THE DEVELOPMENT OF SELECTIVE FISH HARVESTING TECHNOLOGIES IN ATLANTIC CANADA

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The Development of Selective Fish Harvesting Technologies in Atlantic Canada

By

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Abstract

Every year new fishing gears and methods are developed to increase fishing efficiency and effectiveness. Recently, technological innovation has resulted in a variety of "selective" fishing gears which attempt target fishing based on various criteria, such as species, fish size, fish shape and specific behavioural characteristics.

Many of these new harvesting technologies have originated directly from the harvesters themselves. This may be considered a role reversal in the way that fishing gear has traditionally been developed and managed. In the past, most research was conducted onboard government research vessels or through charters of private vessels. These initiatives were primarily designed and managed by the Department of Fisheries and Oceans at arms length involvement from industry.

Today more research and development work is being done within co-operative arrangements in order to identify appropriate harvesting technologies and to enable government and industry to work together to achieve conservation goals. This change in approach, however, requires a more fundamental understanding of the entire process involved, including how fishing communities' approach the question of technology transfers and

how this affects successful implementation of the new gear or method into the management framework.

This paper portrays the development of selective fish harvesting technologies through examination of dedicated selectivity projects completed within a co-operative framework. By promoting significant harvester involvement in project design and implementation, the core of a successful management framework, which ultimately includes voluntary acceptance, may become more apparent.

To illustrate the importance of a co-operative project framework, emphasis is placed on the Atlantic Canadian experience, in particular the Newfoundland region and the involvement of the smaller scale harvester in selective harvesting projects. Examples of selectivity projects are presented following a comprehensive review of the selective fish harvesting concept. This information forms the basis for a discussion on how the transfer of technology is affected by the status of the resource, cost reduction requirements, regulatory considerations, and industry acceptance. Suggestions are made regarding how acceptance of selective harvesting initiatives may be positively influenced by establishing a comprehensive project planning and implementation process.

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1. 0 Introduction

The purpose of this paper is to portray the development of selective fish harvesting technologies through examination of dedicated selectivity projects completed within a cooperative management framework. This discussion is grounded upon two sources. The first is documentary information on the technology and management of selective fishing gears and the way in which technology is appreciated by fishing communities. The second is the recognition that current literature does not usually include both social and technical science, although they are fundamentally connected. This paper attempts to present the material from both of these perspectives in a manner consistent with good fishery management practices. The information used to complete this report was gathered through review of current literature and informal discussions with those who participate in selective harvesting initiatives such as harvesters, technologists, scientists and representatives from the various funding agencies.

In order to effectively discuss a topic as diverse as fishing gear selectivity some background is necessary. This background must include the basic attitudes and difficulties associated with the technology transfer environment, the development of the "selective" harvesting concept, the selectivity process, how selectivity is measured, and the expected effects of selective harvesting on resource dynamics. The information covered in Sections 1.0 and 2.0 will be further considered in Section 3.0, which provides specific project examples to illustrate current selectivity work in this region. Finally, Section 4.0 of this report will consider problem of the achieving stated conservation goals amidst economic constraints and uncertainties whilst maintaining an effective transfer of technology.

Every year new fishing gears are developed and adopted by the fishing industry in order to increase fishing efficiency and effectiveness. Recently, technological innovation has resulted in a variety of "selective" fishing gears which attempt target fishing based on various criteria, such as species, fish size and shape, specific behavioral characteristics, etc. (Ferno & Olsen 1995; Gunderson 1993). These selective criteria are incorporated into gear design and fishing techniques and together with increased harvester's knowledge, have become fundamental properties of responsible fishing practices.

At the same time that what are frequently termed responsible fishing practices and selective fishing gears are being developed, there is the matter of determining the appropriateness of selective fishing gears in certain circumstances. In particular, selection of fish based on size has prompted discussion of how removing a narrow range of size classes may harm stock structure and ecosystem balance (Krohn & Kerr 1997). Canada's Fisheries

Resource Conservation Council (FRCC) has recommended that all fishing gear should be capable of targeting a range of fish sizes of the desired species, providing a degree of protection for both the large successful spawners and juveniles (FRCC 1997a..5). Others believe that the key to sustainable resources may be concentration upon reasonable exploitation levels, somewhat irrespective of harvesting means and range of fish sizes captured. In light of these concerns, the fishing industry in Atlantic Canada has followed a cautious but progressive approach to the development of selective fish harvesting practices through the completion of dedicated selectivity projects.

Successful selectivity can be of significant benefit to harvesters. Development of fishing gear which allows for the harvesting of targeted species, helps ensure that by-catches are reduced and juveniles are permitted a chance to reach reproductive size. This enables increased recruitment, stock biomass growth, avoidance of destructive harvesting practices and maximization of economic benefits by reduction of time spent sorting the catch (Aquaprojects 1995..1-6).

In Canada a growing awareness of these benefits has resulted in increased support for the development and transfer of selective fishing technologies. Industry, in partnership arrangements with various levels of government, has completed over 100 selectivity projects in recent years (DFO 1998..1). These projects have included investigation of the following types of selectivity devices and technologies.

Mesh size (trawls, seines, gillnets and traps)
Hook size (longlines)
Square mesh (codtraps, trawls and seines)
Escape panels (traps and trawls)
Rigid separator grids (trawls and seines)
Electronic devices (marine mammal protection and gillnet retrieval)
Live capture gear (live release of non-target species)

(DFO 1998..4)

Some of the selectivity projects completed have resulted in regulations which require the use of a specific device or operational technique, such as rigid separator grates in the Northern Shrimp and Scotian Shelf silver hake fisheries, square mesh cod-ends, escape devices in lobster pots, and minimum gillnet mesh sizes (Richard 1998..6). Likewise, groundfish hook size and shape requirements have been established for various domestic fisheries (Richard & Claydon 1998). Other selectivity devices have been used strictly on a volunteer basis; e.g. multiple-grid shrimp size separators for the Northern shrimp fishery. On occasion, initiatives that held promise were re-directed towards more easily regulated and effective mechanisms. For example, short lastridge ropes (Brothers et. al 1993) have been proven to maintain proper mesh opening in a trawl. However, they are more difficult to regulate and monitor than a rigid separator grid system (Richard 1998..3).

1.1 The Technology Transfer Problem

The difficulty encountered in regulating various aspects of selective fishing methods contributes to the problem of effective technology transfer from those who design and regulate selectivity devices to those who are expected to regularly employ them. According to Jallade & Prado (1998), current fishing technologies and practices are also a result of continual development over a long period of time, which makes scheduling introduction and change difficult. A myriad of situations in Atlantic Canada which require alternative approaches and a dispersal of harvesters around the region also create significant problems. These problems are compounded by the fact that harvesters commonly perceive changes in gear technology regulations as further restrictions and constraints to their current operations.

While voluntary acceptance of new selective technologies may be the preferred scenario, it may be difficult without financial or other incentives (Watson 1998 ..4). In addition, technologies that result in an increased cost to the harvester or a perceived loss of revenue will be resisted. Successful development and acceptance of selective fishing technologies also requires effective communication between harvesters, fisheries technologists and the enforcement body (DFO). Jallade & Prado (1998) have recognized that although gear technologists have a fundamental role in the development process they may not necessarily have the time or competence to effectively transfer new technology to the harvester.

A significant portion of current literature on the subject of selective fishing methodologies identifies the communication gap between harvesters and technology developers as a problem which has to be overcome, however a definitive approach to overcoming this problem has yet to be identified. In the past, most research and development work in Atlantic Canada was conducted onboard government research vessels or through charters of private vessels. These initiatives were primarily designed and managed by DFO at arms length involvement from industry. DFO was also chiefly responsible for transferal of experimental results to industry and for implementation of new methods, which usually resulted in the addition of more gear-related regulations. This approach has proven too expensive and the "top down" method of introducing gear regulations has resulted in conflict with industry. Harvesters and their representative associations have increased the demand for the formulation of partnerships in order to increase fisher involvement, close the transfer gap, and share more of the associated costs.

The process of developing a selective harvesting method within such a cooperative framework may be represented diagrammatically as a triangle surrounded by a regulatory body which defines regulations under which harvesters, funding agencies, gear manufacturers and scientists/technologists must comply (Fig.1). Scientists and technologists have been responsible largely for formulating the "selectivity" concept and have attempted to design selective devices or methods as well as determining some of their impacts on harvesting characteristics and population dynamics.

Fig.1 suggests the difficulty in fully grasping the potential impacts of selectivity initiatives on the resource where the triangle stretches beyond the regulatory framework. This reflects the inherent inability to exercise measurable control over a natural resource. This is the environment in which selective fishing initiatives and transfers of harvesting technology exist. For their part, harvesters within this framework identify problems associated with various harvesting methods and are chief catalysts in attempts to initiate technology transfers. Harvesters put pressure on the entire framework to provide a means whereby they may 1) continue to fish under noticeable resource decline, 2) increase the profitability of their enterprise, and 3) justify their existence as responsible participants by employing selective fishing gears. Harvesters, because of their traditional practices and practical expertise, assume a technologist role to an extent and have contributed greatly to the process of gear development despite doubts about their "anecdotal" knowledge. To be effective, scientists and

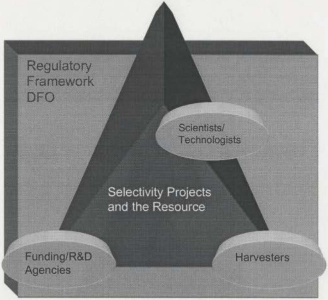

Figure 1.0 : Cooperative Selective Harvesting Project Environment

Technologists, in turn, must view harvesting operations from an economic and social perspective in order to properly understand the environment in which their knowledge and devices will finally be tested. Concentrating on only the "science" of the problem will ultimately lead to difficulty during implementation.

Completing the framework are the funding agencies and associations which provide the essential monetary support and additional technical expertise for the various projects. Although funding agencies tend to vary in their degree of interaction with project participants, success depends on the funding agencie's ability to recognize: 1) the selectivity concept involved, 2) its importance to project success, and 3) that secured funding be delivered when the project demands. The effectiveness of selectivity projects has been reduced on occasion when delays in formal funding arrangements forced at sea testing trials to be conducted during undesirable conditions and when fish aggregations were unavailable.

Fishing gear selectivity may mean different things to different people. To a harvester it may imply the avoidance of species that interfere with the economic capture of an assigned quota or a direct threat to one's ability to pursue the quota. It may also necessitate the modification of harvesting gear or previous methods of capture to reduce the retention of juvenile fish in order to justify continued harvesting efforts. To a fisheries manager, knowledge of selective harvesting characteristics may affect decisions regarding quota allocations amongst various gear sectors and regional boundaries. To the fisheries scientist, selectivity may mean the calculation and recommendation of a balance between acceptable and unacceptable harvesting methods and levels of effort on various species. To the gear technologist or fish behaviorist it may mean matching knowledge of the specific problem to the available or potential array of devices to successfully exclude or retain a specific size or species of fish.

In order to appreciate the rationale behind the development of selective harvesting projects, it is necessary to examine the concept of fishing gear selectivity. The following section outlines selective fish harvesting, the process of selectivity as it applies to the major gear types in Atlantic Canada, the measurement of gear selectivity, and expected benefits or consequences of selective fish harvesting.

2.0 The Concept of Selective Fish Harvesting

2.1 Fishing Gear Selectivity

Traditional technological approaches aimed at reducing exploitation pressure on fish populations have focused on limiting the capture of non-target species and juvenile fish by improving the selective characteristics of gear employed. Gear selectivity issues have been present in some form at least since the 14^{th} Century when a petition was passed in England banning the use of trawls which caught undersized fish (Blades 1995..71). Modern selectivity research, however, was born out of recognition that fishing gears, consisting mainly of flexible twine, rope, and netting, change shape considerably during the course of operation, affecting how fish are retained or released. Russian scientist F.I. Baronov pioneered the study of the change in shape of fishing gears under different forces. Baronov was the first to apply methods of mathematical analysis to the investigation of fishing gear and their properties (Andreev 1976). Baronov was also a scientist who acknowledged the importance of fish behavior patterns for the development of fishing gear. In 1914 Baronov produced a paper entitled "The Problem of Overfishing", where he criticized traditional beliefs current in fishery science at that time (Andreev 1976). One of these beliefs was that exploitation pressure did not influence the future biological production of a fish population. Although Baronov and his early colleagues may not have used the term "selectivity" to describe their work, it is now widely recognized that the way in which fishing gears catch and retain fishes of certain species and sizes can influence [to varying degrees] the growth characteristics of a fish population.

Much of the work of these early pioneers of fishing gear science was motivated by concern over the widespread practice of high grading of commercial food fishes and the discarding of non-target species. In spite of the knowledge gained through early attempts to reduce wasteful fishing practices, the fishing industry and scientists alike did not fully appreciate the consequences of these practices for recruitment and population growth until as late as the 1960's. It is now estimated by the Food and Agricultural Organization (FAO) that over 60% of the world's fisheries resources are overexploited or at maximum output levels (FAO 1996). Today conflict and competition over shrinking resources and an increased knowledge base about population growth and ecological parameters has prompted the development of a new selective harvesting science involving scientists, gear technologists, fishers and academics.

Selective harvesting or fishing gear selectivity is best defined as "the process whereby fish are targeted and captured based on species, size, sex or a combination of these". Under a management framework which promotes sustainable harvesting operations, selective harvesting methods are used to catch only targeted fish, releasing unharmed those which are essentially unwanted.

Selectivity may be divided into two broad categories, **size selectivity**, and **species selectivity**. The basic characteristics of any fishing gear or harvesting method are the ways in which it either retains or excludes a particular size or shape of fish due to gear design and its application.

Size selectivity has become a fundamental tool in fisheries management based on the knowledge that the future of the various stocks is dependent upon the size and maturity of the fish captured. According to Maclennan (1995..1), the primary intention behind the modification of fishing gear has been to facilitate the escape of small fish, which is "clearly beneficial for the future yield". The theory is that new fishing methods, which reduce the capture of small fish will lead to an increase in catch per unit effort over time as the subsequent yield would be comprised more of the older, larger fish. This follows Beverton and Holt's (1957) classical theory of exploited fish populations, which prompted discussions regarding size retention characteristics of fishing gears. The actual change in yield which results due to altered gear selectivity characteristics is being investigated more thoroughly as there is a concern that a selection range too narrow (i.e. targeting only a few year classes) may not be beneficial to sustained stock health. Gillnets, for example, because of the catching principle involved, may effectively exclude both large and small fish. However, when certain year classes are consistently removed over time, it stands to reason that recruitment may be affected.

Species selectivity describes the process of retaining only target species and minimizing by-catch species that are either unwanted because of poor economic return or because regulations limit the percentage of a certain species which may be caught. Species selectivity is defined as the ratio of non-target fish to target fish caught in the fishing gear. Species selectivity may be more difficult to achieve than size selectivity due to the limited opportunity to employ more simple management tools such as mesh size restrictions.

Species selectivity depends on an in-depth appreciation of fish behavior in order to design fishing gear or to suggest ways in which gears should be operated. For example, mid-water trawls used to harvest redfish aggregating at mid depths effectively avoid other groundfish species inhabiting areas closer to the bottom. Another example of species selectivity based on behavioral characteristics is the use of trawls with cutaway headlines. The use of this device is based primarily on gear avoidance behaviors of the studied species. When a fish tires during herding by an approaching trawl, it will turn and swim back towards the trawl mouth. Studies have shown that certain species exhibit noticeable variations in the way that this behavior occurs. Codfish, for example, tend to turn and head directly back into the trawl while haddock show a tendency to turn and head upwards towards the headline (Ferno & Olsen, 1995). A trawl with a cut-away headline gives haddock an improved chance of escape, without a significant reduction in the catch of cod.

The ability to select based on species is of great importance to harvesters, especially those who must avoid by-catches of regulated species in order to continue their operations. One of the examples is by-catch restrictions employed as a management tool to reduce the incidental take of groundfish species, such as cod and haddock, during operations for other species. Under normal circumstances areas would be closed or vessels would have to curtail harvesting if cod or haddock by-catch were to exceed a certain percentage.

The ability to fish in a selective manner is also important for the protection of species which may be considered either endangered or threatened. Marine mammals, seabirds, Atlantic salmon and other species requiring some form of protection have prompted the development of species selective devices such as audible alarms, deflector panels or underwater gear setting mechanisms.

2.2 The Selectivity Process

In a fish harvesting operation, success ultimately varies with environmental and ecological conditions along with the practical and mechanical features of the fishing process. From a pure catch per unit of effort perspective, the most successful operation would effectively employ a gear which retains all fish regardless of size and species. In order to witness a truly non-selective catching process such as this, each individual fish coming in contact with the gear would have to have the same likelihood of capture as any other. Also, the capture of the individual fish would have to be independent from those fish already captured. Any deviation from these two constraints, which is essentially unavoidable, introduces a form of selectivity. True "non-selective" fishing, for all intents and purposes, does not exist (Bjordal & Lokkeborg 1996).

All fishing gears are in some form selective due to the fact that the catching principle of the gear itself and the way in which it is operated results in some species or sizes of certain species being caught more easily than others. Added to this are spatial considerations such as habitat preferences, which means that a fish's availability or accessibility to a certain gear type will differ from area to area. The success of a fishing operation and the resultant catch will therefore depend on where the fisher sets the gear. Once a location has been chosen, catch composition will depend on how the gear performs and how the fish responds to the gear (Bjordal & Lokkeborg 1996). A description of the process of selectivity and associated selective characteristics of the predominant gear types employed in the Atlantic fishing industry is presented in Section 2.2.1 & 2.2.2.

2.2.1 Mobile Gear

The major mobile gear types used in the Atlantic region include trawls or seine nets which are propelled through the water column usually by towing, and which attempt to catch and retain fish by a process of herding and entrapping usually in the after section of the gear. Although the method of seining relies more on the encircling principle and tends to target pelagic species, the selective process is similar to that of trawls.

Trawls

The selective process can be quite complicated. However, for trawls it generally begins when a fish detects the presence of the approaching gear. Fish that react at this point may successfully avoid coming into contact with the gear. Fish that do not detect the gear or react in time will either be caught and retained (e.g. a fish entering the mouth of a trawl and continuing into the codend), or will be released via the trawls ability to fish selectively. Selectivity during mobile gear operations is generally influenced by three factors.

1) Horizontal and vertical distribution of the fish relative to the gear

and fishing location.
2) Specific behavior of the fish in the vicinity of the gear.
3) Intrinsic selection properties of the gear.

One term used in the description of mobile gear selectivity is "vulnerability", or sometimes "catchability" which may be defined as the probability of entering the gear given that a individual is in its path (Gunderson 1993..13). Vulnerability is a measure of a fish's ability to detect the presence of gear and exact avoidance through use of sensory organs and locomotive capacity. Vulnerability can be expected to decrease with individual fish size as these senses become more developed and the fish is better equipped to avoid the gear. This should not be confused with the likelihood that larger fish might be more susceptible to retention because of the selective properties of the gear. Mobile gear selectivity therefore can be considered as the probability that a individual fish will be retained by the gear given that it is vulnerable to the gear and its intrinsic selective properties.

Visual perception and acoustic detection abilities of the fish influence vulnerability. Wardle (1993) concluded that vision is one of the primary senses involved in trawl capture. Unlike gillnets, trawls do not catch fish through a process of passive filtering; the fish perform a series of behavioral responses during different stages of the catching process. The initial response is a reaction to the warps and sand clouds herding fish into the mouth of the trawl, followed by orientation responses to the approach of the trawl netting and, finally, escape reactions within the codend (Ferno & Olsen 1995). Identification of these behaviors provides opportunity to implement selective devices or methods such as the cutaway headline design for groundfish trawls.

Those fish caught are then either retained by the gear or released by escaping through the meshes or via a selectivity device, such as a separator grate or escape window. The final selective process occurs once the gear has been recovered and the catch is accessible on deck. Here, the fisher chooses whether the fish is to be discarded or retained. Discarding is usually reserved for trash species due to the resultant mortality. However, some species of certain size such as juvenile Atlantic halibut, may be returned to the water with a degree of survivability. This is true for both fixed and mobile gears although fixed gear methods, such as longlines or codtraps, have greater potential for the successful release of individuals.

The manner in which the gear selects against (releases) the fish influences the rate of incidental mortality, which is of obvious concern. For example, fish squeezing through cod-end meshes may suffer significant scale loss, rendering them less resilient to disease and predation (see Broadhurst et al 1997; Chopin & Arimoto 1995). This raises a fundamental concern with respect to the development of selective fishing methods. The expected benefit from using the device must clearly outweigh any negative impacts. For example, the use of plasticized netting in the construction of a trawl has the potential to maintain proper mesh opening and improve gear selectivity. However, the netting may be made more abrasive, causing damage to fish escaping through the mesh openings.

2.2.2 Fixed Gear

The major fixed gear harvesting methods, longlines, gillnets, traps and pots, are also referred to as "passive" fishing methods. These gears are stationary and the encounter between fish and gear results from the movement of the fish towards the gear. For longline and pot fishing, this movement is initiated and directed by the smell stimulus from the bait, which aggregates the fish around the gear (Bjordal & Lokkborg 1996). For gillnets and unbaited traps (codtraps), success depends upon setting the gear in such a manner that the fish are caught and retained during normal swimming and feeding activity as well as long distance migration. Knowledge of a fish's daily movement characteristics and migratory behavior is fundamental.

Longlines

The catching process in longlining may be broken down into stages. Longlines are stationary devices so the fish must first be aroused and attracted to the baited hooks. Following the attraction process, which is governed by chemical, visual and physical aspects of the bait, the fish must perform the necessary behavior patterns in order to be caught (Ferno & Olsen 1995). Specific hook size and shape and size or type of bait predominantly determine longline selectivity. Bait size, however, has been identified as the primary selective characteristic of longlines (Bjordal & Lokkborg 1996).

Specific hook and/or bait size effectively target specific size ranges of fish and this also results in a degree of species selectivity. Small flatfish species, for example, are unable to ingest hooks used to catch typical roundfish species (cod, haddock etc) because of their small mouths and buccal cavities.

In all stages of the hooking process parallels can be drawn with the fish's natural foraging behavior. Therefore the development of successful harvesting methods or selectivity devices depends on the investigation of specific fish behaviors when in proximity to the gear.

Baited Pots

During the arousal and location phase, the process of selecting for sizes and species is similar to that of longlines, although the distribution of the odor plume is different (Ferno & Olsen 1995). The process of ingestion of the bait is not important due to the fact that the fish has already been caught by the time they make contact with the bait. Pots have different selective properties from most other types of fishing gears. The design of the pot entrance for example is crucial to the escape or retention of certain species or sizes. Mesh size and shape is also important to the selection of certain sizes once the fish has entered the pot.

Gillnets

Gillnet selectivity is influenced by several factors although mesh size is generally considered to be the most important. Other factors include mesh shape and hanging ratio, which influences tension on the meshes. Too low a hanging ratio may lead to poor selection as mesh shape and size will distort. Type of netting material used, twine thickness, and color may also influence the catching process, which usually occurs in one of three ways, **wedging**, **gilling** or **entangling**. Wedging occurs when a fish squeezes through the mesh opening until its girth exceeds the opening and the fish is caught. Gilling occurs when the fish's head enters the mesh opening and is prevented from retreating by the gill covers, which become caught in the mesh. Entangling refers to capture when a fish attempts to escape the net and the netting itself closes around the fish's body.

Capture in these three ways depends greatly on the shape of the particular species of fish encountered, meaning that gillnets are inherently both size and species selective (Aquaprojects 1995..4-11). Other factors influencing the selectivity of gillnets include the environment in which the gear is operated (fishing depth, current strength and direction, water clarity, migratory behavior of the fish, etc).

Unbaited Traps (Cod or Capelin traps)

Cod or Capelin traps are similar to mobile gears in that the primary selective mechanism is the size and shape of the netting in the region of the gear that retains the catch. For traps, this occurs in the back panel where the "drying twine" is located. Traps are usually employed in shallow inshore regions through which fish regularly move or congregate. Long leaders, often running from shore to the mouth of the trap, guide fish inside where a funnel effectively prevents their escape. Fish tend to follow along the leader instead of swimming through the meshes, therefore most of the selective process occurs within the trap. However, the way in which the leader is designed (with fish deflectors, for example) and depth fished can be used to select against non-target species such as Atlantic salmon. This introduces a form of species selectivity.

For species such as herring (and capelin), which group in size ranges of mature fish, the mesh size can be selected appropriately (Sainsbury 1996..260). For species such as cod, undersized fish will have a likelihood of being retained in the net. The majority of these fish can be returned to the water safely, suggesting that this particular gear offers an effective means of size selection.

Trap designs that allow for the retention of juveniles in holding nets or cages, for further grow-out to commercial size, hold significant potential.

In addition to the selective characteristics of various harvest methods, a form of selection arises from natural processes within the environment and the fish population itself. For example, as fish migrate, their accessibility and vulnerability to fishing operations is altered. Changing tides and currents affect the operation of gear and the behavior of the fish, both of which influence selectivity. Further, changes in water temperature over time and location affect fish behavior, altering the catching process and resulting gear selectivity.

The entire process of gear selectivity is therefore an interaction between the fish population, the catching principle of the gear involved, and the state of the natural environment. All of which must be factored into the final analysis of gear selectivity and the appropriateness of the gear for commercial use.

2.3 Measuring Gear Selectivity

The ability to determine the selectivity of a fishing gear is of fundamental importance to sustainable fisheries management. During the 1980's Canadian cod stocks were managed under the assumption that selectivity of commercial gears (mainly otter trawls) decreased at older age classes. Statistical analysis has since proven this a false assumption (Myers & Cadigan 1995). For most species and gear types, selectivity increases with size, while vulnerability to the gear decreases (Gunderson 1993..13). This oversight may have led to the overestimation of spawning biomass which in turn led to the collapse of the stock (Myers & Hoenig 1996..1). The selectivity of a gear must also be measurable with some accuracy in order to estimate the potential of a selective method or device to be included as part of the regulatory framework.

With increased fisher involvement in the transfer of selective fishing technologies there is a growing need for industry standardization with respect to conducting selectivity experiments. For example, the 4R cod fishery for 1997 enabled fishers to harvest their quota either by using longline, or by conducting experimental selectivity trials with various gear types providing that the catch did not exceed the individual quotas (DFO 1998a..1). For harvesters and gear technologists proposing to undertake a study there are three main sources of published selectivity information from which such projects may be generated. The International Council for the Exploration of the Sea (ICES) has completed the " ***Manual of Methods of Measuring the Selectivity of Towed Fishing Gears*** (1996). This document was designed to assist in the practical application of size and species selectivity projects in the absence of readily available specialized knowledge . The Responsible Fishing Operations Branch of the Federal Department of Fisheries and Oceans has produced a ***Manual for the Measurement of Gear Selectivity*** (1995). This manual has since been used as a basis to publish a series of specific protocols for individual gear types which have been released in pamphlet form for easy dispersal to interested harvesters and industry personnel.

The requirement for specific protocols stems from the changing nature of the research into fishing gear selectivity and the concepts that are involved. One of the fundamental concepts is the size retention or **selectivity curve**. When length frequency data are collected from selectivity experiments, a curve may be generated which indicates the selection range of a specific gear type. The steepness of the curve indicates how effective a gear is at retaining a specific size of fish. Selection curves are normally compared at the points where 50% of the fish are retained, the **L50** reference point (Royce 1972..221). The **selection range** is defined as the range between the 25% retention size **(L25)** and the 75% retention size **(L75)**. A shallow curve that gradually changes between L25 and L75 suggests a poor selection process, while a curve that exhibits a steep slope indicates optimum selection (Aquaprojects 1995..2-11)

Mobile gears tend to retain a wider range of sizes and generally produce S-shaped selectivity curves (Fig. 2). The characteristic S-shape of the curve is produced when the gear allows the escape of small fish through the meshes, while the larger fish become more likely to be retained. As size increases escapement approaches zero and all fish are retained.

The relation between the size of the mesh and the size of the fish retained depends on the relation of mesh circumference to fish girth and to a lesser extent the diameter of the twine, stretch factor of the fibre, and hanging ratio of

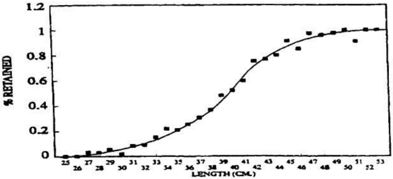

Figure 2.0 : S-Shaped Selectivity Curve **(Source : Aquaprojects, 1995)**

the netting. The selectivity of trawl nets is usually determined through comparative experiments in which trawls of different construction are fished side by side and the results compared. The selection potential of a trawl can also be determined by covering the codend with a fine mesh liner or by rigging a "trouser trawl" with a different mesh size or device in each leg from which the fish can be examined after the selection process.

It must be noted that the information gathered from generating a selectivity curve would not indicate other forms of selectivity that may occur before the fish is actually in direct contact with the gear.

It is believed that only a portion of the fish small enough to escape through the meshes of a trawl actually do so (Whileman et al 1996). Therefore the lower limb of the selectivity curve (Fig. 2) may not reach zero as some fish which are small enough to pass through the meshes become mixed with the rest of the catch and are prevented from escaping . This is commonly referred to as the cod-end 'masking effect'. The ability for escape from a trawl depends on many factors including fish exhaustion, the shape meshes take while the trawl is being towed, and whether the proper stimulus is present to encourage the fish to attempt escape.

Fixed gears such as gillnets produce a more pronounced bell shaped curve (Fig. 3). The characteristic bell shape is produced via the typical selection properties of these gears, which may prevent retention of the large fish but also permit the escape of smaller fish in relation to size. The width of a bell-shaped curve illustrates the selection range of the gear and the height at any given point will indicate the efficiency at a given length of fish. The highest point on the curve will indicate the optimum size of fish captured by the gear (Aquaprojects 1995..2-10).

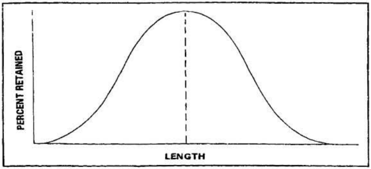

Figure 3.0 : Typical Bell-Shaped Selectivity Curve (Source: Aquaprojects 1995)

To compare the selectivity of most fixed gears it usually is necessary to compare catches of each gear under well-defined fishing conditions against the population of fish available to the gear. The most difficult step is obtaining a reliable estimate of the proportion of the population available to the gear. This is usually approximated by employing a gear that is relatively non-selective, i.e. a small mesh survey trawl. This provides an indication of the size classes available to the experimental gear. The difference in selectivity curves between gear types is attributable to the catching principle involved and any modifications made to the selective characteristics of the gear.

2.4 Expected Benefits and Consequences of Selective Harvesting

In 1997 the Northwest Atlantic Fisheries Organization (NAFO) held a symposium entitled "What Future for Capture Fisheries?" The symposium included discussions that addressed the need for a reduction in exploitation levels and reduced pressure on fish resources to ensure viable stocks for the future. In particular, improved fish capture technology through projects aimed at developing more selective methods of harvest was identified as a priority.

Selectivity projects are essentially attempts to investigate the selective properties of a harvesting method in the hopes of improving the sustainable growth parameters of a fish population. Selective harvesting projects may be designed from a size selective perspective (e.g. retaining only larger, mature fish), a species perspective (avoidance of by-catches), or a combination of both. Selective harvesting may also be employed in a limited capacity to retain or exclude a specific sex or level of maturity.

In previous management frameworks, minimum mesh size requirements were determined at a time when catch rates and yearly landings did not give cause for concern regarding resource sustainability. Today it has been established that not only is minimum mesh size important but the actual shape of the mesh may also be critical. Minimum mesh sizes are determined by examining the form and function of the target species and matching the optimal mesh size to the desired size or species of individual fish. For example, for mobile gear, the regulated minimum mesh size for cod is 130mm square or 155mm diamond shaped mesh, which is determined by the fish's shape at a desired harvesting length (in this case, greater than 43cm).

In principle, a fish size restriction is used to control both growth and recruitment overfishing by increasing the size at which fish are caught. When a fishing gear is designed or modified in a way to effectively select and release smaller juvenile fish, the expected benefits are a higher yield per recruit resulting in a larger spawning stock size over time.

Selective harvesting projects are becoming an important part of the management framework as future gear regulations may depend upon the information gathered from these initiatives. At present, problems with gear restrictions may be problematic for selective harvesting projects. For example, in a multi-species trawl fishery the optimal mesh size for release of juveniles may be different for each species. Under these circumstances the likelihood of achieving a selective gear design that is of benefit to each single species is reduced. This may lead to industry resistance and less willingness to provide funding for projects (Organization for Economic Co-operation and Development [OECD] 1997). To the extent possible, the expected results of a selectivity project must be outlined for each individual species that is expected to come in contact with the new gear design. In this way industry and science can more accurately evaluate the true benefits of a proposed selective gear design.

The future for the Atlantic fisheries depends on resource sustainability to the extent that a stock must support a fishery at least until it becomes secure enough to switch efforts to a more abundant species or one that promises a higher rate of return per effort. History has shown that fish stocks consistently become over-exploited in spite of considerable management efforts to achieve otherwise. Selectivity projects are best suited, not for perpetual resource sustainability, but for the benefit of increasing the period of time whereby a particular stock can be economically harvested.

As more selective fishing gear is developed and fisheries managers gain a deeper understanding of the biological interactions amongst fish species, the question remains whether or not imposing more species-or size-selective harvesting technologies and practices is beneficial overall. The full economic and biological consequences in terms of resources expended and benefits to harvesters, processors and consumers must be determined before regulations can be set that would require or induce harvesters to use more selective gear. In order to accomplish any of these goals, the potential for incorporation of a selective device or method must be thoroughly investigated by the completion of selective harvesting projects.

The following sections 3.1 & 3.2 outline two selective harvesting projects. The first involves an attempt to reduce by-catches of turbot from a mobile gear (shrimp trawl). The second description illustrates projects designed to reduce the catch of juvenile cod in a codtrap using a combination of mesh size investigations and specific exclusion devices. The section outlines the specific problem studied, indicates who were involved in the two projects and the degree to which the projects were successfully completed. This prepares the reader for the final section of this report, which will discuss the importance of comprehensive project planning and how this will improve the technology transfer environment in which selectivity projects can be implemented.

Section 3.0 Selective Fishing Gear Development

3.1 Mobile Gear: Reduction of Turbot By-Catch from Newfoundland Midshore Shrimp Vessels

In April 1997, the Department of Fisheries and Oceans announced that the total allowable catch (TAC) for Northern Shrimp (*Pandalus borealis)* would be increased from 37,600 metric tons to 59,050 metric tons for the 1997 shrimp fishing season (DFO 1997). About half of this increased quota (10,580 tons) was destined for the midshore fleet (vessels 45' to 65') representing a significant increase in harvesting opportunity. Many of the vessels entering into the fishery were not previously equipped or designed to operate trawls and subsequently required significant modification. In 1998, the shrimp quota was again increased, to 85,270 metric tons, which included a 46,200 ton total quota for Shrimp Fishing Area 6, NAFO region 3K-2J (Appendix A). Traditionally the Newfoundland midshore fleet has not previously participated in this fishery to any significant extent. However, because of the reductions in groundfish availability many harvesters have sought resource alternatives. Moving in the opposite direction to the shrinking traditional groundfish resource base has been the marked increase in the abundance of shellfish species, particularly Northern Shrimp. The Department of Fisheries and Oceans (DFO) is now encouraging a rapid expansion in the harvesting capability of Newfoundland midshore vessels to match the apparent availability of the shrimp resource.

Both mid-shore and offshore participants in the Northern Shrimp fishery from the Atlantic region are concerned with the by-catch of juvenile turbot. Although all of the trawls in this fishery must be equipped with a rigid separator device (Nordmore Grate), small to medium sized turbot are able to pass through the bar spacing and into the cod-end. These shrimp allocations which form the basis of a relatively new and important midshore fishery are considered temporary and their continuance depends upon the ability to harvest within certain conservation restrictions. One of the conservation issues is the bycatch of small turbot. Harvesters were very keen to find a solution before the situation worsened.

The requirement to harvest Northern Shrimp under by-catch restrictions as stipulated under the annual shrimp management plans, coupled with an increased recognition by harvesters regarding resource sustainability, has resulted in pressure from fishers for assistance from government and industry to find solutions. In 1997, a relatively new entrant to the Northern Shrimp fishery approached the Fishing Technology Unit (FTU) of the Marine Institute for assistance in gear modifications in order to reduce turbot by-catch. The FTU earlier had been involved in various projects involving selectivity of shrimp gear, including the design and testing of rigid species separator grates, shrimp size separator grates and various mesh size/shape investigations. Together, the

FTU and the harvester approached the Canadian Centre for Fisheries Innovation in St. John's (CCFI), in search of funding and project support. CCFI recognized the need to find a solution to turbot by-catch, and subsequently agreed to become involved in the project's development. The Department of Fisheries and Oceans, through the FRCC, was subsequently apprised of the project and gave support to the development of an at-sea-testing regime. Since then DFO has adopted an advisory role and has expressed interest in expanding the project for further tests in the fall of 1998.

The main objective of this initial project was to investigate a means whereby modifications could be made to the trawl, which would allow the escape of turbot while maintaining positive catch rates of shrimp. FTU specialists determined through discussions with the harvester that the most effective way to reduce turbot by-catch may be to lengthen the roller chains used to attach the lower section of the trawl (fishing line) to the footgear (Fig. 4). It was hypothesized that by lengthening these chains the turbot would be given more room to escape under the trawl as the area between the bottom of the trawl/mouth region and the footgear would be significantly greater. Although turbot are believed to occasionally migrate vertically for feeding purposes, they generally stay in relative proximity to the bottom. As shrimp are distributed more evenly over a larger vertical range, catch rates of shrimp would not be expected to decline appreciably when using lengthened toggle chains. Research on pelagic trawls, for example, has indicated that gear contact with the seafloor may not be critical in the capture of shrimp species.

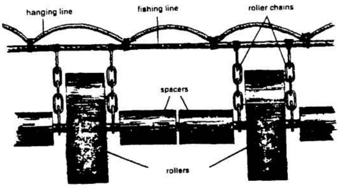

Figure 4 : Typical Toggle (Roller Chain) Arrangement (Source: Sainsbury 1996)

Studies of other flatfish species have indicated that the average size of fish escaping the trawl from the region of the footgear was smaller than that for the fish being retained (Walsh 1992). This suggests that juveniles especially can avoid capture from this region of the trawl if provided an adequate means of escape. Although the project was directed at an overall reduction of turbot by-catches, the ability to avoid catching small juvenile turbot was paramount. Avoiding larger individuals that would normally be selected by the rigid grate system would also prove beneficial, by increasing the probability of survival after the selection process. Although rigid grates are relatively effective selective devices there remains concern for post selection mortality due to contact with the grate and the associated stresses involved when fish pass through these devices (Soldal and Engas 1997).

Prior to the at-sea trial stage of the project the harvester involved was observing turbot by-catches ranging from approximately 13% to 38% of the total catch of shrimp with most being small turbot less than 23cm in length (FTU 1997a).

The original trawl used by the harvester was a two-seam, 1000 mesh circumference trawl with a cod-end mesh size of 44mm diamond. Modifications to the trawl involved replacing most of the 8" toggle chains with 38" chains. This increased the effective opening between the fishing line (lower trawl mouth) and footgear by 30" (Fig. 5). Chains at the ends of the fishing line were shorter at 23" and 8" due to the presence of a large plate, which connects the lower bridle arrangement to the footgear. Additional floats were also attached to the fishing line to counteract the weight of the larger toggle chains. If this had not been accounted for, the additional weight would have pulled the lower section of the trawl down closer to the sea-floor, negating any possible benefit from the use of longer chains.

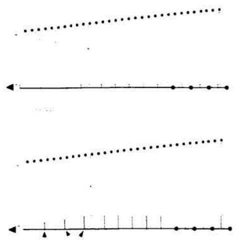

Figure 5.0: Toggle Chain-Footgear Modifications **(Source: FTU 1997a)**

During at-sea trials, a total of seven tows were completed using the long toggle chain trawl. On board the vessel was a FTU gear technologist along with the regular complement of 4 fishers plus the master. The toggle chain modifications were made to the trawl at dockside prior to leaving for the chosen test area. These modifications, although simple in principle would be difficult to perform while at sea on a 55ft vessel (Walsh pers.com. 1998).

Once trials began, total weights for northern shrimp, turbot and other by-catches were recorded for each tow. Length frequencies were obtained for turbot from three of these tows. A total of 519 individual turbot lengths were obtained (FTU 1997a). Gear geometry (trawl opening, horizontal spread, towing speed) was recorded with a hydro-acoustic net monitoring system throughout the trials.

Precise by-catch data for turbot was unavailable prior to the start of the project. However, a reasonable estimate was made through catch statistics from previous trips. Before the trawl modifications, turbot by-catch was usually in the vicinity of 600 lbs. or 275kg per tow (FTU 1997a). After the existing toggle chains were replaced with the longer ones, mean turbot by-catch was 146lbs per tow, which meant a 75% reduction in the amount of turbot retained by the trawl.

At present, a large percentage of the skippers involved in this fishery are reportedly abandoning the shorter toggle chain arrangement in favor of longer chains based on these and similar results and subsequent DFO recommendations (Brothers pers.com 1998).

Overall this selective harvesting project produced what appear to be positive results. However, those involved recognize the need for additional testing in order to quantify the potential of this modification for incorporation in the management plan. At present DFO has recommended the use of the longer toggle chains when possible. However, it has deferred regulating specific toggle chain length or footgear design pending further testing.

3.2 Fixed Gear- Cod Trap Selectivity : Mesh Size Investigations, Use of Square Mesh Panels to Release Juvenile Cod

The use of cod-traps as a method of fish harvest has come to symbolize the inshore fishery of Newfoundland. For over 120 years, cod traps have been used to catch and retain migrating fish using a simple, yet efficient, catching method.

Major modifications to cod trap design occurred in the 1960's when variants of Japanese inshore traps were introduced in hopes of improving catch rates. From the design influences of the Japanese style traps came the modified Newfoundland cod trap. An overall improvement over the traditional trap, the modified trap possessed a funneled entrance, which improved fish retention.

Typically, codtraps are constructed with meshes measuring 89mm (3.75") for the bottom and rear section (the "drying twine"). As a result, codtraps can retain a significant percentage of small fish during certain times of the year. The front section of the trap and the leader are constructed of 127-178mm (5"-7") [FRCC 1994]. Significant efforts have been directed towards determining how an increased mesh size would benefit the fishery. Unfortunately, even an increase in mesh size to 4" in the drying twine has the potential to retain as high as 40% small fish (FTU 1997b..1). An increase in mesh size throughout the trap also has the potential to cause a loss of marketable size fish (Brothers & Hollet 1991). For reasons such as these harvesters have been reluctant to agree to proposals to increase the minimum mesh size.

Although investigations into mesh size characteristics have been occurring since W.H Whitley first introduced the trap in the 1870's, there has not been an industry consensus regarding the most appropriate mesh configuration from both an economic and sustainable fishery perspectives. Studies conducted in 1960 by The International Commission for Northwest Atlantic Fisheries (ICNAF), determined that a 4.5" mesh size in the drying twine produced a sharp selectivity curve, and that this size was "not far from being right for this gear" (Boulanger 1961..1). Although the 4.5" released 85% of the total catch, the author considered this understandable considering the very small average size of fish in the population (Boulanger 1961..1).

During the 1970's, the Provincial Government of Newfoundland became increasingly involved in cod trap selectivity work. Although harvesting operations are federal jurisdiction, it was realized that changes in cod trap regulations would have a much more profound effect on Newfoundland fishers than those from the rest of the Atlantic region (Mercer & Allan 1979..4). Most of the studies carried out during this time period suggested that an increase in mesh size above 3.5" allowed for the release of small fish and that further studies be completed to determine the most appropriate mesh size from between 3.5" to 5". During the 1980's, in addition to continuing mesh size studies, selectivity characteristics of square shaped meshes were evaluated based primarily on similar work with groundfish trawls which showed that use of this shape of mesh reduced the catch of small fish (Johnson 1985..1).

One common thread to these investigative projects was the role of the harvester in its completion. Generally harvesters were contracted to employ and use the experimental gear designed by the scientists and technologists and had limited involvement in the project design and the evaluation of results.

In 1997, three selectivity projects were conducted with financial support from the Canada/Newfoundland Cooperation Agreement for Fishing Industry Development (CAFID). These projects were part of an effort to improve the performance of cod traps from a selectivity standpoint, before any future re-opening of the cod-fishery (CAFID 1998).

One of these projects was a cooperative effort between a group of harvesters in Petty Harbour (Best Partners and Associates), the Fishing Technology Unit of the Marine Institute and the Canadian Centre for Fisheries Innovation. Initiated primarily by the fishers, this arrangement was more typical of a cooperative project environment, in which harvesters identified and monitored the problem and assumed a more direct role in the determination of an appropriate technical solution.

The primary objective of this project was to evaluate the selectivity potential of a codtrap modified with a 11m x 5m panel with 4" mesh and a panel with 4 ½" mesh to act as a release mechanism for undersized cod retained in the box of the trap. The control for the experiment was the use of the standard 3 5/8" mesh in the drying twine. A second objective involved the investigation of which combination of mesh sizes would be the most appropriate for use in a commercial fishery (CAFID 1998).

The trap used was based on a Japanese design with a trap circumference of 110m and a total circumference including the retainer of 139m, similar in size and shape to those used most frequently in the area (FTU 1997b). The leader was 240m in length with 70mm mesh in the wall construction of the trap and 91mm in the back panel (drying twine).

The two panels installed as potential release mechanisms, were tested separately over a 30-day period. Each of the two panels were 11m deep by 5.5m wide and were installed in the middle of the drying twine, occupying 1/3 of the entire width of the back panel from top to bottom (Fig. 6). The panels were covered with a guiding funnel, which led into a small mesh retainer bag where all of the cod that escaped via the panels could be collected for examination.

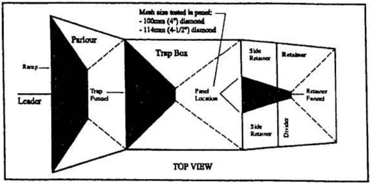

Figure 6.0 : Installation of Square Mesh Panel/Retainer Bag (Source:CAFID 1998)

The experimental trap was hauled each day by the fishers involved and random lengths were obtained from the fish in the trap and the retainer respectively. A representative from the FTU was also present each day to assist in the collection of data and the hauling of the trap. Once length and weight was recorded for the sample, the fish were immediately released to minimize potential mortality. All the fish remaining in the trap were subsequently released through a series of zippers installed in the trap.

During testing of the 4" panel, 1,866 fish were sampled with 1,103 taken from the retainer (after escaping the trap) and 763 sampled directly from the trap. A significant number (90%) of the fish sampled from the retainer were under 40cm in length. The trap also retained a large number of small fish with 76% being under 40cm. This indicated that although the panel did allow smaller fish to exit the trap via the panel, a number of small fish also remained in the trap itself.

Cumulative length frequency distributions showed that the average length of fish caught in the trap was 5cm longer than that in the retainer. Although this would suggest that the panel was effective in releasing more small fish while retaining more of the larger, the average size of the fish in the trap was only 38cm. The 4" panel released all fish under 28cm in length and retained all fish over 46cm. Those involved in the project however warn that since the population consisted mostly of small fish, results are difficult to interpret.

The 4 ½" panel was also tested, however due to time/seasonality constraints, and relatively poor catch rates, only limited data was collected on the effectiveness of this device. Similar constraints also prevented the completion of the investigation into the most appropriate mesh size combination, which could be used throughout the trap.

Although the lack of cod in the area, and the small sizes observed prevented a complete test of the experimental gear (local fishers felt most fish migrated out of the area before the test began), the results that were obtained suggested that the use of a 4" panel did in fact have a positive influence on the selectivity characteristics of the trap.

It was felt that as a pilot project to investigate the design and implementation of the selective panel concept, this experiment proved to be a success. Recommendations were subsequently made that further tests be conducted during a more appropriate time during the fishing season to ensure that an adequate representation of the fish population could be obtained.

Project extension however may require the establishment of additional sources of funding along with the possibility that new funding agencies and support personnel may have to be involved. This is a problem for virtually every selective harvesting initiative that is launched under the current environment of government cutbacks and the difficulties funding agencies face in acquiring consistent sources of revenue to administer research and development programs.

The following section (Section 4) will discuss the transferal of selective harvesting technologies between industry and government, and how despite the fact that funds are sometimes scarce, the transfer of these technologies will continue through cooperative attempts to meet conservation objectives.

Section 4.0 Effective Transfer of Selective Harvesting Technologies

4.1 Current Resource Status and the Requirement for Selective Harvesting Projects in Atlantic Canada

The stock status reports released annually by DFO portray a bleak picture of the health of groundfish stocks in the Atlantic region. Harvesting moratoria continue to be in effect for 7 of 50 groundfish stocks reviewed yearly by the FRCC with low exploitation levels being established for many others. Many of the stocks not currently under moratoria, with the possible exception of 23OB1B-F Greenland halibut, 3LNO Yellowtail Flounder and 4VWX (Scotian Shelf) Silver Hake, are showing poor signs of recruitment and growth (FRCC 1997a).

Fortunately, the fishing industry in Atlantic Canada is being supported by increases in landings and value of shellfish resources such as shrimp, lobster, crab, scallop and surf clam. In 1996, figures for commercial landings by weight for the region indicate that shellfish accounted for 281,073 metric tons or 40% of all fish and marine plant products (Fisheries and Oceans 1996a). Nowhere is the importance of shellfish more prevalent than in the Newfoundland region where in 1996 the total landed value for all shellfish products in the province reached $233 million or approximately 80% of the total value for groundfish, shellfish and pelagics combined (Fisheries and Oceans 1996b).

Unfortunately for many inshore harvesters, the dispersal of income from the shellfish-harvesting sector has been regionalized and economic benefits are concentrated in the hands of the larger operations. To alleviate this disparity, the groundfish fishery should be restored under a sustainable framework, to a level that provides more economic return for inshore harvesters than what is now present.

Although the conditions that hastened the decline of groundfish stocks (i.e. unsustainable harvesting practices, complex predator-prey relationships, and change in oceanic conditions) may have influenced a rapid growth in shellfish biomass there are indications that this trend has slowed. This leads to a degree of uncertainty regarding the future composition of the region's fish and shellfish resources.

From a national perspective, nowhere in Canada has the importance of selective fish harvesting received as much press recently as has been the case with the Pacific salmon fishery. Elements of more than 65 proposals regarding selective harvesting methods have been forwarded by all four sectors harvesters, processors, government and First Nations representatives, in the development of the 1998 Salmon Management Plan (DFO 1998b). These proposals include small individual selective harvesting projects in addition to gear modification, in keeping with the requirement to satisfy the conservation criteria established by DFO to protect the Coho salmon. DFO Minister Anderson, has stated that a new "selective fishing strategy dramatically changes the historic organization of BC fishing" (Vancouver Province 1998). Minister Anderson, has also stated that he would only consider "selective" commercial fisheries in waters where intermingling of the various river stocks was low and the risk of accidentally catching Coho salmon was reduced (Vancouver Sun 1998).

The significance of Minister Anderson's comments for the Atlantic region is the recognizable national directive to develop selective harvesting methods as a basis for continued fishing operations. There is a concern, however, that the concept of selective fish harvesting may be pushed beyond reasonable limits. Selective devices work best when there exists an appreciable difference between the physical or behavioral characteristics of two fish species. Applying selective harvesting methods to species so similar, as is the case with the West Coast salmon industry, is very difficult and if nothing else, it identifies the severity of the situation. A reasonable comparison could be made with certain species of flatfish on the Atlantic Coast. Companies operating offshore trawlers in the region are under strict by-catch limits on American plaice while directing for yellowtail flounder. Although these companies are usually willing to apply significant resources to finding a technical solution to this problem, there are limits to what can be done to improve gear selectivity. Surgeon-like precision is not usually possible when adjusting gear selectivity parameters, and attempting to select between species of such similarity goes beyond what can reasonably be expected. For species such as these, seasonal adjustments to fishing operations and avoidance of known species habitat may be the only effective solution.

One of the problems from a management perspective has traditionally been the reliance on the single species approach to resource allocations in spite of the fact that these are multispecies fisheries. This has sometimes forced the concept of gear selectivity to be promoted as a more useful tool to achieve resource sustainability than is realistically possible. In conjunction with increased efforts to address the issues surrounding resource allocation, selective harvesting projects would promote the concept of sustainable fisheries by demonstrating that harvesters can have a positive influence by employing responsible practices whenever possible.

On both coasts fishers are calling for federal aid to support selective harvesting projects and more conservation measures to protect fish stocks. The reality of the situation is that the Federal Department, like its provincial counterparts, is in the midst of cost cutting measures which have curtailed the department's ability to fund various projects.

4.2 Reducing Management Costs by Supporting Co-operative Arrangements

Operating expenditures in 1994/1995 for the Department of Fisheries and Oceans totaled $750 million dollars. By 1999, the annual operating budget will be reduced by 40% to $450 million. Management operations (licensing, enforcement, consultation and planning) will be reduced from $234 to $122 million during this same time period (Burke et. al 1996).

To achieve these significant cuts in expenditures DFO is following three main strategies. 1) the continuing adherence to the core mandate of conservation for sustainable use. 2) a consolidation of infrastructure and employee reduction. 3) the establishment of partnerships with harvesters and stakeholders. Cooperative projects are a necessity in today's environment of cost cutting measures and the establishment of a more transparent management framework. The level of government participation, federal or provincial, will vary with individual projects depending on the nature of the project and the ability of various departments to attach sometimes scarce resources to its completion. Regardless of governmental participation in completing the project, federal agencies must back these initiatives with a solid commitment by providing advice and assisting in the presentation of project results to industry upon completion.

In general, fish harvesters have recognized the need for collaboration and are willing to accept more responsibility, including costs associated with conducting selectivity experiments. Some of these costs may be absorbed by the harvester depending on the nature of the project or by various unions and industry support associations. Within the turbot by-catch project previously examined, a portion of the project's financial requirements were covered by the harvester in terms of vessel operating costs and logistic support. With respect to the codtrap studies outlined, the local area Co-operative was instrumental in providing funds and arranging technical support.

4.3 Regulating Harvesting Technology to Achieve Conservation Objectives

Much of the increased industry involvement and support for selectivity projects can be attributed to the fact that many of the written proposals for project development and support originate directly from the harvesters themselves. Harvesters have become more proactive in their approach to finding solutions to sustainable harvesting issues and are more likely to lead various initiatives to implement these solutions. This change in approach should be viewed as a fundamental change for the better, especially when the time comes for government to implement specific regulations concerning gear and harvesting methods.

The federal government is in the business of cost reduction. Therefore consideration must be given to circumstances where the implementation of a selective technology may be done more cheaply and efficiently by direct regulation. This has not proven to be very effective in the long run as it leads to the perception of industry over-regulation. By far the most beneficial approach would be the inclusion of such technology in an annual Conservation Harvesting Plan (CHP) put forward by the fishers themselves. Conservation Harvesting Plans are developed each year for individual stocks and gear sectors through advisory councils made up of harvesters, DFO officials, and advisory committees. A conservation plan may include the use of specific gear types, gear modifications, or operating practices to meet the conservation objectives set out by DFO. A recommendation is subsequently put forward to the Minister of Fisheries following a review by DFO officials. The minister may then ultimately determine the status of a particular fishery for the following year based on what is included in these harvesting plans.

While there are limits to what fishing gear selectivity can accomplish within the complexities of the natural environment and industry actions, there are numerous examples within the Atlantic region of the benefits that may be obtained. The adoption of the Nordmore Grate in the Northern Shrimp Fishery, or the use of salmon deflectors on cod and capelin traps, are only two examples of successful selective harvesting devices adopted in the past decade.

This paper has attempted to establish that the implementation of selective harvesting technologies through selectivity projects completed within a cooperative environment has a fundamental place within the new framework of sustainable resource exploitation. Pursuant to this, industry acceptance and support of the applied technology is the ultimate goal of selective harvesting projects and ultimately the manner in which this technology is either accepted or rejected plays a critical role within the management framework. The successful establishment of a cooperative environment will depend on how the various participants work together and to a large extent on how they view each others role in the industry. For harvesters especially, the implementation of new technology depends on the confidence they hold in the information used to make the relevant decisions. The following Section 4.4 describes briefly some of the processes that occur when new technologies or "innovations" are introduced within the fishing industry. This will be used as a basis to make certain suggestions to enhance the technology transfer process.

4.4 Industry Acceptance of New "Selective" Fishing Gears and Harvesting Methods

Although this paper has dealt primarily with the theoretical and technological side of selective fish harvesting methods, the fundamental problems faced by the fishing industry are not technology based or even resources based, but are directly linked to socio-economic factors from outside the fishery. These factors are responsible above all else for the chronic problems of over-capacity, unsustainable harvesting practices and dependence on government income support. While it is beyond the scope of any single report to deal definitively with the many social and cultural influences that affect a fishery, from a project development perspective it is important to consider their possible effect on successful testing and implementation.

One of the most important factors in the successful implementation of new harvesting methods is acceptance by harvesters who will be required to use it on a regular basis. Acceptance, in this context, refers to the voluntary adoption of the selective harvesting method into normal harvesting operations. Acceptance of a new or modified harvesting method suggests that government regulations regarding use and operation might only be required as a precautionary measure and to monitor the degree of compliance. Acceptance also suggests that harvesters understand the application of the technology and are appreciative of the economic and biological benefits that may be realized.

Aside from the obvious need to determine whether or not the new technology offered actually works, selectivity projects also require a benchmark to assist in determining overall success or failure. Although the theoretical goal of sustainable harvesting is to maintain a maximum yield from a fishery, given the complexities of the resource it would be difficult to equate project success with any corresponding change in stock dynamics. Therefore, industry acceptance or rejection of the technology involved and the way in which it is adopted, provide more accessible reference points from which to critique selectivity projects. If a project fails because harvesters reject the technology applied it is possible that the solution chosen was inappropriate for that circumstance. Inappropriate technological solutions may occur. However, the information gathered from a "failed" project may be of as much use as a "successful" innovation if the results are interpreted correctly. Inappropriate technology may take the form of a poorly designed device or modification, a cost prohibitive device, a device that is difficult to regulate and monitor, or a technological mismatch between the current method of harvest and the proposed selective innovation.

For example, James Acheson (1988) attributed the hesitancy to adopt new fishing techniques in the Maine lobster fishery in the 1970's to a number of social factors. Acceptance hinged primarily on social relationships and tradition. Although new trap designs were found to catch more lobsters per trap, these facts were not widely appreciated and ultimately acceptance depended on the local "fisherman's harbour gang" and one's position or stature within that gang. Members of these "gangs" are usually fishers whose similar experiences and social place (area fished, gear used, historical involvement etc.) within a particular fishery identify them as belonging to a unique group. There usually exists a flow of information within the gang and fishers rely on this to obtain information about fishing areas, catch rates, and innovations (Acheson 1988). A similar social process occurs in practically all fishing communities in Atlantic Canada. In many circumstances, those members occupying higher levels of status and who are traditionally the most successful harvesters in the community are the ones most likely to become involved in cooperative fishing technology projects. These associations exist in virtually all fisheries at various levels of organization, and must be considered when designing a selectivity project or attempting to implement a gear regulation.

The introduction of new gear technology and responsible fishing practices in Atlantic Canada has been a cumulative process, relying more on initiative and commitment to specific projects than on an established management framework. Although sometimes lacking formal structure, this approach has provided for a degree of flexibility, which has enabled more equitable working arrangements amongst those involved. This is crucial considering the cooperative nature of today's harvesting projects and the number of parties that must be involved to provide basic resources, especially funding. Flexibility in project design also improves logistics, as most projects are sea-tested during regular commercial operations.

The significance this holds for industry and community acceptance is that projects that lack flexibility and do not encourage harvesters to assume a pivotal role will not easily progress from the testing stage to possible implementation, i.e. a lag in acceptance. In other words, if the project doesn't provide a measure of success that the harvesters consider as being largely due to their efforts, interest will fade, and the appropriateness of the project will be questioned.

When discussing the theory behind acceptance or rejection of innovative fishing technologies, it is important to view the idea of "innovation" a degree of restraint. Many selective fish harvesting projects are developed with very little in regard to technical sophistication. For example, by simply increasing toggle chain length one is not advancing fishing gear technology by leaps and bounds. Fish harvesters as a collective are amongst the most innovative of any social group; they must be to survive. However, most regard innovations from outside their immediate grouping with reservation, especially initiatives sponsored primarily by government. Fortunately, many of the selectivity tools available today are based on simple applications requiring a good knowledge of fish behavior and how this knowledge can be taken advantage of to obtain the required results.

Barnett (1953) described innovation as a "novelty" with the emphasis being placed on the newness of the interrelationship of its parts, not their number. In other words it is not as crucial to quantify innovation as it is to understand that possibly the most important aspect is the qualitative departure from habitual patterns. And Barnett poses a fundamentally important question that is "just which individuals in a group are most likely to accept or reject a particular novelty?" This question is important to consider because, as Jallade and Prado (1998) have stated, "current technologies are a result of constant development over a long period of time, which makes change and introduction difficult". Identification of the reasons why certain individuals would be hesitant to adopt new fishing technologies is crucial to shortening this development period.

Returning to Barnett for further clarification, one of the primary problems in moving a selectivity project past the testing phase and having the results implemented is not whether or not the method or device will be rejected or accepted outright, but rather the lag in acceptance that occurs. Eventually all harvesters would be expected to reach the acceptance stage either willingly, reluctantly or unwillingly, given that a method has been deemed to be appropriate from a regulatory perspective. Barnett describes a technology "continuum" where "unrelenting, die-hard conservatives" exist at one extreme and "quick and easy acceptors" the other. Although Barnett's work is rather dated and does not explicitly speak to the fishing industry, the process of technology acceptance he describes seems to reflect the ideals and issues present in today's fish harvesting communities.

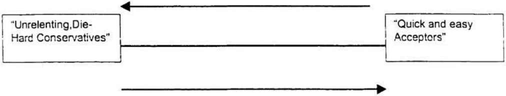

Figure 7: Barnett's "Technology Continuum." (Adapted from: Barnett 1953)

Applying Barnett's description, one can consider that at any one moment during the development and implementation of a selective harvesting initiative there will be a pattern along the continuum. This pattern will be influenced by a number of factors specific to a fishery or fishing community, including:

1. Biological status of the fishery
2. Economic status of the industry
3. Project design and planning
4. Government policy and regulations
5. Current level of technology
6. Social structure of the population

A key concern for those seeking to implement new selective harvesting technologies is the relative location of individuals on this continuum. Hence, does current government policy influence some harvesters to be resistant and more likely to reject the technology or to be accepting and willing to give considerable support?

The practical problem from a fisheries management perspective, is the resulting lag in acceptance that may occur due to an inappropriate implementation process. Rather than attempt to influence the degree of acceptance by limiting attention to problems of resource sustainability and socio-economics directly, fisheries managers should concentrate primarily on project design and planning. Projects that are based within a cooperative framework that includes adequate and timely funding, flexibility in design, uses appropriate technology from a regulatory and operational perspective, and are completed in a timely manner will have a much better chance of becoming a widely adopted and endorsed method of harvest. In this manner, industry will have more incentive to participate and there will be more confidence in the ability of government to properly implement and regulate new conservation oriented fishing gears.

4.5 Building Project Incentive through Comprehensive Planning

Watson (1998) suggested that voluntary acceptance of technology transfers will be resisted without proper incentive, and that those involved in the harvesting of the resource must be active participants in all aspects of planning, development and evaluation of new technologies. Initiative and incentive are factors crucial to the completion of selectivity projects, and will be lost if a number of major issues are not considered. The most logical way to develop and maintain initiative and incentive is to develop a more dynamic and cooperative fishery management regime that provides a ready platform from which to launch appropriate projects.

The following outline identifies major issues, some of which are very broad in scope, that fisheries managers and fish harvesters must consider during the design and implementation phase of selectivity projects.

1. Problem Identification

- ❑ Full consultation required with harvesters who have traditionally fished the area.
- ❑ Quantification is important. Is this a perceived or actual problem? What is the magnitude of the problem? How do the various gear sectors and fishing associations view the problem?
- ❑ Preliminary observations with underwater cameras or gear sensors may prove invaluable.

- Review of published results from similar problems necessary. What does national or international experience suggest?

2. Industry Proposals

- Many proposals now originate directly from harvesters experienced with at-sea observation and matching new fishing techniques to these observations. Careful consideration must be given to the content and project potential of these proposals.
- A project proposal lacking appropriate format or scientific validity will not usually elicit a positive response from potential funding agencies.
- Most successful harvesters are inherently innovative. Therefore they should be encouraged to work directly with the scientists/technologists during design stage and, if applicable, have direct input into the project proposal.

3. Co-operative Arrangements and Privatization

- Government still retains pivotal role. However, an increasing amount of experimental design and research is being done by private entities. This requires an effective liaison between sectors.
- The implementation of technical measures in fisheries management along with the establishment of co-management requires an improved process whereby appropriate institutions and agencies can be identified, and formal decisions can be made.
- Static technical measures alone amount to an incomplete management system (Lane and Stephenson 1995). Co-operative arrangements must emphasis the participatory nature required of those who will be affected the most. Harvesters must have representation at every level in the co-management system.

- As was evidenced in the project examples, harvesters, in return for more decision-making responsibilities, must absorb more of the costs associated with the completion of selective harvesting projects.

4. The Responsibility of Government

- The attempt to link modern technology capabilities and current fishery exploitation practices to improved management is a lofty goai. Government agencies must manage the fishery within reasonable boundaries as determined primarily by the nature of the resource and the ability of selective harvesting initiatives to prove effective.

- The key to voluntary acceptance on behalf of harvesters is confidence in the information used to make management decisions. Government must assume a straightforward approach and maintain the initiative to provide a more transparent management policy.

- Given that many negative influences are in fact external to the fishery, managers must appreciate the need to integrate social scientific research within specific management plans. More documented research should be presented to government officials concerning community conservation ethics.

- Government must provide an improved system to monitor the transferal of management responsibility to the appropriate community level.

5. Completion under Normal Fishing Conditions

- Fundamental to the cost-sharing requirement as well as satisfying the need to acquire representative data.

- Concern lies with the need to maintain profitability plus conclude necessary experimentation. Following standardized protocols while "fishing under normal conditions" requires sound knowledge and generous cooperation. A comprehensive at-sea-testing regime is a must.

- Whenever possible, harvesters must be given the lead role and responsibility in providing "good" scientific data.

6. Communication of Results

- Upon project completion, formal reports should be presented to the fishing industry and applicable funding agencies. In addition, details of the report and further discussions should be presented through follow-up seminars with harvesters.

- If the harvesters or representative associations themselves generate the final reports, these documents should be distributed to the appropriate governmental agencies.

- If the project is successful a media package including videos, brochures, prepared releases etc, should be prepared for wide distribution.

- If the project identifies an improved method of harvest, the results should be incorporated into "Responsible Fishing" training programs to be administered by the relevant education institutions.

- Development of a "real-time" network is crucial. The Responsible Fishing Technology Network Pilot Project for the East Coast has been identified as a high priority project. Benefits of an on-line network would include:

    - Identification of relevant expertise from various sectors of industry and government.

    - Comparative analysis of similar projects throughout the region.

    - Liaison with the various funding agencies who are willing to support selective harvesting initiatives.

    - Sharing of data, especially that generated by the harvesters will help to unify the industry.

    - Important links can be made to international experiences and expertise.

While there will always be more involved in any project's planning and implementation than what has been covered by these few points, they may nonetheless prove very critical to project success. Within the new cooperative management framework that is being promoted there are likely to be many reversals of roles with respect to who designs tests and implements new harvesting methods and technologies. At times harvesters may only be called upon for limited involvement, while at other times it may be the harvesters themselves who require only government supervision as they apply their knowledge and skills to determine appropriate fish harvesting technologies. This change in approach to how gear technologies have been investigated in the past requires a more fundamental understanding of the entire process involved, including how fishing communities approach the question of technology transfers. Finally, acknowledgement of the various points included here will help to improve the environment (Fig.1) in which selective harvesting projects are conducted.

5.0 Conclusion

Future growth in the fishing industry of Atlantic Canada will depend on the ability to sustain available fish resources through increased participation of the industry in the management process and a cooperative effort to fish responsibly. Acceptance of new technologies and management measures are likely to depend on the confidence individuals, especially harvesters, have in the information that is used to make these decisions. Increased participation by all sectors in the completion of dedicated selectivity projects would help to instill confidence in the management framework. As part of the larger "co-management" approach it will be the fishing industry who will be offered the responsibility of applying appropriate technical measures to everyday harvesting operations. Selective harvesting projects based on government-industry cooperation is therefore expected to assume a more dynamic role in the promotion of more responsible fishing practices.

Those involved in the industry must remain recognizant that technical measures alone cannot be expected to alleviate problems such as resource allocation, resource variability, acceptance of technology, and attempts to circumvent harvesting regulations. Nonetheless, the development of more species and size selective harvesting gears and methods may be expected to have a positive influence by demonstrating that industry can work with government to achieve conservation objectives. This would help reduce the damaging effects of overcapacity and the inherent pressure that exists to push exploitation levels to their limits and frequently beyond.

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