic results of these alternate harvesting and processing strategies are shown in the following figure 3-5.

	SOBI Fillets (V. Small Fish)	Blocks (Small Fish)	5 lb Cellos (Medium Fish)	Loins/Tails (Large Fish)
FOB Plant Value	\$1,009,800	\$1,830,500	\$2,029,700	\$2,941,900
Dockside Fish Value	\$396,000	\$968,000	\$1,144,000	\$2,046,000
No. of Fish Killed	2,200,000	1,490,000	1,045,000	550,000
FOB Plant Value per Fish	\$0.46	\$1.23	\$1.94	\$5.34
Dockside Value/lb	\$0.18	\$0.44	\$0.52	\$0.93

Figure 3-5. Economic and Resource Impacts from 1,000 mt of Round Cod

Note: - In reviewing figure 3-5, it should be noted that it is only possible to get so much premium packs out of even the best fillets. A portion of the production will inevitably be lower valued product, such as block and mince. The actual or practical range of product and dockside fish values will therefore be somewhat less than that shown in this figure. Nevertheless, this analysis illustrates the overall patterns.

In other words, catching a given quota of larger cod and processing it into the highest valued products compared to harvesting the same weight of very small fish and processing them into the lowest value product may:

- Increase the dockside dollar value per tonnage landed by four to five times.
- Increase the FOB plant value of the resulting products by up to three times, and
- May result in the need to only kill about one-quarter the number of fish.

When the cod resource recovers, the harvesting strategy should therefore change to one of maximizing the quality and unit value of fish landed, rather than the previous emphasis on volume. Such a strategy may result in the need for a different mix of fishing vessels in the Atlantic Canadian fleet.

How Fisheries Resources are Protected

Section 4

4.1 THE CANADIAN FISHERIES MANAGEMENT SYSTEM

The Canadian fisheries management system is one of the most comprehensive in the world. The Department of Fisheries and Oceans protects and conserves our fisheries resources with a wide variety of systems and approaches. In the groundfish fishery, for example, annual Total Allowable Catches (TACs) are established for all stocks by species and area, based on scientific advice.

A licensing system also limits the numbers and sizes of fishing vessels in all gear sectors. Substantial overcapacity in many sectors of the groundfish fleet still exists, however, despite government funded "buy-backs" of groundfish licenses. As previously explained, such needed reductions in capacity have been most effective in the trawling fleet because much of this sector operates under Individual Transferable Quota and Enterprise Allocation systems.

In addition to setting annual quotas for each fleet sector, DFO also imposes a whole range of conservation measures to reduce catches of juvenile fish, to minimize bycatches of nontarget species, and to limit catches. To illustrate some of these, relevant parts of the 1999 Atlantic Groundfish Management Plan for trawlers under 20 m (65') operating on the Scotian Shelf (DFO 1998) are included below.

Fishing Gear

Regulations require the use of gear which has certain selectivity characteristics. For example, a minimum 130 mm square mesh is required in trawls when fishing for cod, haddock or pollock in this area. These are amongst the most stringent gear restrictions of any country in the world.

Bycatch Provisions

Discards of non-targeted species are also reduced through bycatch provisions in the annual fishing plans. For example, the 1999 plan includes a 5% daily bycatch limit of cod and haddock when fishing for redfish and flatfish in Subarea 4VW. Areas are closed for specified fleet sectors when these limits are reached or exceeded.

Small Fish Protocol

Based on the principle of letting most fish spawn at least once, the Canadian approach is to set a target in any given year, so that a specified percentage of the catch are sexually mature fish. The current objective is to be moving towards a harvesting target of at least 50% being sexually mature. In 1999, for example, cod will be considered undersized if smaller than 43 cm. Areas will be closed when the number of undersized fish reaches or exceeds 15% of the catch of any species.

Catch Monitoring and Test Fishing

Enforcement of regulations is achieved through measures such as an industry funded Dockside Monitoring Program. Small fish and by-catch closures have a minimum duration of 10 days and are followed by test fisheries. Once an area has been opened, onboard observers are required to ensure that catches of bycatch species or small fish are within acceptable levels.

Open and Closed Seasons

Fishing effort is also controlled through open and closed seasons. For example, Subarea 4Vn is closed to all fishing from January 1 to April 30, 1999.

Spawning and Juvenile Closures

Areas where spawning and aggregation of juvenile fish are known to regularly occur are also closed annually for specified periods.

4.2 FISHERIES CONSERVATION OBJECTIVES

Although a wide variety of fishing gears and vessels are used in the groundfish, pelagic and shellfish fisheries of Canada, the following conservation characteristics are common to all harvesting methods. These are the characteristics which fisheries managers try to control and which gear designers try to improve. In addition, although specific gear developments are usually focused on improving one or several of the following characteristics such as selectivity, the overall impact of the gear and conservation devices relating to all of these characteristics have to be considered.

How Fisheries Resources are Protected—continued

Size Selectivity - One of the most important features of any type of gear is the way in which it retains certain sizes of fish and allows other sizes to escape. It is also an important part of fisheries management, since the future of any stock is influenced by the size and maturity of the fish which are captured. Size selective harvesting maximizes the long-term yield from a resource.

Species Selectivity - The ability to catch only target species, and to minimize the bycatch of other species is another conservation requirement of harvesting operations. This is especially true with quota management systems. Having both size and species selective gear reduces the incentive to discard unwanted catches overboard.

Limiting Catches - Having the ability to control the volume of catches is an important characteristic of fishing gear. This assists fishers to stay within quota or trip limits, and thereby minimizes the motivation for adverse practices such as discarding or illegal landings. Limiting catches to levels which can be readily processed and stowed onboard also promotes improved fish quality and best use of the resource.

Best Use of the Resource - The key factor here is to maximize the quality of the fish which is landed. Some adverse quality effects may be due to intrinsic characteristics of the gear being used, however, a major cause is also how the gear is operated (e.g. towing trawls for excessive periods, leaving gillnets too long in the water, etc.)

Protection of Marine Mammal and Birds - Although this is primarily a selectivity issue with fixed gear such as traps and gillnets, it is mentioned separately because of its great public interest. Many environmental groups and government agencies have targeted specific fisheries and types of fishing gear because of incidental catches and mortality of marine mammals and birds which have occurred. Besides the actual loss of these important creatures, this has resulted in much adverse publicity and regulatory action for some fisheries.

Impacts on the Ocean Environment - Of all the concerns expressed about the effects of fishing gear on the marine environment, probably the most common relate to the possible effect of trawling on the ocean bottom and "ghost fishing" by lost or abandoned gillnets. The former issue will be examined in some detail in Section 6.

Impacts on the Whole Environment - This would include those characteristics of fishing operation which have an adverse impact on the global environment as a whole. Improving the fuel efficiency of harvesting operations and reducing other sources of air pollution (particularly "greenhouse gases") contribute to the achievement of such an objective.

Survival After Escapement - Since regulations are imposed on fishing gear with the objective of enabling small fish and nontarget species to escape, it is important to know whether the escaping fish survive.

The challenge is not only to optimize these numerous gear performance criteria, but also to achieve a balance amongst conflicting criteria. For example:

- Some characteristics have internal conflicts.
e.g. square mesh trawls are more selective than diamond mesh ones for round fish, however their selectivity appears to be poorer for flat fish.
- Many characteristics conflict amongst themselves.
e.g. increasing mesh size usually has a positive effect on the resource, but a negative effect on vessel economics.
- A few characteristics have possible different short and long term effects.
e.g. selecting only the largest fish in a population provides optimal short term benefits, but may have adverse long term genetic effects on the resource
- Some characteristics are often beyond our control.
e.g. changes in the environmental and international seafood markets

It should also be noted that changing gear characteristics such as size selectivity will not cure an over-capacity problem and the related incentives for over-fishing. Over-capacity in any gear sector, therefore, should be considered as a separate issue.

How Fisheries Resources are Protected—continued

4.3 RESPONSIBLE FISHING

4.3.1 The Need for Responsible Fishing Practices

As previously mentioned, the negative impacts resulting from the use of any type of fishing gear is often caused as much by the way that the gear is operated or misused, as by the intrinsic characteristics of the gear itself. In other words, the "human" factors are possibly as important in many cases as the "technical" factors.

Regardless of the type of gear, the ingenuity of fishermen and the continued advances of technology can often defeat most regulatory attempts to control fishing effort and impacts. The solution must therefore come from motivating fishermen to assume more personal responsibility for the proper operation of harvesting gear. For example, if there is an aggregation of small or immature fish, or an abundance of nontarget species in an area, then many types of fishing gear will catch them (i.e. regardless of their "technical" selectivity characteristics). Responsible fishermen know from experience when and how to avoid such areas.

Besides fishing in areas where juvenile fish or nontarget species are abundant, irresponsible fishing practices may also include:

- Overfishing, or illegally catching and landing fish in excess of quotas.
- Dumping small fish and bycatches overboard, or "high-grading" by only retaining the most valuable fish.
- Practices which result in the loss of fishing gear, and the resulting "ghost fishing" which may result with certain types of gear.
- Poor quality control of the catch, resulting in some or all of the landings not being useable for human food, increased processing wastes, and lower valued products.

The ease with which fishing gear can be used irresponsibly, and the potential for damage to the resource from such misuse, can vary significantly depending on the type of gear (DFO/CFCL 1994). For example, gillnets can be misused by setting more nets than can be properly handled, or by leaving them for excessive periods in the water. Such practices result in poor quality fish, as well as lost or "ghost" nets, which can

continue fishing and killing marine life for extended periods. The irresponsible operation of trawls includes the use of smaller than regulation mesh sizes, adjusting the trawl geometry to retain small fish, or towing for excessively long periods which results in poorer fish quality and selectivity.

Although fixed gear such as longlines can catch juvenile fish, nontarget species and excessive amounts of target species, mobile gear such as trawls and seines are usually more powerful harvesting tools. For example, longline gear has a clearly defined level of catching capacity, which is limited by the number of hooks operated per day. In comparison, trawl fishing has no such limit on catch rates. Of all fishing gears, therefore, longlines are simply the most difficult to use in a destructive way. This does not imply, however, that a "hook and line" fleet cannot catch too much fish, catch excessively small fish, or participate in wasteful practices such as discarding or dumping fish.

As a result, if fishing gear such as otter trawls are used irresponsibly, they can quickly cause significant damage to a fish stock. The real challenge, as repeatedly mentioned, is to motivate all fishermen to focus more on long term conservation and less on short term economic gains.

The tragedy of human behaviour in the fisheries is that economic pressures motivate fishermen to increasingly participate in destructive practices as a resource becomes depleted. Under such conditions it is especially important to convince fishermen to adopt responsible fishing practices. Quota cutbacks by governments, and increasingly stringent regulations, are simply not enough to protect fisheries resources in the long term.

4.3.2 Government/Industry Cooperation

The collapse of many traditional fisheries, and the devastation which this has caused to coastal communities around the world, has demonstrated that the way in which fisheries are managed and prosecuted must change. This need for change is well described in Section 164 of the FAO International Expert Consultation document on Responsible Fishing Practices, which states:

The challenge that lies ahead in most fisheries of the world is for fisheries administrations to move into a new era of cooperation between government and industry. The partnership must be real and extend into all facets of fisheries

How Fisheries Resources are Protected—continued

management including scientific and technical research, regulation, enforcement, inspection, marketing and education. Direct industry participation should lead to a sense of ownership which will foster a greater sense of responsibility.

In response to the above described challenge, the Department of Fisheries and Oceans (DFO) has been gradually redirecting the management of the Canadian fisheries towards such cooperation and partnerships with the industry.

The beginning of this process began many years ago when DFO began to formally consult with the industry through a system of Advisory Committees for each of the numerous fisheries sectors in this country. The next phase included the active participation of industry organizations in the development of Annual Harvesting Plans. Increasingly, however, fishermen have begun to develop their own solutions to specific management problems. Such solutions are frequently accepted and implemented by DFO where they are shown to be effective and enforceable.

4.3.3 The Canadian Code of Conduct for Responsible Fishing Operations

Recognizing the need to improve the management and prosecution of the world fisheries, an International Code for Responsible Fisheries was adopted by 80 countries, including Canada, at the 28th Conference of the FAO in 1995. This concept of a Code of Conduct not only requires closer cooperation between industry and government during its development, but also in its implementation in day-to-day fishing operations.

Several years ago, some representatives of the Canadian fishing industry saw the need for a Canadian Code of Conduct for Responsible Fishing Operations, which would be compatible with the FAO Code, but also reflect the specific needs of the varied fisheries in this country.

A series of regional industry consultations were held across Canada, culminating in the National Fishing Industry workshop held in Toronto, on January 1998. At this workshop, representatives of fisheries associations from across Canada agreed on the wording of the Code and the next steps for its implementation. Fisheries associations across Canada are currently in the process of ratifying this Code.

This Canadian Code consists of two major parts (DFO/ Code Secretariat):

Part I - INTRODUCTION - This includes the basic principles that support the development of the Code, and the underlying goal of sustainable fisheries.

Part II - GUIDELINES FOR FISHERMEN - This Part provides general guidelines in seven specific areas for implementing the principles of the Code.

For example, the application of a Code guideline relating to minimizing catches of non-targeted species, could result in the following hypothetical requirement for a particular shrimp fishery .

When fishing for shrimp using a trawl in area (x), fishers must employ a rigid selectivity grid with maximum bar spacing of (y) mm, to avoid exceeding (z)% incidental by-catch of groundfish (fictitious example).

4.3.4 Conservation Initiatives by Industry Associations

Fishing industry associations in Canada have been increasingly involved in programs to improve fisheries conservation, and in some cases have been established with this as a primary mandate. For example, the Canadian Groundfish Research and Conservation Society (CGRCS) is a non-profit society with was created in 1994 to support the conservation of groundfish resources and the sustainability of groundfish fisheries on the Pacific Coast. It is composed of participants in the British Columbia commercial groundfish trawl fishery, and is funded entirely by its members. The CGRCS is an important contributor to the research, assessment and management of groundfish on the B.C. coast through activities which include:

- Collecting biological and oceanographic data vital to understanding fish behaviour, genetics, growth, and migration. This includes the use of commercial fishing vessels to carry out surveys to assess the size and health of fish stocks, and to evaluate the selectivity of new fishing gear. Scientific staff is also employed to assist in the planning, management and analysis of such projects.
- Sending members on DFO research vessels as technical advisors to provide important traditional knowledge about groundfish behaviour and habitat.

How Fisheries Resources are Protected—continued

- Participation in the Pacific Stock Assessment Review Committee process – DFO's forum for peer review and evaluation of scientific research on groundfish.
- Working with DFO on the development of long-term research and assessment strategies for the Pacific groundfish fishery, as well as the Canadian Code of Conduct for Responsible Fishing Operations.
- Promoting education programs in Responsible Fishing both for the industry and for Secondary Schools in B.C.

Cooperative projects by DFO and the CGRCS to develop and evaluate selective fishing technologies have been especially effective. For example, the implementation of such new technologies, as well as various management measures recommended by the trawl fishermen, have resulted in a more than 90% decrease in halibut bycatch between 1991 and 1997. The B.C. groundfish trawl industry's success at dramatically reducing bycatch is often used by DFO as a model to demonstrate how trawl fishing can be selective and responsible.

4.3.5 Professionalization of Fish Harvesters

Efforts to promote the professionalization of fish harvesters was begun in the early 1990's by fisheries organizations in the Atlantic region. This was based on the concept that all full-time fishers should be formally recognized as experienced professionals with the specialized knowledge and skills to manage their enterprises and their industry.

The movement towards responsible fishing and cooperative fisheries management is therefore clearly related to this process. A profession is by nature a self-regulating body, and the regulation of most professional organizations is based on an explicit Code of Conduct. Training and practical experience are also key requirements since members must fully understand and conduct their affairs in accordance with the objectives and standards of their profession.

4.3.6 Training

Historically, successful fishermen only had to know how to operate fishing vessels and how to catch fish. To effectively assume more responsibility for fisheries conservation, however, requires a broader range of knowledge and skills.

For example, today's fishermen have to be effective during consultations with fisheries scientists and managers, and in the development of new conservation initiatives.

In response to this need, the New Brunswick Department of Fisheries and Aquaculture, DFO and the local fishing industry jointly developed an Industrial Training Course in Responsible Fishing several years ago. This program has been delivered through the School of Fisheries in Caraquet, New Brunswick and is presently being offered by the Marine Institute in St. John's, Newfoundland. There has also been substantial interest in the course from outside of New Brunswick (DFO 1994).

4.4 EFFECTS OF CHANGES IN THE OCEAN ENVIRONMENT

Overfishing and poor fishing practices by both Canadian and foreign fishing fleets certainly contributed to the collapse of groundfish stocks in Atlantic Canada. It is being increasingly accepted, however, that changes in the ocean environment may have been the most important factor in the dramatic decline of these stocks.

Many fisheries scientists now believe that changes in the ocean environment may be a major cause of variations in fisheries stock abundance (Jakobsson 1992). As stated by Mann (1993),

"It seems almost certain that global patterns of atmosphere-ocean interaction are in some way responsible. Stocks have varied synchronously in spite of widely different management patterns, and it looks as if physical factors, operating through marine food webs, are often the dominant forces for changes in the fish stocks".

In other words, although fishing mortality is certainly a factor in resource declines, environmental factors are also significant in recruitment (i.e. numbers of juvenile fish entering a fishery).

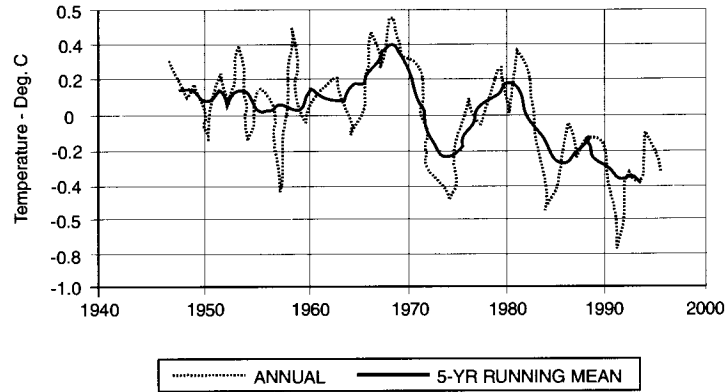
Many stocks exhibit synchronous recruitment over broad areas of the ocean. For example, cod and haddock stocks exhibit widespread year-class synchronicity in the Northwest Atlantic. Scientists have concluded that only large-scale changes in the marine environment could explain these kinds of effects on biological production. Indeed, physical properties of the ocean play a very important role in particularly the Arctic and Sub-Arctic ecosystems. For example, the recruitment of many groundfish and pelagic fish stocks were negatively affected

How Fisheries Resources are Protected—continued

by an unusually large mass of high salinity water which migrated across the North Atlantic during the early 1970's.

The significant decline in water temperatures in northern Canadian waters during the late 1980's could therefore be a major contributing factor to the rapid decrease of groundfish stocks in the this area. For example, long-term (1947-1995) hydrographic measurements representative of the Newfoundland and Labrador shelves are available from Station 27, which is located off St. John's Harbour. The annual depth-averaged (0-175 m) temperatures at this Station are illustrated in figure 4-1.

It may be seen from this figure that water temperatures were near normal through the 1950's, rose to peak values in the 1960's, and have declined since then. In addition, since 1960 there has been a near decadal oscillation with minima in the 1970's, the mid-1980's and in the 1990s. Such lower



Source: DFO Atlantic Fisheries Stock Status Report 96/41 E

Figure 4-1. Trends in Station 27 Temperatures

temperature trends not only may have impeded fish recruitment, but may have actually caused significant mortality when the cod stocks encountered sub-lethal temperatures.

Conservation Technology in Trawls

Section 5

5.1 DEVELOPMENT OF CONSERVATION TRAWLING TECHNOLOGY

Increases in harvesting capacity and advances in fishing technology have contributed to the decline of many fish stocks around the world. At the same time, however, technology has also been used to improve the conservation of fisheries stocks. These applications of technology for conservation purposes has resulted in more accurate stock assessments, improved sea and air surveillance, as well as improved selectivity features of fishing gear.

The first requirement for achieving sustainable fisheries is to limit catches to sustainable levels through effort and quota controls, and to minimize adverse practices such as discarding undesired catches. Optimizing the conservation aspects of harvesting gear and operations, however, is also an important requirement for conserving fisheries resources and protecting the marine environment as a whole.

The growing conservation awareness of Canadian fishers and the fishing industry as a whole has resulted in substantial industry support for the development or transfer of conservation harvesting technology. As a result, the industry in partnership with the Department of Fisheries and Oceans (DFO), has completed more than 100 conservation harvesting technology projects from coast to coast in recent years. These have included both demonstration projects and controlled experiments, and have included all types of fishing gear such as trawls, seines, longlines, gillnets and traps.

These types of gear development projects have originated either from the industry or government agencies in Canada, or the concepts have been transferred from other fishing nations. It should also be noted that DFO and the private sector have been active participants at many international conferences and workshops dealing with the development and evaluation of fishing technology, as well as the impacts of such technology on fisheries stocks and the marine environment.

Canadian development projects to improve the conservation features of trawling gear are described in the following sections. These projects were carried out during the past decade or so, and are categorized based on the conservation objectives being targeted.

5.2 SIZE SELECTIVITY

5.2.1 Introduction

Size selectivity, or the way in which a fishing gear retains certain sizes of fish and allows other sizes to escape, is an important characteristic of any type of gear. It is also an important part of fisheries management. Resource managers can influence the future of any stock by controlling the size at which individual fish are captured. For example, it may be desirable that the size being harvested is such that most fish can reproduce at least once. It may also be desirable to avoid the capture of the largest sizes, again because of their spawning potential.

The fact that trawling gear can be as size selective as other types of fishing gear, however, is generally supported in the international scientific literature. For example, the longline is regarded by many as a size selective fishing gear, however, this is true only to a certain extent since hooks will catch fish over a fairly wide length range.

Size selection is perhaps best explained by a “classical” trawl selection curve as shown in figure 5-1, which is simply a plot of the fraction of the catch retained by a particular gear against the fish body length. The selection curve in this figure has a 50% selection point (L50) of 40 cm. If all the fish larger than that size were selected and all those smaller escaped, the curve would be the vertical line which illustrates “knife-edge selection”. In reality, this is never the case, as some above and below 40 cm are retained. What is usually observed is a “S-shaped” curve with 25% and 75% retention points. Curve A for example, has a selection range of 10 cm.

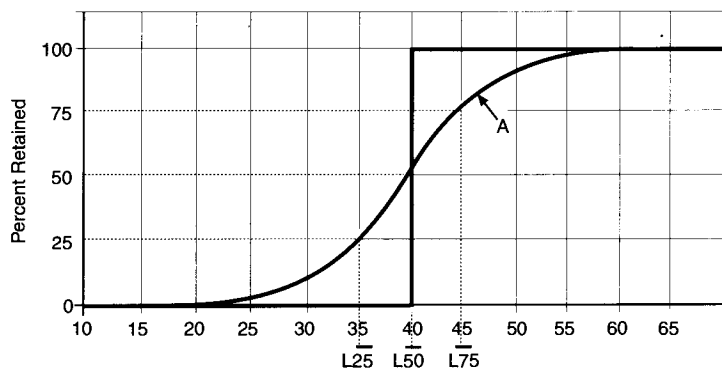


Figure 5-1. A Selection Curve

Conservation Technology in Trawls—continued

In 1993, Halliday and Kenchington carried out experiments on the Scotian Shelf to determine the size of cod caught by longlines and otter trawls at the same time and place. The results are illustrated in figure 5-2, which shows the percent cod selected by different hook sizes and trawl mesh shapes, as a function of the cod size. These experiments indicated that the large #14 hooks caught the largest fish, as was historically the case in this area. In recent years however, the size of cod began to decrease. Fishermen then began using smaller and smaller hooks, until a majority were using #10

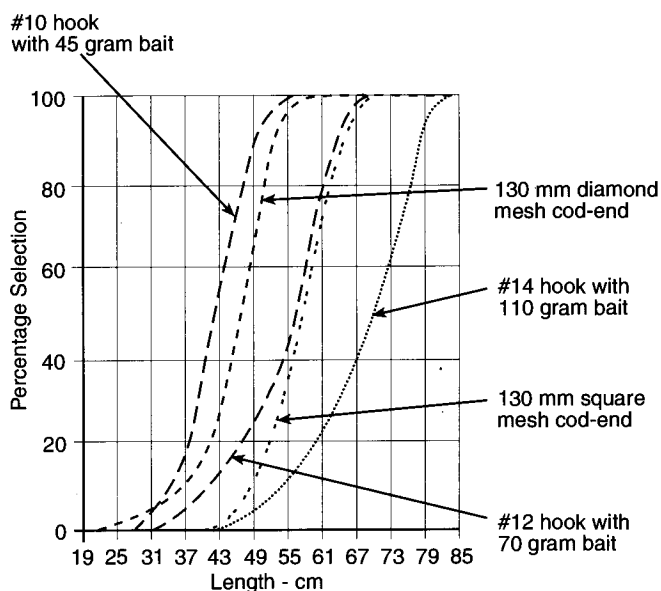


Figure 5-2. Selection Curves for Scotian Shelf Cod

hooks. With this small hook size, it appears that longline gear was harvesting proportionately smaller cod than trawlers using 130 mm square mesh.

Such experimental selection curves should, however, be interpreted with great caution. For example, if fishing vessels target aggregation of small fish, they will catch substantial amounts of them, no matter what type of gear is used (Lokkeborg 1992).

5.2.2 Square Mesh

To improve trawl selection performance, attempts have been made to design trawl gear in which all of the meshes remain open during fishing operations. One such development has been the use of square mesh rather than diamond mesh codends. Differences in codend shapes while towing, as illustrated in figure 5-3 show that this selectivity improvement occurs because nets with square mesh remain more open under tension than those with diamond mesh.

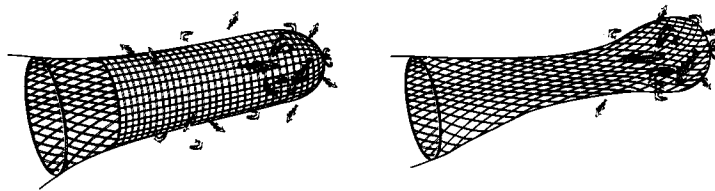


Figure 5-3. Square and Diamond Mesh Codends While Fishing

Most square mesh is just diamond mesh "turned on the square". The best material for this purpose is knotless netting to minimize "knot slippage", however this is not commonly used due to higher costs. In some case the complete codend is made from square mesh, but it is possible to insert sections of square mesh at strategic points in the net (i.e. "windows") and still obtain good selectivity.

Numerous experiments to evaluate the selectivity characteristics have been conducted in various trawl fisheries across Canada. The results from a few of these are outlined below.

- Scotian Shelf Demersal Fishery

Studies in this fishery have indicated that the catch of small cod (i.e. under 43 cm) could be reduced to as low as 5% of the total catch through the use of either a 140 mm square mesh or a 155 mm diamond mesh cod end (Cooper 1990).

- Atlantic Shrimp Fishery

Experiments carried out on offshore and nearshore shrimp trawlers also indicated that square mesh codends were more size selective than those with diamond mesh. The disadvantage of the square mesh codends, however, was that they resulted in more broken or damaged shrimp. Tests to evaluate the effectiveness of larger or plasticized square mesh panels in shrimp trawls have been inconclusive (DFO 1992,1993).

- Newfoundland Demersal Fishery

The effectiveness of large square mesh in reducing the catch of cod while directing for flounder has also been evaluated in the offshore trawl fishery off Newfoundland. These trials indicated that most of the cod was released with 183 mm square mesh, however

Conservation Technology in Trawls—continued

some of the commercial sizes of flatfish also escaped. Further tests with smaller square mesh sizes were recommended (DFO 1992).

- **Great Lakes Fishery**

Experiments in the Great Lakes have shown that in the directed trawl fishery for larger target species such as white perch and whitefish, the use of either square mesh panels in the trawls as well as square mesh in the entire codend, can significantly reduce bycatches of other species and result in a much "cleaner catch" (DFO 1994).

- **Pacific Demersal Fishery**

In the trawl fishery on the Pacific coast, some fishermen have voluntarily begun to use square mesh extensions and codends to reduce bycatches of nontarget species such as blackcod.

Although numerous tests as described above have proved conclusively that square mesh is extremely effective in releasing roundfish, trawls with such mesh unfortunately seem to retain proportionately more small flatfish than those with diamond mesh of the same size. As a result, experiments are ongoing in an attempt to use codends and extensions made of both diamond and square mesh. This is achieved by alternating the different mesh configurations on the sides, top, and bottom of the codend as illustrated in figure 5-4. The objective is to optimize the release of both juvenile roundfish and flatfish.

As a result of this experimental work, the use of either minimum 130 mm square mesh or 155 mm diamond mesh is now a regulatory requirement for most demersal trawl fisheries in Atlantic Canada. The use of 130 mm square mesh is mandatory in Atlantic Subareas 4X and 5, however, many nearshore trawlers are using larger 140 mm square mesh on a voluntary basis.

5.2.3 Shortened Lastridge Ropes

Lastridge ropes are used to reinforce the trawl and are installed lengthwise on the codend. By making such ropes shorter than the net (i.e. a "hanging ratio" less than 100%), the towing load is absorbed by the ropes, leaving the meshes more open. The meshes are then less distorted under the towing tension,

thereby facilitating the escape of small fish or other species. This selectivity concept is illustrated in figure 5-5. To achieve a hanging ratio of 85%, for example, the ropes are measured equal with the codend and the netting is then fastened tightly to the ropes with about 15% slack. The elasticity of alternate rope materials has also been evaluated, and there have also been attempts at designing a device to measure the percentage of slack netting on the ropes.

The effectiveness of this concept has been evaluated during a variety of sea trials on the Atlantic Coast.

- **Northern Shrimp Fishery**

Experiments were carried out on an offshore shrimp vessel using lastridge ropes hung at 80%. The results indicated some improvements in selectivity, however further tests were deemed necessary to assess the effects of varying hanging ratios (DFO 1993).

- **Newfoundland Demersal Fishery**

Sea trials on an offshore groundfish vessel indicated that the use of shortened lastridge ropes resulted in only 1% of the small fish (i.e. under 43 cm) being retained. When longer lastridge ropes were used, 8 to 18% of the small fish remained in the trawl (DFO 1994).

- **Gulf of St. Lawrence Demersal Fishery**

Extensive tests of shortened lastridge ropes have been carried out on smaller trawlers (i.e. under 20 m) in this area to assess the selectivity effects of different hanging ratios (e.g. 72 to 90%) and different types of rope materials. Although lastridge ropes hung at 72% proved most size selective, the codend was difficult to retrieve and handle on deck. A 85% hanging ratio was found to provide the optimum balance between improved selectivity, less damage to escaping fish and operating efficiency. Some types of ropes such as braided Spectra have also proven to be very stretch resistant (DFO 1994).

In summary, although shortened lastridge ropes do work, it is unlikely that this selectivity approach will be regulated until a way is found for fisheries officers to effectively measure the related rigging parameters

Conservation Technology in Trawls—continued

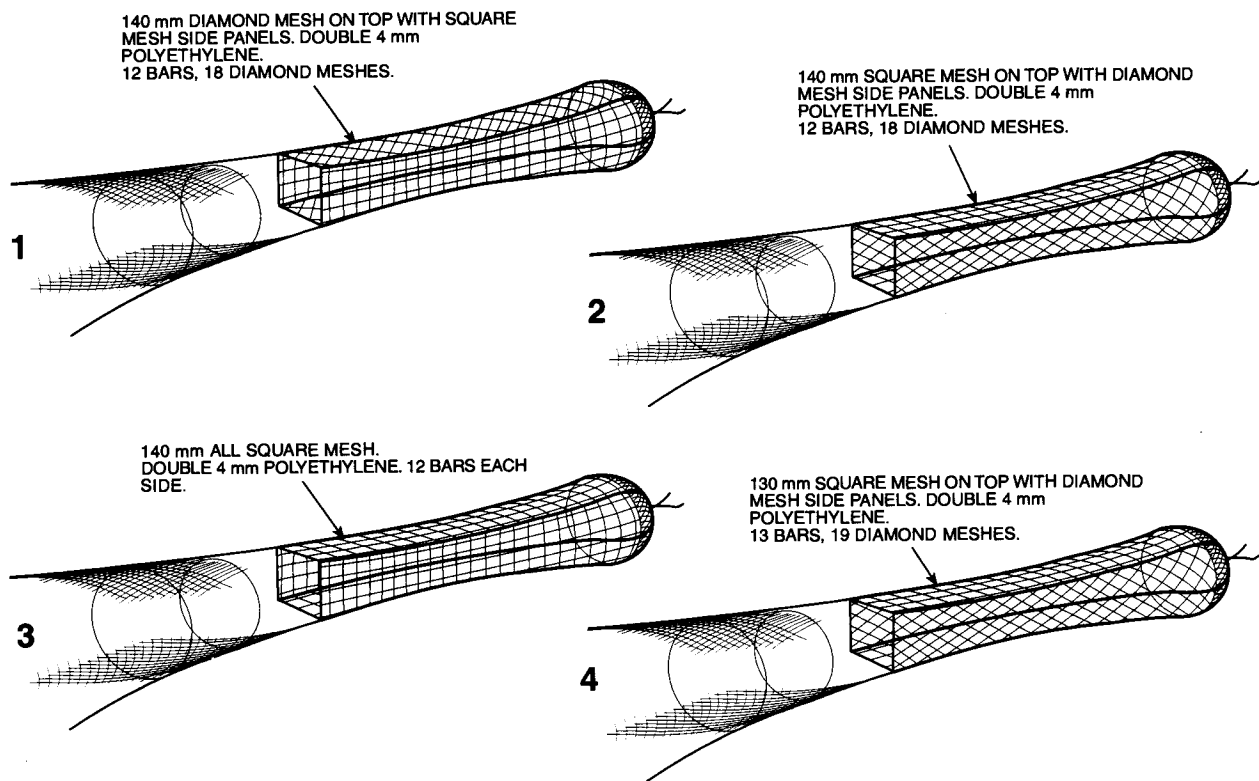


Figure 5-4. Alternative Configurations of Square and Diamond Mesh in Codends

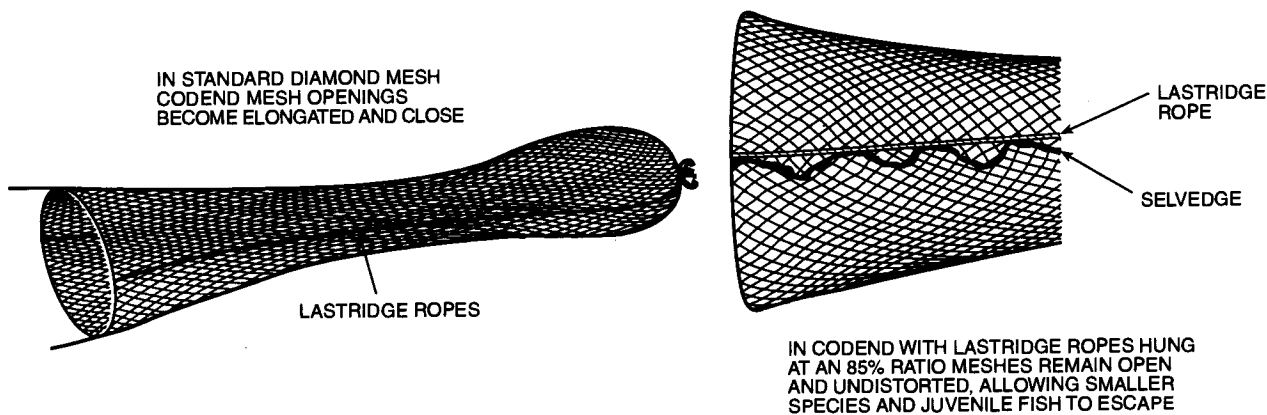


Figure 5-5. Shortened Lastridge Ropes

5.2.4 Multiple Grid Bycatch and Shrimp Size Sorting Systems

The basic Nordmore Grid was designed primarily to reduce finfish bycatches in the shrimp trawl fishery and it has not been as effective in reducing catches of smaller and less valuable "industrial" shrimp. As result, significant gear development work has been undertaken to improving such shrimp size selectivity.

Most of the recent experimental work on shrimp size selectivity, both in Canada and elsewhere, has focused on the use of multiple grids in the trawl. The basic configuration of this system is shown in figure 5-6.

In this system, the Nordmore Grid first sorts out the groundfish bycatch, which exits the net though the outlet at the top of the net. After the shrimp passes though this grid, it is guided by a

Conservation Technology in Trawls—continued

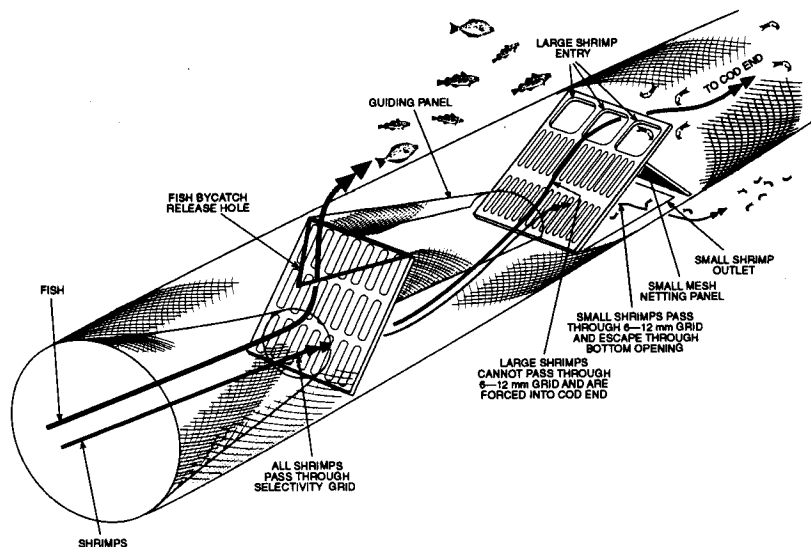


Figure 5-6. Multiple Grid Bycatch and Shrimp Size Sorting System

net panel towards the bottom of a Size Sorting Grid (which has smaller bar spacing than the first grid). The smaller shrimp pass through this second grid and exit through an outlet at the bottom of the net. The larger shrimp reach the top of the size sorting grid and pass into the codend. It is also expected that the ability to size sort shrimp will also enhance the ability of these systems to sort out and release very small groundfish. It is also expected that the ability to size sort shrimp will also enhance the ability of these systems to sort out and release very small groundfish and pelagic species.

Experiments to evaluate and refine this multiple grid technology have been ongoing in both the Gulf of St. Lawrence and the Northern shrimp fisheries in Atlantic Canada. Some offshore shrimp trawlers occasionally use this system when they encounter high concentrations of small shrimp. These vessels have reported catching 10 to 15% less industrial (i.e. small) size shrimp than other vessels fishing in the same area.

5.2.5 The Sort-X System

This system was developed in Europe, and it consists of a metal grid fitted into the top side of the trawl ahead of the codend, as illustrated in figure 5-7. The design intent of this system is that small fish will go through the grid and escape from the trawl, while the larger fish will slide by into the codend.

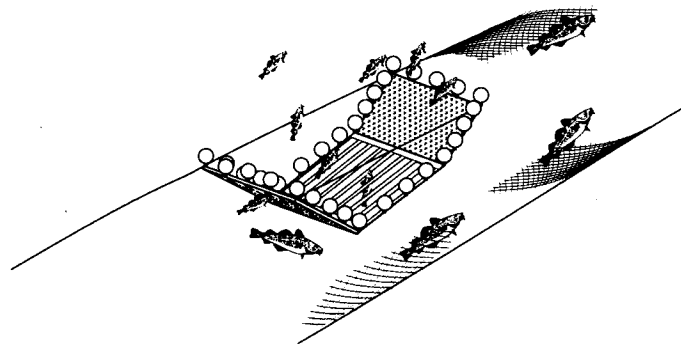


Figure 5-7. The Sort-X Trawl Selectivity System

Sea trials of the Sort-X system in Canada indicated that it was effective with smaller catch rates, however it was no better than square mesh in releasing small demersal fish. As the catch rates of certain species such as cod increased, there appeared to be a substantial decrease in the selectivity performance of this device. With other species such as redfish, the system seemed to be effective even when catch rates were high (DFO 1992).

5.2.6 The Sort-V System

This single grid system for size sorting groundfish, especially cod, was developed a few years ago in Russia. Comparative fishing trials with both the Sort-V and Sort-X systems were jointly carried out by Russia and Norway, and the size selectivity with these two grid systems were found to be very

Conservation Technology in Trawls—continued

similar (Isaksen 1995). The size selection process with the Sort-V system is illustrated in figure 5-8. With the system, smaller fish pass through the grid and exit the trawl, while larger fish are directed under the grid and into the codend.

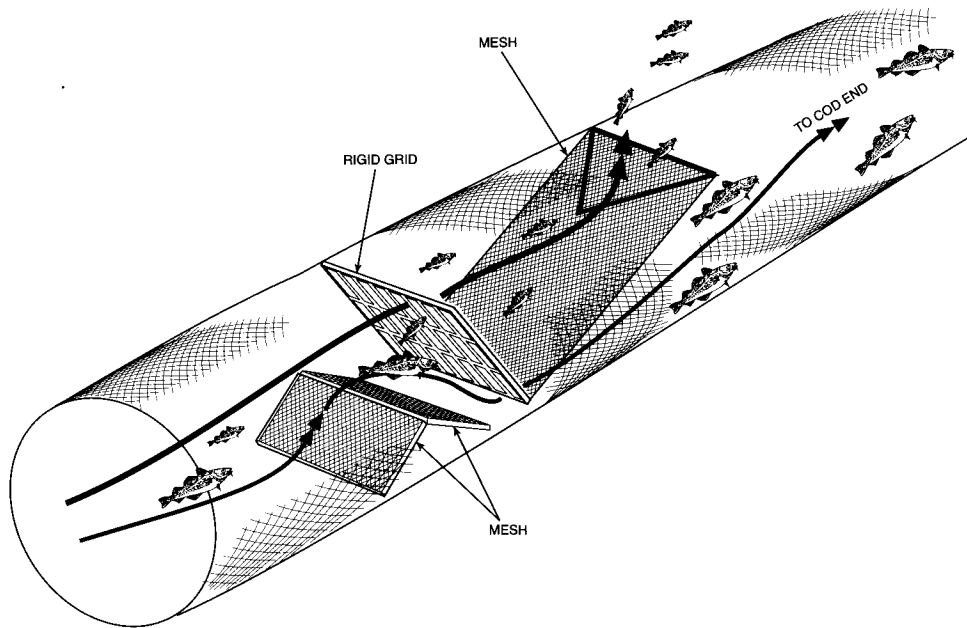


Figure 5-8. The Sort-V Trawl Selectivity System

Many Norwegian trawlers have begun to use this Sort-V system rather than the Sort-X system, primarily because of its handling and operational characteristics under adverse sea conditions. In Canada, the Sort-V system was one of the technologies tested in Newfoundland during 1997 as part of a cooperative study by DFO and the Canadian Food and Fisheries Allied Workers into methods of reducing the catch of small cod in otter trawls. Encouraging results from these experiments led to this system being commercially used by one <20 m (65') trawler in the 3PS cod fishery during 1998 (unpublished Canadian report).

5.2.7 Plasticised Exit Windows

This technology was developed in Sweden during 1993 to reduce the catch of small cod in trawls. The basic idea is to improve the selectivity of a traditional diamond mesh codend by mounting two longitudinal window panels along the sides

of the codend, as illustrated in figure 5-9. These "windows" are constructed of a plasticised material with larger and more rigid meshes than the remainder of the codend. The material is now being manufactured in Denmark

As a result of experimental trials which demonstrated the improved size selectivity of this design (Tschernij 1995), it has been adopted into the fisheries legislation of the European Communities. In Canada, this technology was first evaluated several years ago on a Northern Shrimp trawler in an attempt to reduce the catch of small shrimp, however the results were discouraging. During 1998, experiments to evaluate the selectivity of these "windows" in the Northern Turbot fishery gave encouraging results, and there are plans to continue these experiments in 1999.

5.3 SPECIES SELECTIVITY

5.3.1 Introduction

Species selectivity is more difficult to achieve with gear technology than size selectivity. It is usually achieved by fishing in certain areas or seasons when the target species are most abundant. It is also achieved by targeting the gear at certain temperature profiles or depths in the water column. For example, mid-water trawls are often used to harvest redfish. This is because redfish often aggregate at certain depths in the water column, and can be harvested with this type of gear with little bycatch of other groundfish species which live closer to the bottom.

Some trawl technologies have been developed, however, to improve the effectiveness in capturing certain species and releasing others. Some of these developments are described overleaf.

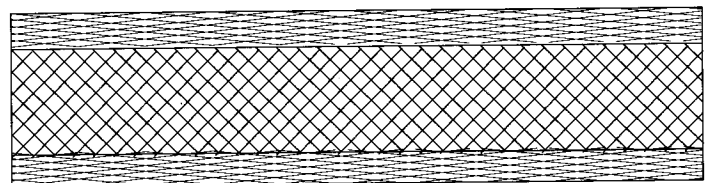


Figure 5-9. Plasticised Exit Windows in Trawls

Conservation Technology in Trawls—continued

5.3.2 Rigid Selectivity Grids

Rigid separator grids (i.e. Nordmore Grids) as illustrated in figure 5-10 have proven effective in separating target and bycatch species (Amos 1993, Isaksen 1990). These grids are made of plastic, stainless steel, or aluminum and are placed at various angles in the extension of the trawl. They deflect nontarget species upward towards a triangular escape hole at the top of the net, whereas the target species pass through the bars in the grid and are captured in the codend. Guiding funnels made of fine mesh netting are also used to direct catches to the bottom part of the grid, and to thereby increase the grid sorting area to which the catch is exposed.

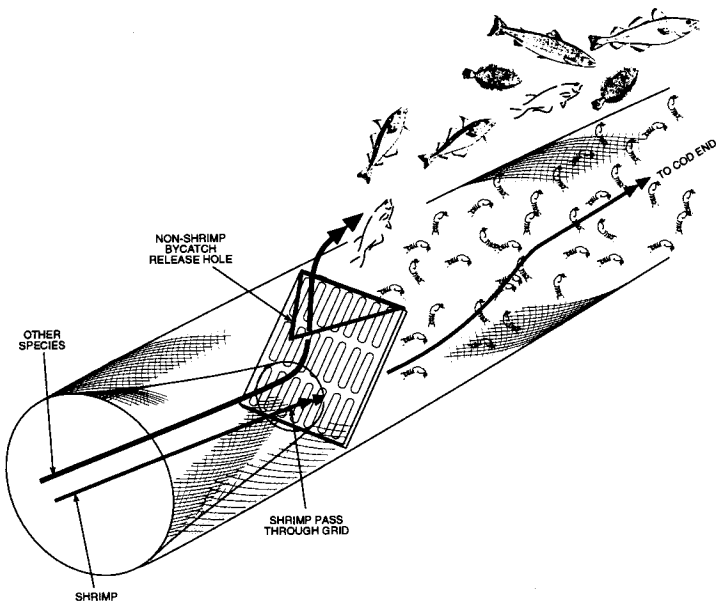


Figure 5-10. A Rigid Grid in Shrimp Trawls

Grid evaluation tests began in Canada during the 1980's, and have been conducted in the shrimp and groundfish fisheries on both the Atlantic and Pacific coasts, as well as the smelt fisheries in the Great Lakes. These experimental trials and results are described below.

Shrimp

Numerous grid evaluation experiments have been conducted in all the shrimp fisheries of Atlantic Canada. In the offshore Northern shrimp fishery, these trials have resulted in regulations requiring the use of such grids. As a result of the

use of these grids, groundfish bycatch rates in this shrimp fishery dropped from 15.3% in 1991 to less than 2% in 1998. Experiments in the nearshore shrimp fisheries of the Gulf of St. Lawrence and the eastern Scotian Shelf showed that the use of rigid grids reduced groundfish bycatch rates from the previous levels of 20-30% to less than 5%. It is now a regulatory requirement that all shrimp vessels must use such grids at all times (Boudreau 1993, DFO 1992 and 1993, Kulka 1995).

Since total allowable catches of Atlantic shrimp could be in the order of 100,000 mt during the next few years, it has been estimated that the use of rigid selectivity grids will result in groundfish bycatch reductions (i.e. wastage) of over 15,000 mt per year.

In the British Columbia shrimp fishery, experimental trials have been conducted using grids made of plastic for greater ease in winding around net drums. With the use of such grids, it has been found that finfish catches could be reduced from between 30 and 70 % of the total catch to less than one percent. As a result, a large portion of the Pacific otter trawl shrimp fleet have begun to use rigid grids on a voluntary basis (DFO 1993).

Silver Hake

Another example of the effectiveness of such grids has been in the silver hake fishery of Atlantic Canada. Although past bycatch rates of commercial gadoid species in this fishery were only about 3% by weight, there was a continuing concern that these catches were still significant in numbers since they consisted primarily of juvenile fish. Experiments then determined that a grid with a bar spacing of 40 mm could effectively separate bycatch species of cod, haddock and pollock from the target silver hake. As a result, the use of rigid separator grids in this trawl fishery became mandatory in 1994, and bycatch rates of groundfish have dropped to very low levels in the order of 0.2% (Cooper 1993).

Pacific "Idiotfish"

On the Pacific Coast, the trawl fishery for this species (i.e. spiny-cheeked rockfish) results in bycatches of other demersal species. Since this target species is relatively small, trawlers have found that the use of rigid grids allowed the capture of

Conservation Technology in Trawls—continued

the Idiotfish while letting other species escape. Many of the vessels in this fishery are now voluntarily using these grids.

Pacific Halibut

The bycatch of halibut in the Pacific trawl fishery has been a problem since the landing of this species is restricted to the hook and line fishery. Sea trials of various selectivity devices have therefore been conducted to determine their effectiveness in reducing this halibut bycatch. One of the configurations tested consisted of two rigid grids connected together, the bottom one having horizontal bars and the top one having vertical bars. The results were promising, however further experimental work is required.

Great Lakes Smelt

Various rigid grid systems have also been evaluated in the Lake Erie smelt trawl fishery. Initial experiments demonstrated the effectiveness of such grids since over 97% of the catches consisted of smelt, while almost all of the larger nontarget species were released. Both plastic and aluminum grids were evaluated in subsequent tests, together with a number of other devices. For example, a "flapper" (i.e. free flowing mesh panel) was installed over the escapement outlet in an attempt to reduce the escape of smelt. Although the grid system has always resulted in cleaner smelt catches, further development work is necessary to reduce the unacceptably high loss of smelt (DFO 1994).

Separating Flat and Round Demersal Species

Experiments have also been conducted in the Atlantic offshore fishery to assess the effectiveness of rigid grids in controlling the bycatch of cod while trawlers are primarily directing for flatfish (e.g. American plaice). The objective was to not completely exclude cod catches, but to limit them since flatfish quotas were three to four times larger than those for cod. Grid configurations tested included both vertical and horizontal bars deployed at a number of different angles. These tests showed that a grid system having bars set at a 65 degree angle and with 127 mm spacing proved effective in excluding over 80% of the cod (Brothers 1993). Similar grids were commercially used in 1998 to reduce the bycatch of cod while fishing for yellowtail flounders on the Grand Banks.

Tests of innovative grid systems to reduce the bycatch of cod when vessels are targeting for flounder have also been conducted in the Gulf of St. Lawrence. Two grid configurations were evaluated over a two year period, figure 5-11 illustrating the last version which was tested.

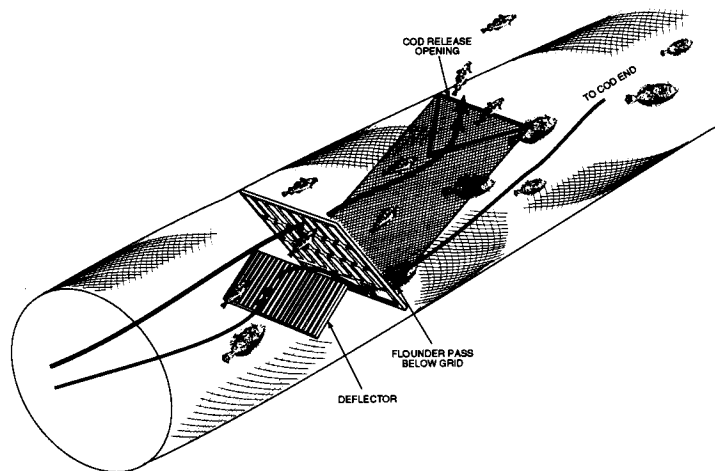


Figure 5-11. A Rigid Grid System for Separating Cod and Flatfish

Observations with an underwater video camera showed that many flounder did go over the deflector panel and vertically downwards into the codend. Most cod and other roundfish passed through the vertical bar grid and escaped, however significant amounts of flatfish were also lost. Further tests to refine this concept are planned.

Size Sorting of Redfish

Sea trials have also been conducted in the Atlantic redfish trawl fishery to assess if rigid grids can be effective in the size sorting of this species.

Conservation Technology in Trawls—continued

5.3.3 Horizontal Separator Trawls

Experiments have shown that the installation of horizontal separator net panels in trawls can also improve species selectivity. This trawl selectivity device is illustrated in figure 5-12.

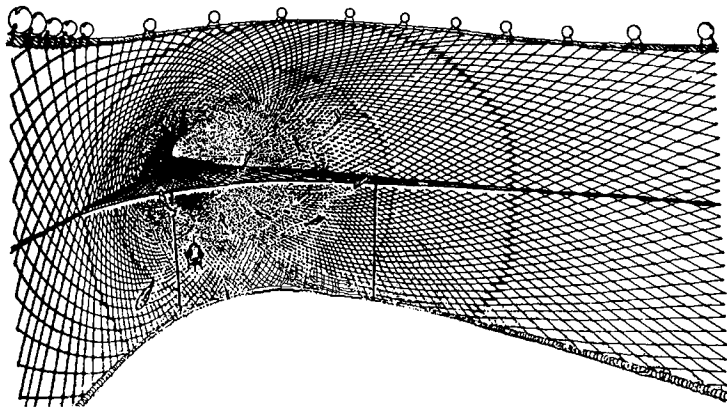


Figure 5-12. Horizontal Separator Panel

The selection process of this device is based on the fact that various species behave differently when they tire of swimming in front of the trawl, and fall back towards the codend. Haddock rise as they fall back, for example, whereas flatfish tend to remain close to the bottom of the trawl. Inserting a horizontal mesh panel in the trawl offers the potential to separate the higher and lower swimming species. The design intent is that the nontarget species would pass over the panel and be released through openings in the top part of the trawl, whereas the target species would pass under the panel and be captured in the codend.

These panels are usually made from small mesh to prevent migration of the fish from top to bottom, and their height during experiments is altered using strops attached to the footgear. The panel commences at the front of the trawl and runs all the way to the back of the trawl. In the experimental trawls, the split terminates into a top and a lower codend, whereas in the commercial versions the upper panel would lead to an escape vent.

Separating Flounder from Cod

Experiments to determine if such horizontal panels could reduce the bycatches of cod while directing for flounder began

on an offshore trawler off Newfoundland. Four panel heights were evaluated, however all proved to be unsuccessful in separating cod and flounder. Subsequent experiments carried out on smaller trawlers in the Gulf of St. Lawrence resulted in 75% of the cod being separated into the top section of the trawl (DFO 1992).

Separating Flounder from Haddock

On the Scotian Shelf, similar tests were conducted to determine if flounders could be separated from non-targeted haddock. After varying the panel heights it was determined that with an optimum height of 2.5 ft., 89% of the haddock were separated above the panel and 98% of the winter flounder went under. Results with cod separation in these various experiments have differed. For example, on the Scotian Shelf, a large portion of the cod went into the bottom section in contrast to the results during experiments conducted in the Gulf (DFO 1994).

The inconsistent results of these experiments, together with the potential difficulties of regulating this device, suggest that further development work in Canada will be focused on more promising selectivity devices such as rigid grids.

5.3.4 Large Mesh Skate Trawls

When a directed trawl fisheries for skate began several years ago in Atlantic Canada, partly in response to the closure of other groundfish fisheries, a major concern was the possible bycatch of these depleted stocks. As a result, the management objective for this emerging skate fishery was that the combined bycatch of species such as cod and plaice should be less than 5% of the total catch. Evaluations of various large sizes of square and diamond mesh demonstrated that this bycatch objective could be achieved if a minimum 300 mm (12") mesh was used in the codend and a minimum 250 mm (10") in the remainder of the trawl. These large mesh sizes are now required by regulation when directing for skate. As a result of cooperative efforts of government and fishers to further improve selectivity in this fishery, however, most of these trawls now have 12" mesh throughout.

On the Pacific coast, this technique is also being used on a voluntary basis by some vessels targeting skate.

Conservation Technology in Trawls—continued

5.4 SURVIVAL AFTER ESCAPEMENT

Since minimum mesh size regulations are imposed to enable small fish to escape from nets and grow to maturity, it is important to know whether the escaping fish survive. If survival rates were low, then mesh regulations would be of little value in conserving fisheries stocks.

There is a scarcity of information on this topic, nevertheless some conclusions can be drawn from the few studies to date (De Alteris 1993, Sangster 1992).

- Scale loss and body injuries (especially near the tail) are common in fish escaping through diamond and square mesh nets.
- Pelagic species such as herring and mackerel are more susceptible to injury than most groundfish species.
- Cod appear to be less susceptible to injury than haddock.
- Survival rates of fish escaping through diamond meshes in trawls may exceed 90%.

5.5 LIMITING CATCHES

5.5.1 Escape Panels in Trawls

In trawl fisheries where catch rates are exceptionally high, measures are often taken to limit the amount of fish which is caught during individual tows. Very large catches often result in diminished fish quality, as well as onboard processing problems. One approach to this problem has been to install electronic sensors in the codend to allow the monitoring of the amount of fish or shrimp which has been caught.

Another method has been to install escape "windows" in the upper part of the trawl net to limit the amount of fish caught. With this latter method, when the catch fills the net to a predetermined level, the excess fish escape through these escape holes.

This concept was used on a voluntary basis in some of the offshore trawlers on the Atlantic coast during the northern cod fishery several years ago. On the Pacific coast, all trawlers participating in the joint venture hake fishery are required by

regulation to cut such escape sections in the intermediate sections of their nets. The regulations specify that a row of mesh not less than six feet long must be cut in the intermediate section on the trawl, at a point six feet from where it joins the codend, as shown in figure 5-13.

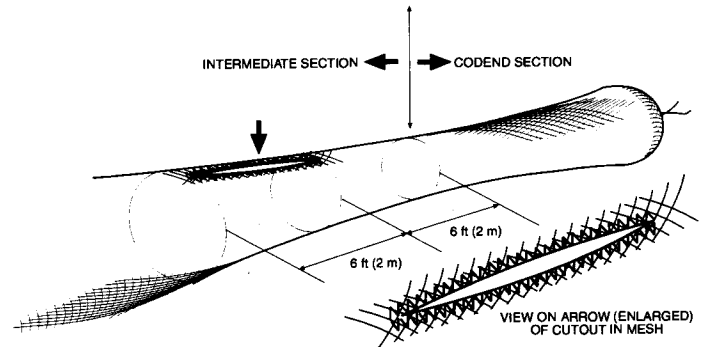


Figure 5-13. Escape Panel for Pacific Hake Trawl Nets

5.5.2 Electronic Catch Sensors

Electronic systems are now available to allow captains to determine how much fish has been caught in the trawl. This information is provided by electronic sensors which are installed in the trawl codend.

Such equipment is presently used in the Atlantic shrimp trawl fishery to limit catches so that they can be properly handled and processed onboard.

5.6 MINIMIZING GHOST FISHING

A significant conservation and environmental concern in the fisheries is the problem of fishing gear which is lost, and which continues to fish, as well as pollute the ocean bottom. All lost gear can continue to catch fish, but by far the most hazardous type is the set surface or bottom gillnet. Hundreds of kilometres of such nets are lost each year, primarily through storm action. Most of these nets are made of modern synthetic materials which does not decay. In shallow waters, tide and wave action can roll up the netting, and algae growth reduces its catching ability. In deeper waters, however, these nets can go on fishing for much longer.

The DFO strategy to minimize this problem has included limiting the numbers of nets which can be set, requirements on how they are operated, and the compulsory use of

Conservation Technology in Trawls—continued

biodegradable components. A Canadian company has also recently developed an electronic system for locating lost gillnets.

It is interesting to note that set gillnets are banned more frequently in various countries of the world than any other type of fishing gear. For example, such gear is banned in the Scottish fishery, as well as the major fisheries off Southwest Africa. The use of surface gillnets has also been significantly curtailed in the Pacific Ocean because of their large bycatches.

In contrast, trawl nets are often damaged on the bottom, but rarely lost. It is generally accepted that “ghost fishing” is not a conservation problem in the trawl fishery.

5.7 PROTECTING MARINE MAMMALS AND BIRDS

A substantial proportion of the worldwide incidental catches of marine mammals occurs in fixed fishing gear, which includes gillnets and fish traps. This type of fishing gear is usually quite size-selective, but not very species-selective. As a result, bycatches and mortality of air-breathing species such as whales and porpoise are often a problem (Lien 1996). Such catches of marine mammals are, however, quite rare in trawling gear.

In addition, seabirds are sometimes caught and suffer mortality in fish traps or fixed gillnets when diving for fish. Attempts by seabirds to remove the bait from longline gear during setting and hauling operations often leads to mortality as well.

Although such catches of marine mammals and birds by fixed types of fishing gear are a continuing concern in Canada, significant reductions in such incidents has been achieved. Remedial measures have included adding acoustic alarm devices to this type of gear, reducing fishing activities when such occurrences are most likely, and providing assistance to release such marine mammals alive (DFO 1995).

5.8 PROTECTING THE WHOLE ENVIRONMENT

A major and worldwide environment concern is the emission of “greenhouse” gases and the impact this may be having on global warming. One way of reducing such gases is through improving the fuel efficiency of our transportation and industrial processes.

Improving the catch rates of trawlers through the use of more effective trawling gear is one way of achieving use improved fuel efficiency. One example of an industry / government cooperative project with such an objective was recently carried out in the Gulf of St. Lawrence shrimp fishery. The purpose of this project was to assess if twin trawl technology would improve energy efficiency and product quality, while maintaining effective conservation.

Towing multiple trawl rigs from one vessel is not a new idea, and has been practised in various forms in a number of countries. Such trawl systems allow greater swept areas and volumes to be achieved without adding significantly to the towing drag forces. This usually results in a significant increase in catch rates, with minimal increases in fuel consumption. The general arrangement of such a twin trawl system is illustrated in figure 5-14.

Results of this development project (DFO 1997) have indicated that:

- The use of twin trawl systems could reduce the fuel consumption of shrimp trawlers in the order of one-third.

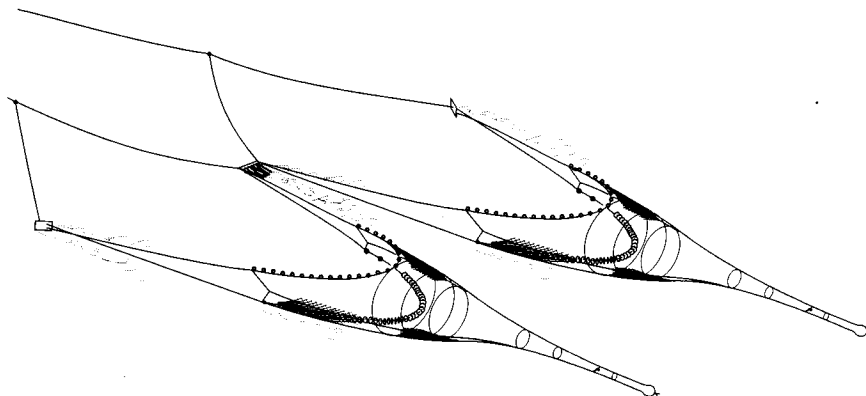


Figure 5-14 . General Arrangement of a Twin Trawl System

Conservation Technology in Trawls—continued

- If all shrimp trawlers in Canada used such twin trawls, this could result in savings of over 40 million litres of fuel annually. Energy cost savings would then be in the order of 11¢ per kg of shrimp landed or over \$10 million annually for the fishery.
- The increased catch rates would not be a conservation concern since most shrimp fisheries are managed with individual vessel quotas. As well, the mandatory use of selectivity grids in both trawls will also minimize bycatches with this system.
- Higher catch rates will also result in fewer or shorter trips. This will reduce operating costs and improve the quality of landed shrimp; both of which are growing priorities.

Effects of Trawling on the Sea Bottom

Section 6

6.1 THE MARINE ENVIRONMENT

Information Sources: Dorsey et al (1998), Watling et al (1998), Lindeblom et al (1994/98), ICES (1991).

6.1.1 The Sea Bottom

Most trawling occurs on the relatively shallow areas of the oceans over the continental shelves. Only 7.4% of the world's ocean area is less than 200 metres in depth, and only a further 4.3% of the ocean area has water depths between 200 and 1,000 metres.

Contrary to common opinion, the ocean bottom in the northern latitudes is not a highly varied terrain, covered in plant life such as kelp and organic structures such as reefs. In depths below a few tens of metres, most of the Canadian continental shelf consists of sand, gravel, cobble or boulder. Deeper basins often consist of flat mud bottom.

Reefs and coarse sediments are most prevalent on shallower parts of continental shelves, where storm-generated waves can re-suspend and remove finer sediments. Sand chutes and exposed rocky outcrops occur on steep-sided submarine canyons. They also occur in northern areas where large boulders, cobbles, or pebbles were deposited by icebergs or retreating glaciers. In general, sandy bottoms are the least stable substrata and their surface is often rippled with waves, indicating interference by surface water waves.

On both hard and soft substrates, the structural complexity of benthic ecosystems is further increased by living organisms. A wide variety of marine organisms (including foraminiferans, coralline algae, corals, brachiopods, bryozoans, worms, and mollusks) form structures of calcium carbonate on rocks. Many other organisms (including algae, sea grasses, sponges, polychaete worms, amphipod crustaceans, sea urchins and crinoids) create solid or tubular structures on the seabed.

Since most of the sea bottom is level, the structures created by larger organisms are common habitation sites for small

invertebrates and post-settlement fishes. Studies have indicated that areas of the continental shelf seabed with biogenic structures have higher levels of species diversity compared to those areas lacking such structures.

6.1.2 Natural Physical Disturbances

Causes of bottom disturbance include wave-generated turbulence; currents generated by tides, winds, or waves; and scouring by icebergs and pack ice.

Very large storm waves can affect the seabed to depths of at least 120 m. Although wave intensity is high during major storms, the longer term effects on the sea bed in shallower areas is low because most species living in storm-affected areas are adapted to resisting these events or to recovering quickly.

Near-shore tidal current can also re-suspend and remove all but the largest sediment particles, leaving bottoms of boulders, cobbles or pebbles. In deeper offshore waters, however, currents are rarely strong enough to remove even fine, silt-sized particles.

Icebergs can also plow deep gouges in the seabed as they are moved by winds and currents. They are a major cause of bottom disturbance along the northeastern Atlantic coast and on the Grand Banks. In these areas, for example, iceberg scour marks up to 60 metres wide and 3 metres deep can be seen on side-scan traces. Few if any organisms can withstand the tremendous forces of such icebergs. In areas where both ice scouring and trawling occur, such as on the Grand Banks, trawl marks represent a very small proportion of bottom disturbances.

6.1.3 Natural Biological Disturbances

Biological disturbance processes include sediment movement by animals burrowing and tunnelling, as well as digging for food by larger marine life such as whales, walrus, and crabs.

Effects of Trawling on the Sea Bottom—continued

Animals moving through marine sediments shift sediment particles through the process of bioturbation, thereby disrupting the lives of smaller sediment dwellers. Digging by large, deep-dwelling polychaete worms, bivalve mollusks, and thalassinid crustaceans can slow recruitment of other bottom dwellers by covering newly settled larvae repeatedly with layers of sediment.

At the same time, bioturbation is a natural phenomenon which also has many positive effects (release of nutrients, oxygenation of sediments, etc.) and to which bottom communities have adapted.

Fish feed on the bottom and affect sediment structure. Some species of whales and seals also feed on bottom fauna and this process involves digging into the sediments. For example, foraging animals such as whales, can remove up to 6 square metres of the sediment surface in one bite, whereas fish and birds can disturb patches in the order of tens of square centimetres. There are large areas of the shallow Arctic ocean, for example, which have been exposed to this activity for centuries, indicating a balance between harvesting, bottom restructuring and production.

6.1.4 Habitat and the Life Cycle of Demersal Fish

With a few exceptions (e.g. skate, sand lance, herring) most marine fish species including cod, haddock, pollock do not lay their eggs on the bottom. Thus discussion of the possible negative impacts of trawling on ground fish in their first year of life should be limited to the effects on young ground fish which have settled to the bottom.

The life stages of cod, a pelagic spawning fish, begin with eggs and larvae up in the water column. On Georges Bank, for example, the larval fish settle onto the entire surface of the Bank, but because of predation they are very quickly restricted to an area of gravel pavement on the northern edge. When they grow larger, they spread out and adults are widely distributed over the entirety of the Bank, as well as off the bank.

Protruding objects, especially complex ones like corals, provide shelter for smaller life forms of invertebrates and fishes. Such physical crannies or niches enhance the survival of small fish and other marine life. The absence of, or reductions in such shelters, may therefore result in higher

predation and mortality, and therefore reduced biodiversity. These effects have been observed on dredged scallop beds on Georges Bank. Preservation of such uneven protruding topography and biological structures may therefore be important for the conservation of some species.

6.2 TRAWLING PRACTICES AND OBSERVATIONS

6.2.1 Where Trawling is Conducted

Trawl fishing does not take place uniformly everywhere (ICES 1991, Jenner 1991). It takes place much more in some areas than in others, and this is dependent on:

- The type of bottom, since some rough or "hard" bottoms prevent fishing with bottom trawls, and by
- The abundance and species of fish in the area, since fish tend to aggregate in relatively few areas.

As a result, trawlers tend to operate on a relatively small proportion of the continental shelf. For example, recent analyses have shown that trawlers fish less than 6% of the ocean floor off the coast of British Columbia. On the other hand, some fishing banks and other areas where fish congregate can be trawled extensively. It has been estimated, for example, that Georges Bank on the Atlantic Coast is trawled on average 3-4 times per year. Trawling effort on other banks, such as the Grand Banks, is usually much lower.

Analyses of side-scan sonar records from Georges Bank and the Scotian Shelf showed that less than 2% of the records contained any evidence of physical disturbance from mobile fishing gear. Most of the observed disturbance was due to groundfish trawls and was restricted to areas of low sediment transport. Similarly, on the Grand Banks, less than 10% of the records showed any evidence of disturbance caused by otter trawls.

6.2.2 Changes in Gear and Practices

In the past, otter trawlers were limited to relatively smooth bottoms, because of damage incurred by trawls when fishing on harder bottoms. In recent years, trawl designs such as the "Rockhopper" have been developed to allow fishing on rougher or "harder" bottoms. These trawls have large rubber

Effects of Trawling on the Sea Bottom—continued

disks on the bottom of the mouth opening (i.e. ground rope) which allow the trawl to ride over obstructions such as boulders that might otherwise snag the net.

As well, the shift towards trawling in deeper waters (which has occurred more in areas of the world outside Canada) has often been with the use of mid-water trawls. Species targeted with such trawls include deep water redfish and orange roughy. These mid-water trawls are designed to fish off the bottom in the water column, and therefore have no effect on the sea bottom.

6.2.3 Observations of Fishermen

The greatest concern about the impacts of trawling gear is usually expressed by fishermen who use other types of gear such as longlines and gillnets (Dorsey et al 1998). Such fishermen often report seeing significant losses of habitat in areas which they traditionally found to be good for fishing.

Three distinct types of habitat are reported to have been reduced:

- 1) Topographic or geological features; which have decreased in height or disappeared, possibly from either fishing or from natural causes such as waves or tidal currents.
- 2) Concentrations of benthic invertebrates, such as mussels; some of which previously formed large beds over which fishing was usually productive.
- 3) Bottom formations such as reefs and corals created by bottom dwelling organisms

In contrast, other fishermen (who usually operate trawling gear) often describe positive effects which they have observed in trawled areas. For example:

- Some fishermen describe repeatedly trawled areas that have remained productive.
- Other fishermen maintain that seabed disturbances from mobile gear can actually enhance some fisheries.
- Improved scallop recruitment has been observed in some

previously closed areas soon after scalloping was resumed. Their view is that this may occur because stirring the bottom by mobile gear could help keep the bottom from going “sour” (i.e. becoming hypoxic or anoxic).

- Trawling tactics often include towing repeated in the same area, to draw fish to the disturbed areas.

6.3 SCIENTIFIC STUDIES

6.3.1 Introduction

There has been an increase in experimental work on the short term effects of trawling on nontarget fish and bottom dwelling communities since the 1970s. Research on the effects of fishing gear has been conducted on a wide variety of sea floors which differ in depth, substrate type, benthic fauna, fishing gear use and the degree of human and natural disturbance. Some studies have compared fished areas with unfished areas of similar depth and substrate, while other studies have looked at the same area before and after trawling activity. The most rigorous studies are planned experiments that make both kinds of comparisons. Such experiments have been performed primarily in Europe and Canada.

The earliest studies into the direct effects of trawling on the sea bed were conducted in the North Sea, and these provided basic information such as the depth to which trawls penetrated the substrate, and the number and identity of nontarget animals removed from the sea bed.

The majority of the early published work in Europe on the effects of demersal fishing gears examined the effects of beam trawling on the organisms living in the bottom sediment and scavenger populations. Subsequent studies have also concentrated on the wider implications of demersal trawling, such as the physical disturbance to the sea bed, the damage to organisms in the path of the gear, and the discarding of fish and other marine life which make food available to other members of the ecosystem.

Since 1990, the Department of Fisheries and Oceans has been conducting an experimental program on the impacts of mobile fishing gear on the sea bottom ecosystems in Atlantic Canada.

Effects of Trawling on the Sea Bottom—continued

Much of the initial effort went into developing the imaging and sampling technology needed to conduct controlled disturbance experiments on sea bottom ecosystems. The initial experiments were conducted in the inter-tidal region of the Bay of Fundy, while more recent efforts have concentrated on off-shore fishing banks.

The major accomplishment to date, however, has been a three year experiment (1993-1995) on the effects of otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland (120-146 m depth). Each year, three 13 km corridors were trawled 12 times with an otter trawl equipped with rock-hopper footgear, which created a disturbance zone in the order of 120 m to 250 m wide. Parallel reference corridors were established alongside each trawled corridor. Measurements were made to document bottom conditions before and after trawling using a variety of oceanographic instruments.

Two similar experiments have begun on the Scotian Shelf. An otter trawling experiment on a gravel bottom area of Western Bank was initiated in October 1997. This site was revisited in 1998 and 1999 to see what bottom recovery had occurred. Bottom trawling was also repeated at these sites and immediate effects observed. A second experiment began in 1998 to assess the impacts of hydraulic clam dredging on Banquereau Bank. This site was revisited in 1999 to assess recovery.

Other experimental studies on the effects of trawling on the sea bottom have also been carried elsewhere in the world, but primarily on the east coast of the United States, Australia and New Zealand. These studies have been fewer than in European waters, and have been generally less extensive and controlled, as for example those in Canada.

6.3.2 Canadian Studies

Information sources: Brylinski et al (1994), Gordon et al (1995), Jenner et al (1991), Messiah et al (1991), Swinghamer et al (1998).

Experiments in an inter-tidal zone of the Bay of Fundy showed that the trawl doors made furrows in the bottom, and the rollers compressed surface sediments. The trawl bridles caused no obvious bottom disturbances. Door furrows and roller marks in this high energy environment remained visible for only 2

to 7 months. (Note that trawl marks in less energetic areas have lasted for almost 5 years in a sandy mud bottom).

No significant impacts were observed on bottom living organisms in the area. Chlorophyll A levels (a measure of primary productivity) in the trawl door tracks were initially depressed relative to the control site for about 1 month. After that time, however, these levels increased at a much faster rate and eventually became twice as great as the control site, perhaps because of increase nutrient availability resulting from sediment disturbances. No differences in the abundance of polychaete worms were observed. The most persistent impact of the trawling was a depression in the number of nematodes for almost 2 months. Overall, the impacts in this particular environment were judged to be minor, especially since the inter-tidal sediments are already exposed to natural stresses imposed by storms and winter ice.

Subsequent experiments on the Grand Banks have clearly indicated that trawling changed physical habitat structure, but sediment grain size was not affected. Video observations revealed that trawling reduces both surface sediment structures and the abundance of organic matter. The total biomass of surface dwelling invertebrates (e.g. sand dollars, brittle stars, soft corals) was lower in trawled corridors; many specimens showed significant levels of physical damage and there was an influx of scavenging snow crabs. No significant effects of trawling were apparent in the four dominant mollusc species.

It generally appeared from this experiment in deeper waters that the observed effects of otter trawling are moderate, and that recovery occurs in about a year. The biological effects of such experimental trawling, however, have yet to be examined.

6.3.3 European Studies

Information Sources: De Groot (1984), ICES (1991), Lindebloom and De Groot (editors - 1994 and 1998), Redant (1990).

Studies have shown that almost 100 years of trawling in the North Sea has certainly re-structured the benthic system. For the longest time span observed (1902-1986), a decline in bivalves can be seen, whereas scavengers and predators such as crustaceans, gastropods and sea stars have increased. For example, the sea bottom in the German Bight shows a change

Effects of Trawling on the Sea Bottom—continued

in community structure, with a growing dominance of opportunistic short-lived species and a decrease in long-living organisms like several bivalve species.

In general, opportunistic (small size, fast reproducing) species increased in abundance while sensitive (large size, fragile) species declined in numbers due to trawling disturbance.

Longer term disturbance effects on epifauna were less easy to quantify, and results were contradictory for some species. The ability of mobile scavengers to migrate in and out of disturbed areas makes the detection of trawling effects on these species difficult.

Despite clear, and in many cases quantifiable effects from trawling, it has still been difficult to separate these effects from natural fluctuations in the reproductive success and predator-prey interactions of commercial fish species. The long term trends in the relative species composition of demersal fish and bottom dwelling invertebrates appeared to have changed in the research areas. The shift in species mix has been towards dominance by opportunistic, short-lived species and a decrease in long-living sessile (i.e. relative immobile) organisms such as bivalves.

While it has been relatively simple to detect significant changes in the abundance of large animals living in the sediments as a result of beam trawling, both decreases and increases in the abundance of small invertebrates have been found. The effects of beam trawl disturbance have been undetectable in the mobile sediments affected by currents and waves, however, in stable sediments, the effects of fishing are more noticeable. Studies have also revealed that less common species were most severely depleted by beam trawling.

The regular passage of trawl gears through areas of fragile or long-lived invertebrates living on the surface of the sea bottom will have obvious implications of the diversity of the benthic community. Indeed, observations that such communities had been altered in heavily fished areas provided the first indications of the potential long term effects of fishing on the sea bottom. For example, the disappearance of reefs of the

calcareous tube-building worm *Sabellaria spinulosa*, and their replacement by small polychaete worms indicated that dredging activity had caused measurable changes in the Wadden Sea benthic community.

Many long-lived epifaunal organisms perform a structural role with benthic communities, providing a microhabitat for some species. In contrast, many of the mobile bottom dwelling species of the European Continental Shelf are scavengers of both discards and damaged fauna, and their presence is often indication of areas of trawl disturbance.

In the 1960s and 1970s, an increase in growth rate was reported for both plaice and sole which could not be related to changes in temperature. Repeated observations have shown that significantly more fish aggregate over recently beam trawled areas compared to adjacent unfished areas. Analysis of the increased growth rates of plaice and sole also confirmed that such increases may have been due to a combination of beam trawl and eutrophication effects. Dietary analyses of these species revealed a switch in diet caused by the large numbers of amphipods which were made available to these predatory fish as a result of trawling. Scavengers can therefore increase their food intake in trawled areas and also alter their diet in response to trawling.

6.3.4 Studies Elsewhere

Information Sources: Dorsey et al (editors 1998), Jones 1992

Studies conducted in New England and elsewhere have also indicated significant impacts of bottom trawling gear on benthic habitats. Such impacts have been particularly noticeable in bottom habitats with 3-dimensional structures, in contrast to flat bottoms.

Observations have also shown that hard bottoms (e.g. boulders and gravel pavement) support complex epifaunal communities that are removed by bottom fishing. In contrast, mobile sand habitats are less vulnerable to gear impacts because the sediments are periodically re-suspended by severe storms.

Effects of Trawling on the Sea Bottom—continued

6.3.5 Conclusions

One of the few general conclusions that can be drawn from the various studies to date is that mobile fishing gear reduces habitat complexity on the sea floor. This results from the tendency of trawling gear to:

- smooth out structures on the bottom and
- remove bottom flora and fauna that contribute to sea floor complexity.

Such effects have been documented in eastern Canada, Europe, New England, and elsewhere.

Reduced habitat complexity is expected to reduce shelter for juvenile fish and thus increase their mortality rates due to predation from larger fish. As well, removal of benthic fauna may reduce the availability of food from invertebrates for fish of all sizes. The longer term effects of such loss of benthic fauna from fishing gear is expected to be greater for stable sea beds with long-lived bottom dwelling organisms than for sediments that are frequently disturbed by natural processes, such as the shifting sand dunes on Georges Bank.

Bottom trawls also frequently create clouds of muddy water as they move over the sea floor. There are indications that this may be a major cause of sediment re-suspension in the deeper waters of the outer continental shelf, whereas storms and currents are the principal cause in shallower waters. There may be both positive and negative consequences of this effect.

- One positive implication is that phytoplankton productivity may be increased by trawling because nutrients trapped in the sediments may be released into the water column. This in turn may lead to increased productivity of invertebrates and fish on the ocean bottom.
- A possible negative effect of sediment re-suspension caused by trawling is perhaps the reduced survivorship of juvenile bivalves and fish due to the clogging of their gills.

Experiments in the North and Irish Seas with beam trawls have shown a significant reduction in invertebrate numbers and species inhabiting stable sediments of sand, gravel, and shell, but no effects on invertebrates in nearby mobile sediments. Another study found that re-colonization after fishing is slower for large, long-lived clams than for small polychaete worms and bivalves. Intensive trawling has also removed fragile or long-lived species like reef-building tube worms and calcareous algae that formerly dominated areas of the European sea floor.

Many benthic invertebrates are exposed and damaged or killed by the passage of trawls. These provide food for both invertebrates and fin fish scavengers. Such an influx of scavengers in trawled areas has been observed in both Canada and Europe. Sole, which is a major commercial finfish species harvested on the sandy floor of the North Sea appears to have benefited from the long term effects of intensive beam trawling. This is probably because the trawling disturbance has shifted the benthic community towards small, opportunistic species which are the sole's preferred food source.

Effects of trawling are likely to be more significant in areas that are not subject to high levels of natural bottom disturbance such as waves and currents. Organisms living in areas of high natural disturbance are adapted such disturbance. On the other hand, many organisms living in naturally undisturbed areas may lack such adaptations and may take years to recover from the effects of trawling on the bottom. If fishing disturbance occurs more frequently than the recovery time, then susceptible species could be eliminated in that area and the biodiversity would thereby be reduced.

In "hard bottom" areas, where the seabed consists of various combinations of rocky reefs, boulders, cobbles, and pebbles, mobile fishing gear removes large surface dwelling invertebrates such as sponges, and moves rocks and boulders along the bottom. This reduces habitat for a myriad of small species and food for others. Such habitat structure provides feeding and hiding places for juvenile fish and may therefore be important to early life stages of some species. For example, juvenile cod settle in all habitats, but survivorship and growth seem to be higher in structurally more complex habitats where they can avoid predators.

Effects of Trawling on the Sea Bottom—continued

6.4 OBJECTIVES FOR MARINE ECOSYSTEM USE

The studies described in this section have suggested that trawling does have an impact on those parts of the sea bottom where it is conducted. The differences of opinion regarding the significance of such impacts, however, may be due in part to differences in views or goals regarding the human use of the marine ecosystem

Some groups, including many in the fishing industry, focus on sustainable fishery productivity as the principal objective for our utilization of marine resources. Others, including many in the environmental movement, believe that preservation of biological diversity should be a primary goal. Although these goals may not be mutually exclusive, they differ in emphasis and expectation.

The supporters of biological diversity maintain that such diversity on the sea floor benefits fisheries by increasing structural heterogeneity and food availability. They believe that the protection of upright biota (such as sponges) not only provides refuge for early life stages of harvested fish species, but also enhances prey for larval, juvenile and adult fish. Thus, scientists and fishermen with an interest in biological diversity contend that maintaining a heterogeneous environment will improve fish populations.

Those who support marine productivity as a primary objective usually want a focus on maximizing the yield of targeted species. An analogy to farming is often used to frame this

position. In agriculture, cultivation of the soil is used to increase yields of specific crops. Proponents of productivity goals are usually interested in the ecosystem processes and components that enhance the productivity of commercial species. Examples of their areas of interest would include:

- Understanding how nutrient releases from sediment disturbances affect the food available to targeted fish species.
- Evaluating the role of trawling and dredging in reducing predators of targeted species through catch mortality or increased exposure to scavengers.

Some environmental spokesmen have made a comparison between the effects of trawling on the bottom and clear cutting forests (Watling 1998). Perhaps the comparison should be made between forests and cultivated land. The overall plant productivity per acre of both scenarios may be the same, and may even be higher in the case of sustained cultivation. There is no doubt that the virgin forest has a greater biological diversity than cultivated land, however the latter perhaps better meets the requirements of mankind.

It is hoped that a balanced approach will be used in relation to our Canadian marine resources similar to that used in our forestry and agriculture sectors. That is, we treasure and protect the natural forests that exist in our national and provincial parks, and elsewhere, but at the same time focus on the sustainable use of our other land based resources.

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