AN EXAMINATION OF THE FACTORS AFFECTING THE SUSTAINABILITY OF THE NEWFOUNDLAND & LABRADOR SNOW CRAB FISHERY

NOEL C. MILLEY

An Examination of the Factors Affecting the Sustainability of the Newfoundland & Labrador Snow Crab Fishery

by

Noel C. Milley

A major report submitted to the

School of Graduate Studies

in partial fulfillment of the

requirements for the degree of

Master of Marine Studies
Fisheries Resource Management

The Marine Institute of
Memorial University of Newfoundland

May, 2005

St. John's Newfoundland

0-494-06648-2

Your file Votre référence
ISBN:
Our file Notre reference
ISBN:

ABSTRACT

The Newfoundland and Labrador (NL) snow crab (*Chionoecetes opilio*) fishery has become the backbone of the fishing industry since the closure of the groundfish fishery in the early 1990's. In 2003, snow crab contributed approximately $277 million to the total landed value of the fishery. This represented 50 per cent of the total landed value for the entire fishing industry.

For the fishing industry, snow crab expansion has been the order of the day throughout the 90's. However, in 2000, based on the fall surveys of 1999, warning signs were raised. As a result, snow crab quotas were cut for the first time in over a decade. Since 2000, the crab fishery has been showing signs of declines in certain areas. The fear among industry is that this trend is going to continue and spread to other or all areas.

A key management objective of the snow crab fishery is to protect the reproductive potential of the resource. The reproductive potential is thought to be protected by the retention of only snow crabs over 95mm (3.74 inches) carapace width and discarding all female crab. Given that the resource is declining two questions arise. First, why is this resource declining given the current management strategy? Second, what can be done to prevent the snow crab resource from further reduction? Hence, this study will review the NL crab fishery to examine the factors affecting its sustainability. The focus of this study will consist of an examination of the snow crab biology, discuss the development of the snow crab fishery, state the importance of the snow crab fishery to the NL economy, identify factors affecting sustainability (natural and man made), with special emphasis on snow crab discards, exploring other fishing related impacts and method of harvest. Finally, the study will identify possible measures to protect the reproductive potential of the resource.

ACKNOWLEDGEMENTS

I am deeply indebted to Kevin Anderson, my project supervisor, for his time, patience, suggestions and input during the course of completing this report. To Dr. Scott Grant, Instructor/Researcher at the Marine Institute, I would like to express a sincere gratitude for sparking my interest for this project through comments, discussions and presentations on the subject. To both, a sincere thanks for your insights and valuable contributions.

To other individuals who encouraged me and made contributions along the way, I deeply appreciate your time, effort and understanding. Thanks to everyone.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BCD	Bitter Crab Disease
CPUE	Catch per Unit of Effort
CW	Carapace Width
DFA	Department of Fisheries and Aquaculture
DFO	Department of Fisheries and Oceans
FDP	Fisheries Diversification Program
FRCC	Fisheries Resource Conservation Council
GRT	Gross Registered Tonnes
IQ	Individual Quota
NAFO	Northwest Atlantic Fisheries Organization
NL	Newfoundland and Labrador
RAP	Regional Assessment Process
SSR	Stock Status Report
TAC	Total Allowable Catch
VMS	Vessel Monitoring System

1.0 INTRODUCTION

1.1 Purpose

The purpose of this paper is to review the Newfoundland and Labrador (NL) crab fishery, to examine the factors affecting sustainability and identify possible measures to protect and maintain the reproductive potential of the resource.

1.2 Scope

This paper will first examine the biology of snow crab. Next, it will discuss the development of this fishery focusing more specifically on the last decade. In addition, the importance of the expansion of the snow crab fishery to the NL economy will be discussed. In more detail, it will identify factors affecting the sustainability of the resource, including fishing related mortalities. Finally, it will draw conclusions and identify possible measures to protect and maintain the reproductive potential of this resource.

1.3 Limitations

This paper depends entirely on a literature search of the NL snow crab fishery.

1.4 Background

The snow crab fishery in Newfoundland and Labrador began in 1968, however, it was a small and relatively localized fishery until the 1990's. During the 1990's, the snow crab fishery emerged as the "backbone" of the fishing industry. With the closure of most major commercial groundfish stocks in the early 90's, existing fisheries such as snow crab have been used to fill the void. In fact, at a time when some Newfoundlanders and Labradorians would suggest that "our fishery" (remembering that cod was king) is closed, record landed values are being achieved. Harvesting licences for snow crab increased from 50 in the early 80's to approximately 3300 by the late 90's(DFO, 1999a). Snow crab processing licences increased from 19 in the early 90's to 40 in 2003. In 1999, the snow crab catch peaked at 69,100 tonnes (DFO, 2001a). Total production value for the same year exceeded $1 billion for the first time in the history of the NL fishery. Production values have continued to exceed $1 billion for four of the past five years (1999-2003). In 2003, the landed value of snow crab was approximately $277 million, compared to $13 million in 1990 (DFA, 2004). In 2002, processing income contributed approximately $37 million to the economy. The snow crab fishery makes up 50% of the landed value of the total fishing industry today (DFA, 2004).

The current level of dependence on the snow crab fishery as the primary economic engine of the fishing industry highlights the importance of sustaining the reproductivity potential of the resource. For many harvesters it is a single specie industry. For others, without crab generating the amount of revenue it does harvesters would not be able to fish some of the other smaller fisheries that they are participating in. For example, for the 360 licenced enterprises that are participating in the shrimp fishery, it would not be viable to fish shrimp without the income from the crab fishery to finance their investment. Many in the small boat sector, less than 35', have limited access to most species and without crab they would not be able to operate.

Given its importance to the NL industry, any downturn in the snow crab fishery will certainly have a negative impact on the fishing industry. Clearly, the reproductive potential of the snow crab fishery has to be protected in order for the fishery of NL to succeed and provide significant wealth to the economy.

2.0 ATLANTIC SNOW CRAB (*CHIONOECETES OPILIO*) BIOLOGY

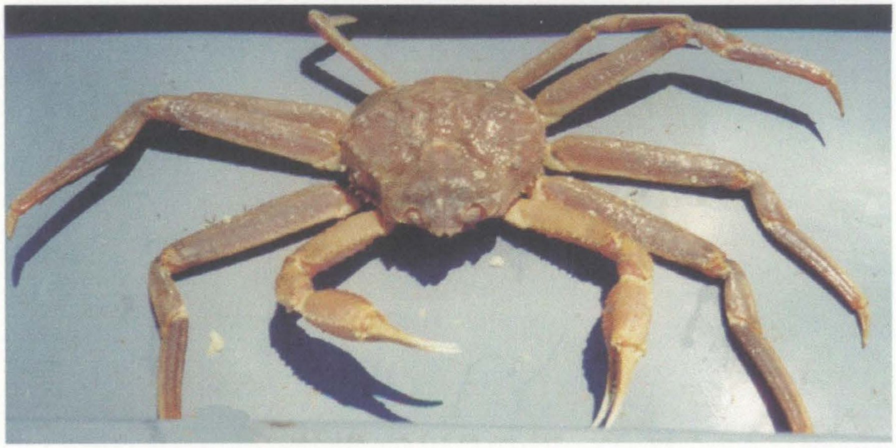
2.1 Description

Underwater World (DFO, 1990) states:

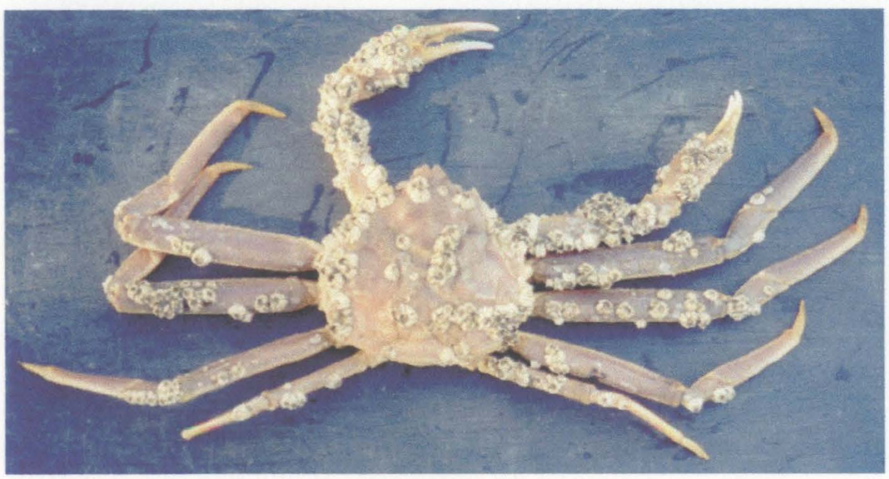
> The snow crab is a crustacean (like lobster and shrimp) with a flat and almost circular body, slightly wider in the back. It has five pairs of long spider-like legs that are somewhat flattened, the first being equipped with claws. The fully grown male is almost twice as large as the female, reaching (although rarely) a maximum shell width of 165 mm, a leg span of over 90 cm and a weight of 1.35 kg. The average size crab in the commercial catch measures approximately 11 cm and weighs 0.5 kg. Females grow to a maximum of only 95 mm shell width, with a leg span of 38 cm and weight of 0.45 kg. They have no commercial value. Males have proportionally longer legs and larger claws than females. The abdomen, which is relatively small and folded under the body, is quadrilateral in males but circular in females.

See Figure 2.1, page 5.

The shell colour of a snow crab varies. When the crab sheds its shell, the new shell is a reddish colour on top and a creamy white on the bottom. The animal is referred to as a "white crab" at this time. As the shell ages, it becomes a dull greenish brown on top and a dull yellow beneath ("Offshore/Inshore Fisheries," n.d.). It eventually will become covered with small marine organisms called barnacles (see Figure 2.2, page 5) (Tavel, 1998).



Source: Personal Photograph
Figure 2.1: Snow Crab



Source: Personal Photograph
Figure 2.2: Snow Crab with barnacles

2.2 Distribution and Habitat

Snow crab can be found in the Pacific from the Sea of Japan to Alaska, British Columbia, and the States of Washington and Oregon. They also extend over a broad range of depth in the Northwest Atlantic, from

Greenland to the Gulf of Maine. Snow crab are not found in the Northeast Atlantic ("Offshore/Inshore Fisheries," n.d.).

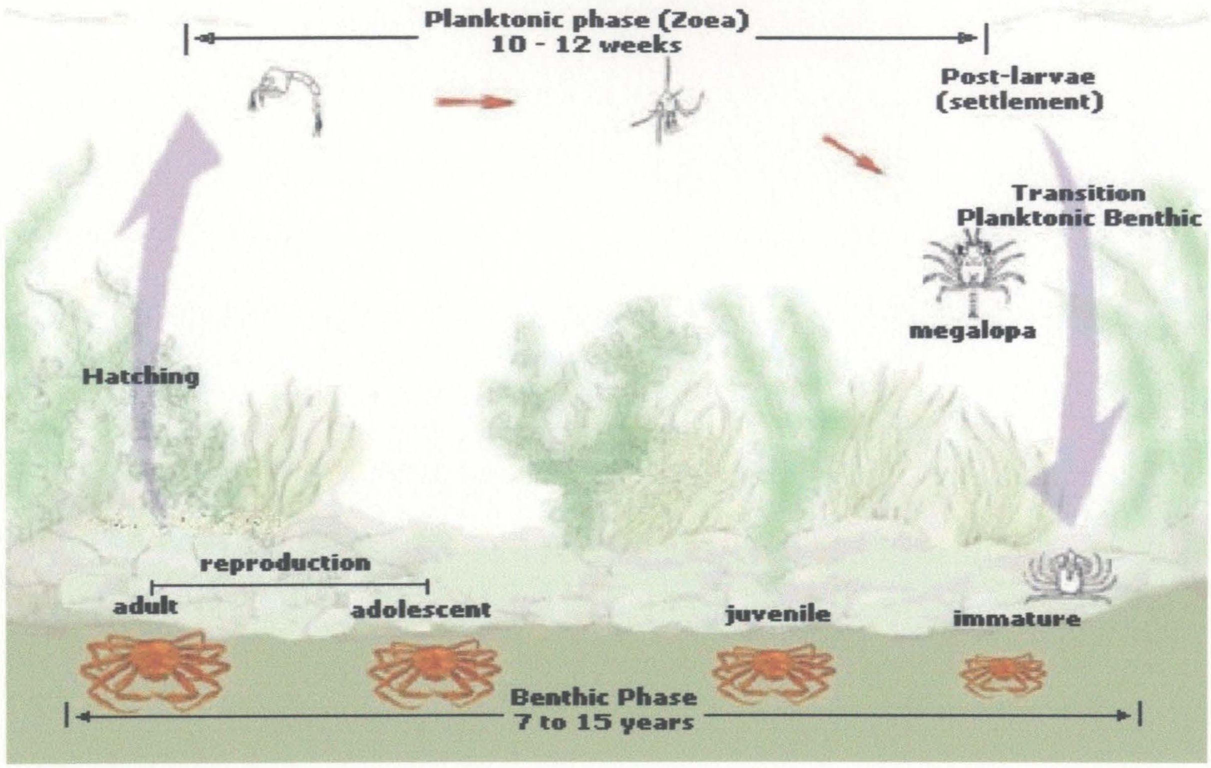
Snow crabs live most commonly on muddy or sand-mud bottoms at temperatures ranging from -0.5 to 4.5°C. ("Offshore/Inshore Fisheries," n.d.) The below normal temperatures found on the Newfoundland shelf from the mid-80's to about 1995 may have assisted in the unprecedented growth of crab stocks (DFO, 2004a). In the Newfoundland and Labrador region, they are usually found at depths of 70 to 400 m. Adult snow crab appear to have preference for muddy bottoms, while juveniles are commonly found on gravel and sandy bottoms. In some areas there are indications that snow crabs move from gravel bottom to mud bottom, usually in deeper waters, as they reach maturity ("Offshore/Inshore Fisheries," n.d.). Tagged crabs have been found from 15 km to 50 km from the point of release in one year (FDP, 2002e).

2.3 Snow Crab Life Cycle

Mating is thought to occur at the end of the winter or in the spring. At this time, the male holds the female with his claws until she molts. The male often helps her out of her old shell. Soon after the female is out of her old shell the eggs are fertilized. Then the eggs are deposited on the female's hairy appendages, located under her abdomen. The eggs are carried until the larvae hatch. The number of eggs that she will lay will depend on her size. She will lay 20,000 to 150,000 eggs over a period of a few days. A female may carry a batch of eggs for between one and two years, depending on ambient temperature (DFO, 2000e). The colour of her eggs will change from bright orange to dark purple or black over this period of time. ("Offshore/Inshore Fisheries," n.d.). Without mating again she can produce another batch of fertile eggs from sperm stored in two sacs called spermatheca, as she can store sperm for up to three years ("Offshore/Inshore Fisheries," n.d.).

As soon as the crabs are hatched they rise to the surface where they are carried by currents. At this time they are about 3 mm wide across the shell. At the surface layer they will go through a planktonic larval development process that will last from 10 to 12 weeks, depending on temperature. Before settling on the bottom they will go through three different larval stages before the regular shape of crabs are formed. These stages include: a short prezoea stage, two zoeal stages and a megalop stage (DFO, n.d.). See Figure 2.3, page 8.

To grow, crabs have to go through a process called molting (ecdysis or shedding). Lobsters and other crustaceans do the same. This process involves the animal shedding its shell several times during its lifetime to permit growth. To begin the molt process the crab has to build extra organic



Source: DFO, Snow Crab by Francois Plante
Figure 2.3: Snow Crab Life Cycle

tissues and develop a new shell under the old one. When the timing is right for the crab to complete the molt process the old shell splits at the back and the crab molts by backing out of the old shell. Depending on the size of the crab it could take up to 10 hours for the process to complete. Within a few hours, the soft crab takes up water and swells to its new size. The new shell starts to harden gradually and more muscles and other tissues grow inside replacing the water that was absorbed at molting. It may take two months before a commercial size crab loses its soft-shell condition. As the crab gets older and larger this process becomes less frequent. When both male and female crab reach sexual maturity they cease molting. This final molt is referred to as the 'terminal molt' ("Offshore/Inshore Fisheries," n.d.).

Every time they molt, mature male crabs grow about 20 percent in width and 60 percent in weight (DFO, 2000e). Age and growth are very difficult to determine because the frequency of molting is not known. In the Newfoundland and Labrador fishery, crabs of minimum legal size are thought to be at approximately eight years old (DFO, 2003c).

The male snow crab develops in three stages: immature, adolescent and adult. At the immature stage there are no reproductive organs. During the adolescent stage there are functional reproductive organs, but undifferentiated claws. At the adult stage there are functional reproductive organs and differentiated claws (DFO, n.d). At about 40 mm CW, approximately 4 years old, both male and female may become sexually mature (DFO 2003c). Males develop enlarged claws when they undergo a final molt, which may occur at any size larger than 40 mm CW. The enlarged claws enhance their mating ability. Only males with small claws will continue to molt and subsequently recruit to the fishery. Only a certain percentage of immature males in a population eventually reach the commercial size of 95 mm CW and recruit to the fishery. The passage from adolescent to the adult stage happens with the final molt (DFO, n.d.).

The terminal molt for the male happens in early spring. A limited number of adolescent males may molt in the winter and some may postpone their molt until the following year. This is referred to as 'skip molting' (DFO, n.d.). The male molting period is variable, thus making stock management difficult especially for the long term. When males reach the final molt they remain new-shelled for the remainder of the year. They have very low meat yield and are considered to be pre-recruits until the following year when they begin to contribute to the commercial fishery as older-shelled adults. Males may achieve maximum sizes of about 140 mm CW. Crabs may live 5-6 years as adults. (DFO, 2003c)

Female snow crabs also develop in three stages: immature, prepubescent and adult. The immature stage of the snow crab is described as having a narrow abdomen and no detectable ovaries. During the prepubescent stage the description is a narrow abdomen and ovaries without eggs followed by ovaries containing eggs. For the adult stage they have a broad abdomen and reproductive capability. Females undergo a terminal molt before becoming reproductively active. Females that are carrying their first clutch of eggs are called primiparous. Those that are carrying egg clutches for a second time or more are called multiparous. Adult females vary in size from 40 mm to 75 mm CW. With a life expectancy of only five to six years after the terminal molt, females carrying their eggs for two years will only have two to three clutches during a lifetime (DFO, n.d.).

When entangled or held by a predator, the crab can release itself by breaking the leg from its body. At the point of breakage a valve prevents major blood loss. The wound heals quickly. At the next molt a small leg is formed. After two more molting periods the leg will return to normal size ("Offshore/Inshore Fisheries," n.d.).

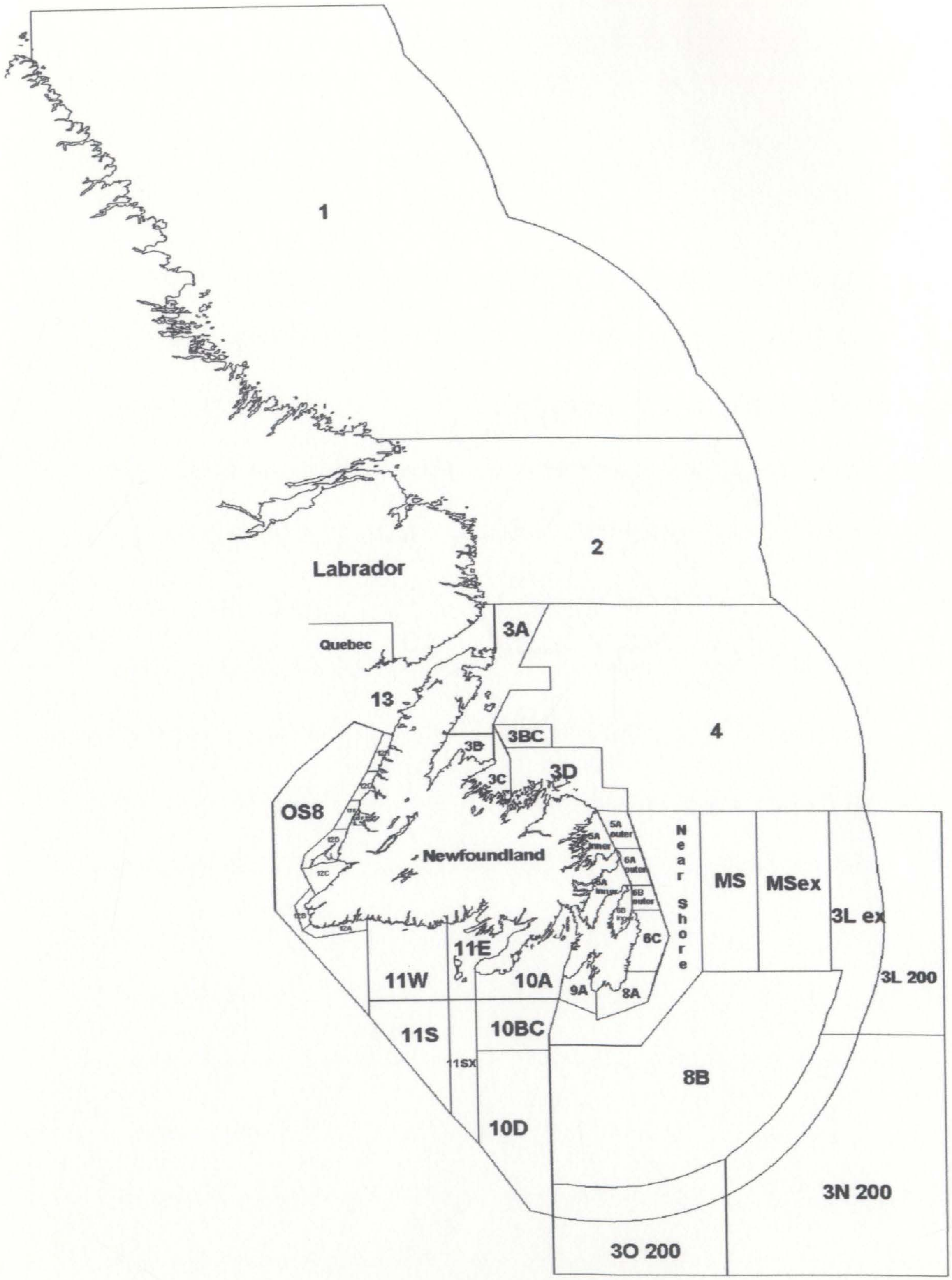
Predators for snow crab include cod, wolfish, bearded seals (which eat female crab found in shallower water), other snow crab, turbot and to a lesser extent halibut (DFO, 1990). The snow crab diet is diverse. Their stomachs may contain remains of fish, clams, polychaete worms, brittlestars, sea urchins, shrimp, snow crab and other crustaceans. Crushing hardshelled animals with their strong claws and mouth-parts is not a problem. They seem to prefer feeding activity more at night ("Offshore/Inshore Fisheries," n.d.).

2.4 Resource Assessment Methodology

For the Newfoundland and Labrador snow crab resource it is difficult to provide absolute biomass estimates to resource managers. The reasons being a combination of insufficient resources, bottom topography and such a large area to survey. The Department of Fisheries and Oceans (DFO) does not have the monetary resources to provide such an extensive program of research to cover all the fishing areas. The bottom topography in most of the commercial crab fishing areas is too rough to allow bottom trawling, the method used to survey the resource. Given the large number of management areas (see Figure 2.4, page 13) and the vast area over which they are spread, it is unlikely that it would be economically feasible to conduct cruises in more than a handful of areas in any particular year (DFO, 1997a). These management areas were established as a mechanism to control the distribution of fishing effort and prevent local over-exploitation.

A renewable resource like the snow crab fishery needs proper management to ensure that the resource will be sustainable for future years. To make sure that this happens, the DFO has two main objectives in the management of the snow crab resource. One is to maintain the reproductive potential of the resource and the second one is to achieve a sustainable commercial harvest of legal sized crab (DFO, 1999a). This is a monumental task made up of many variables and uncertainties.

2004 CRAB AREAS



Source: Department of Fisheries and Oceans
Figure 2.4: Snow Crab Management Areas

To protect the reproductive potential a management strategy is put in place to protect the females and males below 95 mm CW from being caught. This is accomplished by regulating the mesh size on crab pots to 135 mm so that the smaller animals can crawl out of the pot (DFO 2004a). By not harvesting the females and undersized males and with a proportion of other unharvested legal sized males remaining in the ecosystem it should be sufficient to maintain snow crab reproduction. Commercial sustainability is not at risk, theoretically, because a sufficient proportion of legal and sub-legal males and all females are protected from the fishery. Assuming reproductive potential is protected and females carrying eggs in each year remains at high levels, recruitment to the population biomass is assumed guaranteed. Quotas are established almost purely as a process to share the resource among competing users at the crab management area level. The paucity of science could not, and is not expected to support the quota levels established in each fishing unit.

To accomplish their management objectives, the DFO has broken the vast area that this resource covers into several management areas. At one point in time there were over 40 management zones including exploration areas that had not been fished before. Since scientific advice is provided on a North Atlantic Fisheries Organization (NAFO) Division basis, there is no scientific reason to have so many management areas. However, the number of management areas is an appropriate tool for managing the crab fishery because it tends to spread the fishing effort over a wide area. By doing so, it minimizes the possibility of over-exploitation of localized areas. Without it, areas closest to shore will be fished out entirely first before moving on.

The DFO produces a stock status report on the past year's crab fishery and releases a management plan at the beginning of the next season's fishery which outlines the overall Total Allowable Catch (TAC) and quotas for each fleet sector and management area. The Stock Status Report (SSR) is prepared by the Science Branch of the DFO. In preparation for the report, the science branch holds an annual Regional Assessment Process (RAP) on snow crab. This process involves analyzing historical and current data on the snow crab fishery. This includes the commercial catch rate data and the scientific survey (fall bottom trawl survey) data as well as comments and observations from industry. The information is presented and reviewed during the regional RAP process. Both internal DFO people and representatives of the industry are present. The purpose of the commercial catch rate data is to reflect fishery performance during the fishing season. The purpose of the scientific survey, which is collected after the fishing season, is to measure the residual biomass and provide biological data (i.e., berried females, bitter crab disease and pre-recruits).

The residual biomass is crab remaining after the fishery has taken place. This particular data provides some indication on the future of the stock. The data from both commercial catch rates and fall surveys will provide trends over time in resource status (DFO, 2000e).

The assessment methodology which is utilized in Newfoundland and Labrador involves a detailed analysis of roughly 15 to 20% of the completed fishermen's logbooks, which must be kept and submitted as a condition of licence. These logbooks are reviewed with regard to overall catch rates for each management area and how they compare to those of the previous fishing season. Such analysis, combined with information gathered from fishers and research cruises, are presented to a regional review committee, which in turn determines the health of the resource for each management area. It is essential to the management process that logbooks are completed accurately.

The bottom trawl survey is a multi-species survey using a Campelen 1800 survey trawl. This type of survey for crab began in 1995. This survey, with regard to snow crab, is a post-season survey. Its purpose is to provide an index of exploitable biomass and an index of pre-recruit legal sized males. The index of exploitable biomass includes the older-shelled adults of legal sized crab available for the next year's fishery as well as the growth from the proportion of the commercial biomass that is still small clawed. The index of pre-recruits includes those males that are larger than 75 mm that will begin to recruit to the fishery as older hard-shelled adults one year later. (DFO, 2004a)

The Campelen 1800 trawl is a shrimp trawl with mesh size of 44-80 mm and a nylon codend liner of 12.7 mm mesh. The trawl has a wingspread of about 16 m and a footrope equipped with rock-hopper gear. It is fished in standard tows of 15 minute duration, at a speed of 3.0 knots, over a distance of 0.75 nm (Dawe, 2001). There are many uncertainties associated with the trawl. The catchability of the trawl is unknown and male crabs of 40-75 mm CW are not well represented in survey catches, therefore, their contribution to recruitment to the fishery is unknown (DFO, 2000e). For example, if catchability from the trawl was 1, it would be an absolute estimate. However, the trawl does not catch everything in its path, such as the 40-75 mm CW, and performs better on sand/mud bottom, then stone/cobble. Hence, catchability is somewhere between 0 and 1.

3.0 DEVELOPMENT OF THE NEWFOUNDLAND AND LABRADOR SNOW CRAB FISHERY

The Newfoundland and Labrador snow crab ***(Chionoecetes opilio)*** fishery began in Hant's Harbour, Trinity Bay in 1968. This industry originally started as a by-catch from the groundfish gillnet fishery. In fact, it was the actual complaints by fish harvesters in the area of high catches of this nuisance species while pursuing other fishing interests which sparked the interest of P. Janes and Sons Limited to examine the potential of processing snow crab. Originally, it was called spider crab. When it was promoted as a delicacy in the United States market, the name was changed to the more appealing queen crab. The U.S. Food and Drug administration had objected to that name and it was later called snow crab (Daily News, 1969). As market acceptance for this product was established, demand increased. With increased demand came the need for an increase in effort by harvesters. Within several years there was a directed trap fishery by some fifty vessels along the Northeast coast of Newfoundland. They were designated as full-time licence holders and limited to a maximum of 800 pots each (DFO, 1997b). Until recent years they fished close to shore, but now they fish as far as beyond the 200 mile limit.

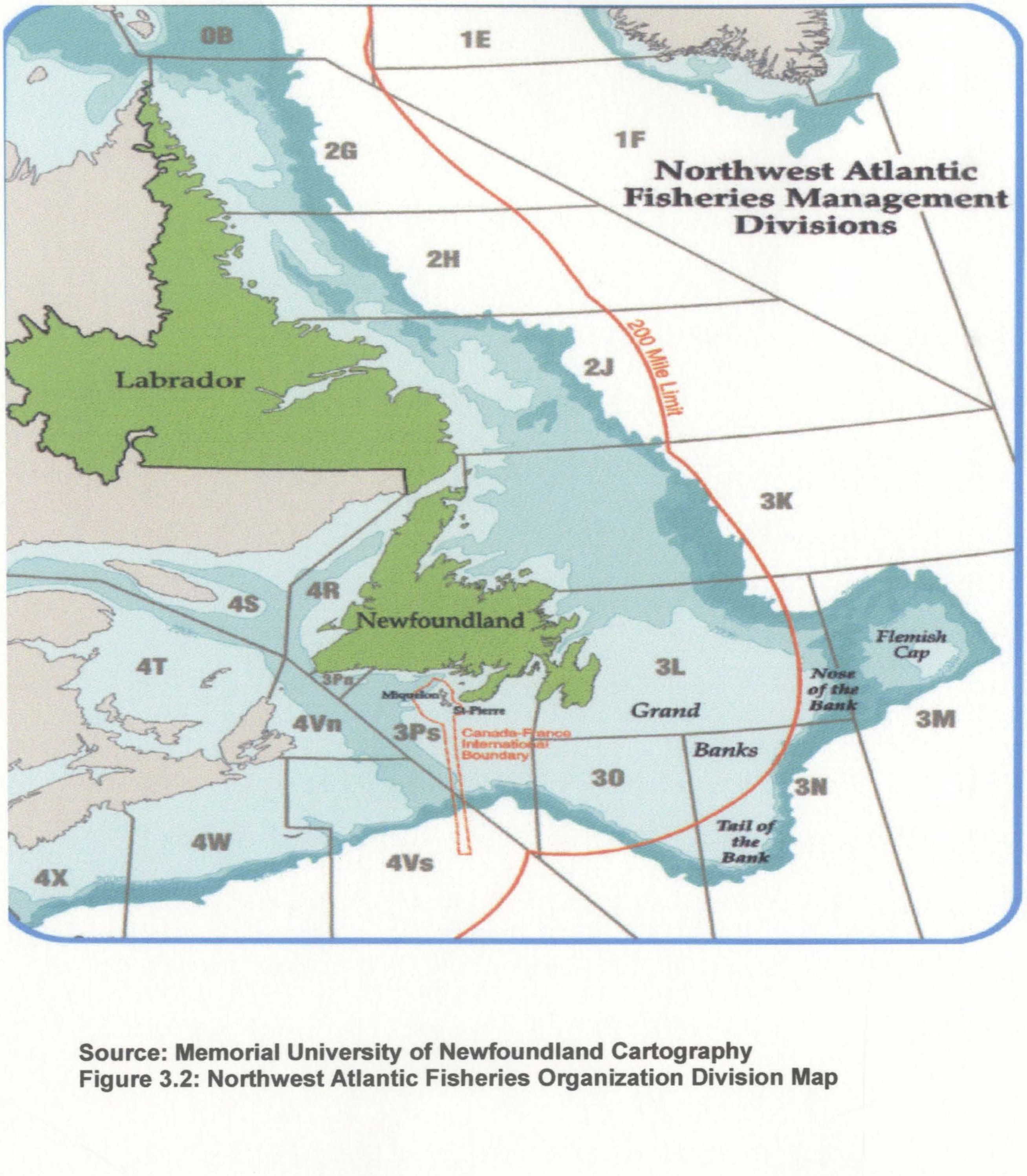
This crab trap fishery is pursued exclusively with Japanese conical "pots". The crab pot, as it became known, is an iron rod frame covered with polyethylene webbing and a plastic cone on top as an entrance for the crab

Source: Personal Photograph
Figure 3.1: Japanese Conical Pot – Crab Pot

to enter the pot. See Figure 3.1, page 19. The baited pots are set in longlines referred to as "fleets" in the industry. Those fleets of gear may consist of 10 to 100 pots, with distances of 15 to 25 fathoms between each pot depending on the size of vessel and the preference of the Skipper. While they have been modified somewhat in recent years to fish deeper water, their basic structure has remained the same. These pots are conical shaped, as mentioned, which allows them, first of all, to stack easily onboard vessels and secondly, to land on the ocean floor right side up. Regulations state that a crab trap cannot have a mesh size less than 135 mm and a volume of which exceeds 2.1 m^3 when measured on the exterior (DFO, 1985). The minimum legal size of crab is 95 mm CW. This mesh size regulation excludes females from the fishery while ensuring that a percentage of the adult males in the population remain available for reproduction. These traps must be cone-shaped and have a bottom ring with an inside diameter not greater than 133 cm. (DFO, 1985).

The crab fishery did not develop in all areas of the province simultaneously. The snow crab fishery was limited to NAFO Divisions 3KL until the mid 1980's. During the 1970's, crab fisheries developed along the Northeast coast, primarily in NAFO (Northwest Atlantic Fishery Organization) Division 3L (refer to NAFO map, page 21). The 3Ps snow crab fishery developed sporadically in the 1970's and on a regular basis during the mid 80's. A 3K crab fishery got started during the mid 1970's. Farther north in Division 2J, this fishery began in the early 80's. On the west coast of Newfoundland in Division 4R, the first substantial landings occurred in the early 90's (DFO, 1999b). Today it has expanded throughout Divisions 2J3KLNOP4R and is prosecuted by several different fleets.

In 1977, the Department of Fisheries and Oceans limited entry into the snow crab fishery (Brothers, 1986). In 1981, Zonal management was introduced which essentially restricted vessels to fishing within the NAFO division where the vessel resided (see Figure 3.2, page 21) (Brothers, 1986). In 1985 the fishery expanded into Labrador. This same year saw



Source: Memorial University of Newfoundland Cartography
Figure 3.2: Northwest Atlantic Fisheries Organization Division Map

the development of a supplementary fishery, prosecuted by enterprises needing to supplement their income from a failing groundfish fishery in NAFO Division 3K and Subdivision 3Ps. The supplementary snow crab fishery was expanded to Division 3L in 1987 and Division 2J in the early 1990's (DFO, 2004a). Catches were small during the early years, with rapid expansion in the period between 1987 and 2000. During 1982-1987 there were major declines in the resource in traditional areas in Divisions 3K and 3L. Since then the resource has recovered and remained high throughout the 1990's, while new fisheries started in 2J, 3Ps, 4R and offshore 3K (DFO, 2004a). 1986 saw the introduction of quotas to all management areas. Since 1989 there has been a further expansion in the offshore. In 1993 a snow crab fishery began in Division 4R (DFO, 2004a).

Also, in 1993, the DFO randomly deployed observers throughout the crab fleet to monitor crab fishing activity (T. Blanchard, Personal Communication, October 30, 2004). Observers help deter illegal fishing and collect samples for resource assessments. This process still continues today. Failure to carry an observer when requested by the DFO may result in charges being initiated against the licence holder (DFO, 1999a).

In 1994, two important changes took place in the snow crab fishery. First of all, in Division 3L access for supplementary vessels was expanded, which meant that there were now three fleet sectors: fulltime, supplementary vessels larger than 40 gross registered tons (GRT) in weight, and supplementary vessels smaller than 40 GRT in weight but having an overall length greater than 35 feet. Those fishers with vessels 40 GRT or greater were designated as the "large vessel supplementary fleet", while those with vessels less than 40 GRT were designated as the "small vessel supplementary fleet" (DFO, 1999b). This meant that the large vessel supplementary fleet had to steam further from land to harvest their quotas. Secondly, a dockside monitoring program run by fishers was instituted in Division 3K with a great deal of success. This was put in place to provide reasonable assurance that data on vessel landings was accurate and to prevent quota busting (DFO, 1997b).

In 1995, the Total Allowable Catch (TAC) was set at 31,175 tonnes. See Table 3.1, page 25. Dockside monitoring was extended to all NAFO divisions. The DFO required all fishers to discharge their catch in the presence of a certified dockside monitor. Discharging catch without a dockside monitor in place may result in charges being initiated against the licence holder (DFO, 1999b). During this year, vessels under 35 feet were issued temporary seasonal permits. The 1995 management plan contained the following statement: "there will be no temporary permits issued should the quota by area fall below that established in 1993."

These threshold levels were reiterated in the 1997-1998 Management Plan. Threshold levels were to remain in effect and apply to the overall NAFO Division quotas in 3K, 3L and 3Ps. This meant that should quota levels in the future be above 1993 overall divisional quotas, then temporary seasonal permits will automatically be issued (DFO, 1999b). In 1995, 360 permits were issued for an allocation of 1800 tonnes. Each bay was allocated a quota, fishing enterprises applied for a permit and a draw system determined which of the enterprises received those permits (Taylor, 1996). Also, during this year IQs (individual quotas) were implemented for the first time in this fishery. The full time fleet in Division 3K and all temporary permits were under an IQ system.

Table 3.1, page 25, outlines the quotas that were distributed for the different Divisions and the total landings for each year from 1995 to 2003. For some years landings were much higher than the assigned TAC's. The reason for this is that exploratory licences were not assigned a quota in the management plan. Landings from those licences were in addition to the original TAC.

Table 3.1: **Quotas and Total Catch for Divisions 2J3KLNO3Ps4R3Pn 1995-2003**

NAFO Division	Quota (tonnes)								
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
2J	3200	2800	2800	3500	4655	3340	3340	3381	2225
3K	12200	13650	14300	15740	18192	13493	13693	15378	15608
3L	13775	16850	18725	19975	26375	22710	23655	26448	27807
3N					2750	2190	2190	2190	2410
3O				2500	500	235	235	235	260
3Ps	2000	3050	3050	6200	7999	7700	7600	7600	6085
4R3Pn		1290	1290	1310	1335	1430	1554	1749	1895
Total	31175	37640	40165	49225	61806	51098	52267	56981	56290
Landings	29132	40054	37950	52152	69119	55507	56721	59306	58295
Source: DFO Canadian Atlantic Quota Reports 1995 - 2003									

Temporary seasonal permits were issued by DFO in 1996 for the second successive year to promote a more equitable sharing of the snow crab resource in Newfoundland and Labrador (DFO, 1997a). After the 1995 crab fishing season fishers rejected the random draw process for temporary permits. During 1996 to 1998 temporary permits were made available to all heads of core enterprises with vessels less than 35' who opted to participate within the criteria established by fishers (DFO, 1999b). Total landings rose to a high of 40,054 tonnes in 1996 primarily due to the expansion of exploratory fishing grounds in all NAFO Divisions to the offshore as far as 200 nautical miles and beyond (Taylor, 1996). The IQ system was expanded. Another new development also took place in this year. A dockside grading program was introduced and still continues today. This program is a means of evaluating the nature of the raw product at the wharf-side by a dockside grader. The role of the grader is to provide an independent and accurate measure of the size and quality breakdown of each landing (Tavel,1998). Industry also initiated a two-tiered price system for this year. It was based on crab size, with one price for crab less than 4" (i.e., "standard") and another higher price for "premium" crab with a carapace greater than 4". This resulted in a considerable amount of highgrading of legal size crab. Highgrading means discarding perfect marketable crabs and saving the higher priced portion of the catch. If the highgraded crabs are subjected to poor handling practices then they are in jeopardy of surviving (DFO, 1997b).

In the following year of 1997, the DFO informed industry that if this price system remained in place in 1997/98, quotas would have to be adjusted downward to offset potential crab mortality caused by highgrading (DFO, 1999b). The objective of most businesses is to maximize profit. A fishing enterprise is no different. In 1997, the two-tiered price system consisted of $0.90 for crab greater than 4" CW and $0.70 for crab less than 4" CW. Just to illustrate, using the above prices, an enterprise with 50,000 lbs to catch could mean the difference of $10,000 in an extreme case. If the enterprise choose to land all 4" crab and discarded legal sized to do so, then it was highgrading.

The Management Plan of 1997 included an increase in the TAC of 15.5% to 41,815 tonnes, up from 36,165 tonnes, for the total quota allocated to all fleet sectors in all areas inside 200 miles. The total quota outside 200 miles was increased to 2,500 tonnes, up from 1,500 (DFO, 1999b). A new management measure was put in place in Division 3L, whereby large supplementary and full-time fleets were restricted in their fishing activity to areas outside approximately 50 miles from land. This meant the small supplementary fleet and those with temporary seasonal permits would have sole access to the snow crab resources inside 50 miles (DFO, 1999b). With the increase in the number of licences issued and quota increases, some measures needed to be put in place to control the pace of the crab fishery. Such measures as staggered season opening dates for different fleet sectors, trip and/or weekly landing limits (i.e. fulltime and offshore supplementary fleets – 35,000 lbs per trip, inshore supplementary fleets – 35,000 lbs per week) and the use of staggered landing weeks was a relatively new measure that was first implemented in 1997 (DFO, 1999b).

The 1997/1998 two-year snow crab Management Plan (DFO, 1997a) included a closure during the month of August to ensure there was minimum mortality of soft-shelled crab. This period was identified as a time with high probability of occurrence of soft-shelled crab. When there is a high occurrence of soft-shell crab there is likely to be a high percentage of dumping at sea, as these animals are not suitable for market purposes. Very few soft-shelled animals that are discarded survive (DFO, 1999b). In 1997, the longest strike in the history of the NL inshore fishery ended in July after fish harvesters ratified a price for crab. The 15-week strike was the third in the crab industry in the past five years ("Noting the news," 1998). As a result of the late start the DFO waived the August closure for that year at the request of both sectors of industry (DFO, 1999b).

In 1998, the TAC was increased to 49,200 tonnes. To reduce the incentive to highgrade, industry agreed to a two-tier price system including a 20% tolerance, whereby an enterprise could be compensated with the highest price for the first 20% of undervalued legal sized crab. As a result, there was evidence that some highgrading did occur in specific areas during the 1998 fishery, but not to the extent estimated in the 1997 fishery (DFO, 1999b). Furthermore for 1998, less than 5% of the crab fishery was fished on a competitive basis. Recommendations for the 1999 season included that the entire crab fishery be conducted on the basis of individual quota (DFO, 1999b). The fishery in 1998 commenced in April, however there were requests from fishers to either delay or waive the closure for soft-shell. For the most part processors did not support any delays. Eventually the August closure was implemented for 1998, however it was delayed by one week (DFO, 1999b).

Quotas were again increased in 1999 to 61,806 tonnes. This included an increase of 18% in fishing areas inside 200 miles. Outside 200 miles the quota increased from 2,500 to 6,000 tonnes. The total catch was 69,100 tonnes, including exploratory areas with no quota attached (DFO, 1999a). The fishing season was scheduled to open on April 14 for all fulltime, supplementary commercial and exploratory fleets. The temporary seasonal fleets were scheduled to start fishing on June 1. An in season closure from August 15 to September 15 to avoid harvesting soft-shell crab was included to prevent handling mortality on those unmarketable crab. The season's closing date was scheduled for November 8 (DFO, 1999a). Other new management measures for 1999 included, redefining fishing areas for the temporary permit holders and increasing observer coverage. Temporary permit holders received exclusive access to inshore snow crab zones. This meant that existing licence holders had to move to areas further from shore (outside 20 miles). Observer coverage was increased to 10% overall (DFO, 1999b). Also, to maintain orderly harvesting and processing throughout the snow crab season, trip and weekly landing limits were put all on fleet sectors except the temporary permit holders (DFO, 1999b).

In April 2000, the crab resource began to show signs of decline and the Minister of Fisheries and Oceans Canada stated " the Scientific analysis has raised a warning flag and we are taking the necessary measures to ensure the future health of the stock" (DFO, 2000a). The Management Plan (DFO, 2000c) stated:

> There will be an overall reduction of 25% (approximately 15,000 t) in harvest level for the snow crab fishery in Divisions 2J3KLNO: 30% reduction in 2J, 30% reduction in 3K and 20% reduction in 3LNO. These reductions will be achieved by reducing the quota fisheries in 2J and 3K by 25% and in 3L by 15% with substantially higher reductions occurring in exploratory fisheries. In addition, there will be no exploratory fishery in Divisions 3LNO outside 200 miles during 2000.

Furthermore, the Stock Status Report (DFO, 2000b) reported that the fall 1999 survey indicates a reduction in residual biomass of commercial sized crab of 45% compared to 1998, continued poor prospects for recruitment and a continuing decline in mature females. This turn of events should not have been a complete surprise to industry, but, nevertheless, it may have been hard to accept given a decade of increasing TACs. Uncertainty with regard to the crab fishery has been highlighted throughout the years in stock status reports, management plans and consultations within industry. Other crab stocks, in the Maritimes and Alaska have shown variability as well over the years (DFO, 2000d).

The declines in commercial biomass may be caused by a combination of factors, such as, environmental warming, bitter crab disease, increased exploitation and mortality from handling and discarding (DFO, 2000d). Since the fishery does not harvest females and small males, the cause of their decline cannot be related to the fishery. However, the causes for this particular decline are attributed to bitter crab disease, environmental warming and cannibalism (DFO, 2000d). During this period, it has been established that highgrading, discarding and poor handling practices have occurred in this fishery and may have had a negative effect on the survival of legal-sized male crabs, particularly soft-shelled crab.

In addition, the 2000 Management Plan (DFO, 2000c) stated other management measures to be implemented. The mid-season closure to address the soft-shell issue was extended to include two months. A study of the possible impact of the shrimp fishery on crab recruitment would be undertaken in conjunction with crab and shrimp fishers. Observer coverage was to be enhanced for all snow crab fleets to provide more scientific information from the fishery and to encourage good fishing practices. Education programs were to be delivered to improve on-board handling of pre-recruits and soft-shelled crab (DFO, 2000d). An education program was initially started in 1998/99. A video was produced entitled "SNOW CRAB, Quality Handling Practices". The program consisted of one-day seminars on snow crab quality. The new education program was to take the quality seminar previously developed a step further to focus on handling mortality of pre-recruits and soft-shell crab (FDP 64, 89 and 330, 2002g).

In the following year, 2001, the TAC for all areas was 54,710 tonnes compared to 53,740 for 2000. A slight increase in quota of 970 tonnes for the overall inshore areas only (DFO, 2001d). The 2001 Management Plan (DFO, 2001a) announced some new measures. Again, in order to address the soft-shell issue, the two-month in season closure for 2000 was replaced by an earlier season, ending August 31. Concerns about the mortality of crab in the turbot gillnet fishery had been brought to the table. Measures where put in place to minimize this mortality of snow crab in turbot gillnets. Research that began in 2000, with regard to shrimp trawling on the crab grounds, continued. Furthermore, the 2001 Stock Status Report (DFO, 2001c) had raised two alarms. The first alarm was that a disease, that is fatal to crabs, has been distributed over Divisions 2J3KL. It was found to be absent in Division 3NO. This disease is known as 'bitter crab' disease (BCD). The disease is probably transmitted during molting and is found in 30-80 mm crabs of both sexes. It is suspected that this disease has contributed significantly to natural mortality. To help prevent the spread of this disease, fishers must be able to identify diseased crab and dispose of them properly by placing them in a leak proof container. They must be brought ashore and taken to a waste disposal site. Also, fishers are asked not to cull their catch while steaming because the discards may include infected crab that will spread the disease from an infected area to an uninfected area (DFO, 2001b). A second alarm was that bottom temperatures have increased since 1995. It has already been noted in this paper how the cold temperatures of the late 80's and early 90's have contributed to the increase in abundance of snow crab. Now, it is a concern how this warm water occurrence will affect larval supply, mortality, catchability, growth of adult crab. Also, according to the 2001 Stock Status Report (DFO, 2001b), male crab under 40 mm have steadily declined during 1995-1999. There is no apparent reason for this, however, other fish eat small crab and cannibalism among crab exists. At the same time, the biomass of mature females have decreased implying that egg production has been reduced, which will ultimately lead to a smaller crab biomass in the future.

In 2002, the TAC was increased from 54,710 t in 2001 to 56,981 t. The inshore quotas increased from 12,000 t to 14,000 t. The fishery was scheduled to close on August 31, 2002 in all areas except Division 2J. With regard to soft-shell, the fishery was monitored as in previous years with areas to be closed as appropriate (DFO, 2002a). Also, a small area, approximately 400 square miles was closed to trawling and gillnetting in

2002, in the Hawke Channel in Division 2J. The purpose of this closure was to study the effect of shrimp trawling on crab stocks (DFO, 2003d).

The TAC for 2003 took a slight reduction of approximately 700 t from 2002. The 2003 Stock Status Report (DFO, 2003c) reported that the status of the snow crab has remained stable with the exception for Division 2J and Subdivision 3Ps. In 2J, south of 54^0 40' N quotas were reduced by 40%, while north of 54^0 40' N quotas remained the same. In 3Ps, the overall quota reduction was 20% (DFO, 2003d). The 2003 Management Plan (DFO, 2003d) contained a new conservation strategy, satellite tracking. All vessels in the supplementary and full-time crab fleets were required to carry a so-called 'black box'. This is a vessel monitoring system (VMS) that allows the DFO to determine the precise course and location of different vessels at all times. The purpose of the VMS is to enhance conservation by the DFO getting more accurate data on fishing activity and location to associated catches. In other words, it made it difficult to cheat, especially on location of area fished. However, this tool did not get enforced for the 2003 fishery. It was made mandatory for the 2004 season. Other new measures from the management plan included in-season closures as required for high incidence of soft-shell crab, additional restrictions on the gillnet turbot fishery in Division 2J and a closing date for the fishery of August 31, 2003. The 2003 Stock Status

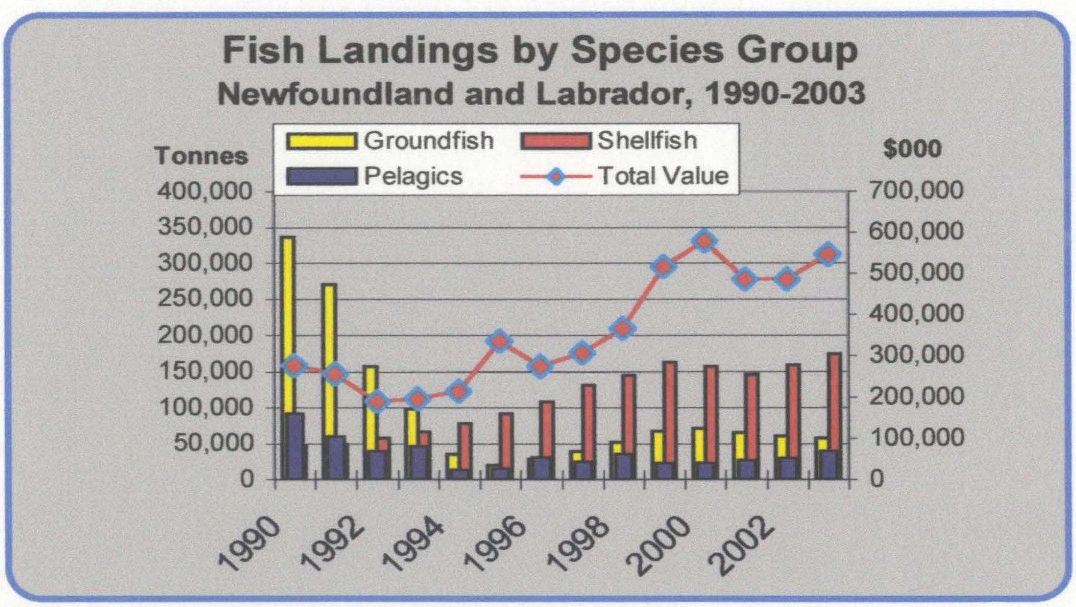
Report (DFO, 2003c) reminded industry that handling mortality on pre-recruits can negatively impact future recruitment. For the current year, 2004, the TAC was reduced 2,700 tonnes, down to 53,571 tonnes. The TAC in Division 2J took an overall decrease of 20%, including a reduction of 40% in the quotas north of 54^0 40' N. Subdivision 3Ps received an overall reduction of 28%, with total closures within the inshore area of Fortune Bay and South Coast (Area 11 E/W) to address continuing declines. Divisions 3KLNO received a slight overall decrease of 500 t resulting from increases and decreases in some inshore areas in 3KL (DFO, 2004d). The 2004 Management Plan (DFO, 2004d) included three new measures other than reductions. The first was to reduce the fishing season by 2 to 6 weeks to avoid encountering soft-shell. The second was to implement soft-shell protocols. When the soft-shell catch rate reaches 20%, the area will be closed, and remain closed for remainder of the year. The third was for the DFO to partner with Department of Fisheries and Aquaculture, Canadian Centre for Fisheries Innovation, the Centre for Sustainable Aquatic resources of the Marine Institute and the fishing industry to develop and test trap modifications that may contribute to a reduction in handling mortality. Furthermore, the 2004 Stock Status Report (DFO, 2004c) showed evidence to support a negative relationship between bottom temperature and Catch per Unit of Effort (CPUE). The warm bottom temperature since 1996 may have led to reduced productivity. Another factor contributing to crab production has been attributed to sea ice cover on the Northeast shelf during the winter and spring. As this sea ice forms and melts it greatly affects the layers within the water column, thereby impacting primary and secondary crab production within the first 50 m of the water column. It has been speculated that these physical, oceanographic processes in addition to nutrient supply and zooplankton production is an important facet in determining snow crab larval survival and reproduction.

Soft-shell has become a hot issue within the crab fishery. Measures have been established to address the problem, if catch rates of soft-shell become to high. This became a reality on July 9, 2004, when the DFO announced they were temporarily closing the crab fishery to full-time and supplementary fleets in fishing zone 3K due to high incidence of soft-shell (Wellman, 2004). As a measure to deal with the problem, Area 4, in Division 3K was divided into grids of 7 x 10 miles to determine areas where soft-shell exceeded the protocol. This strategy would enable the fishers to carry on their fishery and prevent fishing in areas of high soft-shell. Areas where soft-shell catches were low would remain open and those with high catches of soft-shell would close. On July 17, 2004 Area 4, Division 3K reopened (Wellman, 2004). From this experience, emphasis will need to be placed on the soft-shell problem and how to deal with it before next years fishery commences.

The final analysis of the 2004 fishery was not available at the time this report was completed.

4.0 IMPORTANCE TO THE NEWFOUNDLAND AND LABRADOR ECONOMY

The importance of the snow crab fishery to the Newfoundland and Labrador economy has increased dramatically over the years. Since 1992 with the closures of the groundfish, the fishing industry diversified. It went from a groundfish dominated industry to a shellfish dominated industry. See Figure 4.1, page 38. In 1990, the top five species by landed value in Newfoundland and Labrador were cod, shrimp, capelin, flatfish and turbot. See Figure 4.2, page 40. A catalyst to the diversification of the industry has been the exponential growth of shellfish fisheries – in particular crab. For example, in 2003, the top five species by landed value were crab, shrimp, lobster, turbot and cod. See Figure 4.3, page 40. Crab representing the top position. Crab

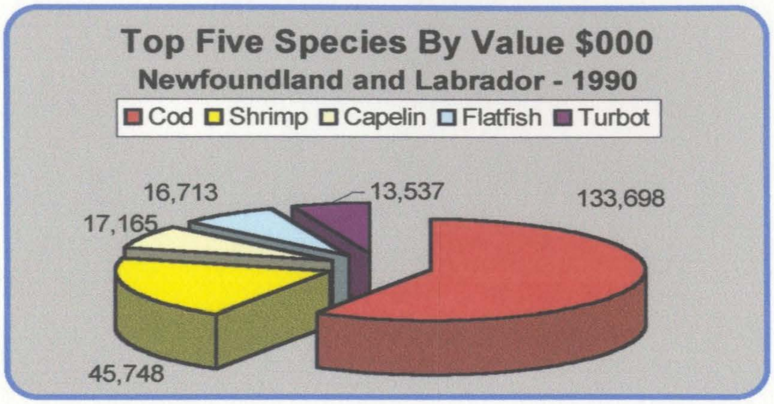


Source: Department of Fisheries and Oceans and Department of Fisheries and Aquaculture

Figure 4.1: Fish Landings by Species Group Newfoundland and Labrador, 1990 – 2003

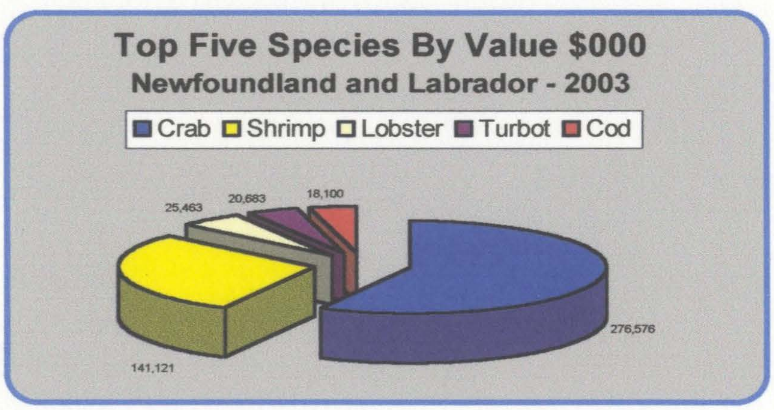
populations have increased dramatically since the collapse of groundfish and market demands have been relatively strong.

Shellfish began to make its mark within the fishing industry in 1992, and by 1994 shellfish became the leading species group. It has remained in that position. In 2003, crab and shrimp were the two most important species in the fishery and accounted for 76.2% of the total landed value. Snow crab represented 50.4% of the total landed value (DFA, 2003). Figure 4.1 demonstrates that even though the high volume years of the Newfoundland and Labrador's fishery ended with the closure of most groundfish stocks, the harvesting sector is much better off in terms of landed value.



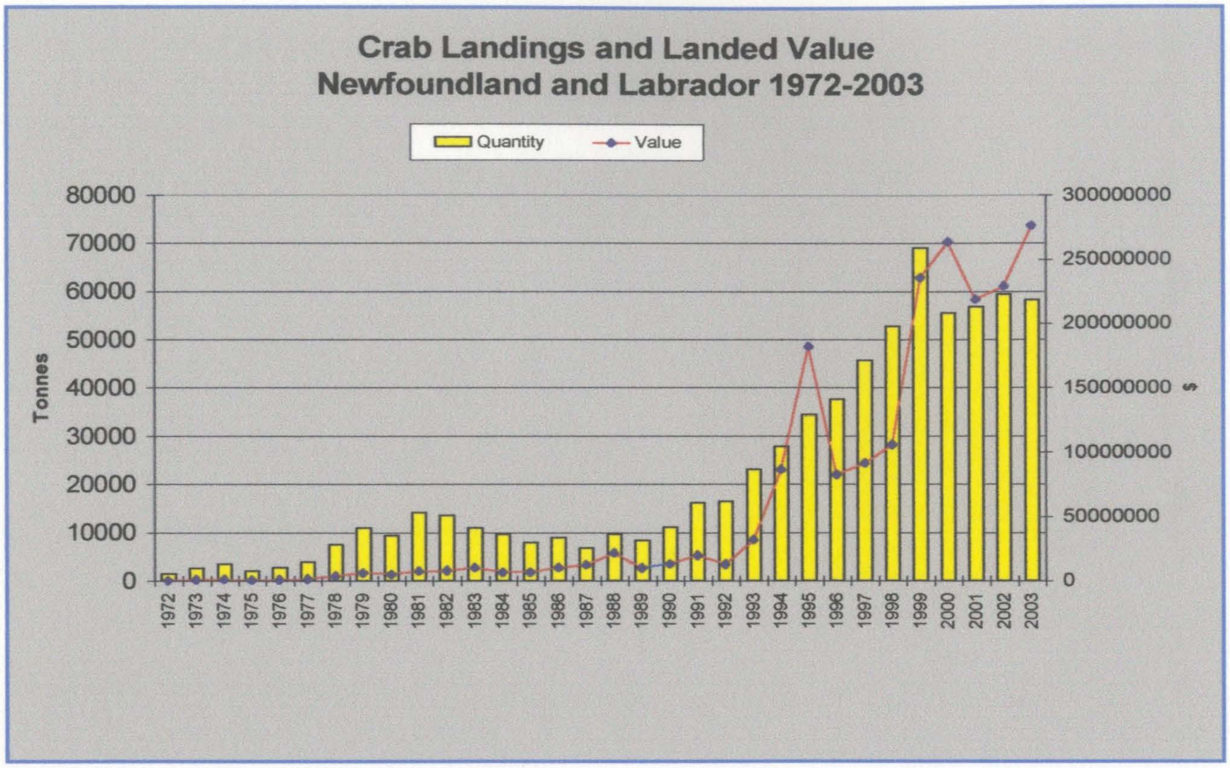
Source: Department of Fisheries and Oceans

Figure 4.2: Top Five Species by Landed Value Newfoundland and Labrador 1990



Source: Department of Fisheries and Aquaculture

Figure 4.3: Top Five Species by Landed Value Newfoundland and Labrador 2003



Source: Department of Fisheries and Oceans and Department of Fisheries and Aquaculture
Figure 4.4: Crab Landings and Landed Value, 1972 - 2003

The snow crab fishery's relative importance stems from an increase in landings, the relatively high prices paid, and the collapse of the groundfish fisheries. Landings in all areas combined were less than 5000 tons for most of the 1970's and subsequently increased to 10,000 tons by the end of the decade. Refer to Figure 4.4, page 41. During the 1979 to 1984 period landings were fairly stable, and averaged approximately 12,000 tons. This period was followed by a gradual decline in landings, and in 1987 fell to a low of 6,700 tonnes. Regular increases in landings occurred subsequently and peaked at 69,100 tonnes in 1999, largely due to expansion of the fishery to offshore areas. In 2000, there was a decrease in landings to 55,500 t, the TAC was reduced due to stock uncertainty. Since 1999 snow crab landings have remained under 60,000 tonnes.

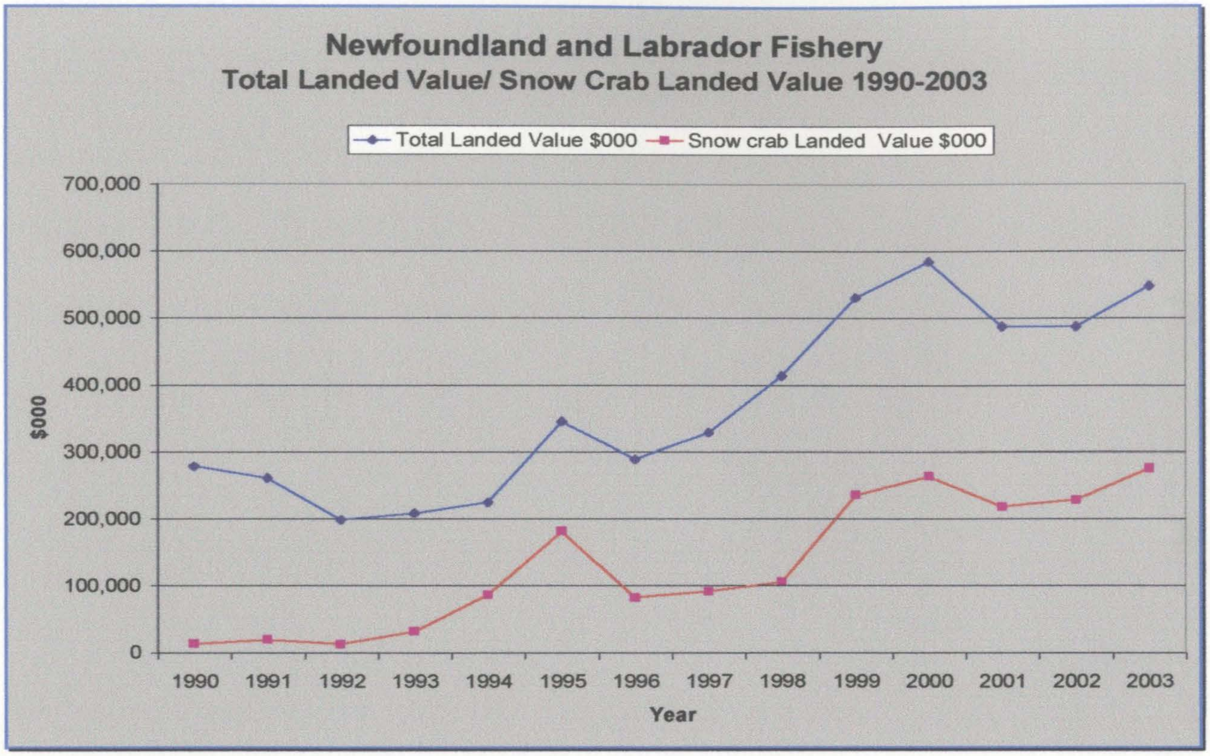
The landed value of snow crab remained under $50 million until 1994. It nearly tripled in 1994 to $87 million from 1993, peaked in 2003 at $277 million, and for the period 1999 – 2003 averaged $245 million (see Table 4.1, page 43). From 1995 to 2003, crab contributed an average of 40.9 percent of the total landed value for the Newfoundland and Labrador fishery compared to the period of 1990 to 1993 when it was 8.75 percent of the total value. In the period 1999 to 2003 the average was 46.5 percent. In 2003, crab represented just over half of the total landed value for the entire industry.

Figure 4.5, page 44, clearly shows the relative importance of snow crab to the NL fishing industry, especially in terms of landed value. Without snow crab Newfoundland and Labrador's fishery would be very small, not only in terms of landed value, but many of the harvesters distributed throughout this province would not be in business. The income generated from the crab fishery permits most enterprises to finance the vessels they use to participate in other fisheries. For example, there are approximately 360 enterprises under 65 feet participating in the shrimp fishery. Without the lucrative revenue from the crab fishery, fishers would not be able to operate those vessels. For the smaller vessels, revenues generated from other small scale fisheries would not be possible. If the spin-off generated from the fishery were taken out of the small communities today, many of those communities would probably not survive.

Table 4.1: Total Landed Value and Snow Crab Landed Value 1990-2003

	Total Landed Value $000	Snow Crab Landed Value $000	Snow Crab as a % of the Total Landed Value
1990	279,474	13,159	5%
1991	261,973	19,902	8%
1992	199,177	13,003	7%
1993	209,112	32,059	15%
1994	225,340	86,771	39%
1995	345,818	182,296	53%
1996	289,759	82,637	29%
1997	328,736	91,794	28%
1998	413,937	106,122	26%
1999	530,539	236,121	45%
2000	584,984	264,000	45%
2001	487,763	219,000	45%
2002	487,800	229,234	47%
2003	548,100	276,576	50%

Source: DFO and DFA Various Reports



Source: Department of Fisheries and Oceans and Department of Fisheries and Aquaculture
Figure 4.5: Total Landed Value/Snow Crab Landed Value 1990 – 2003

4.1 Harvesting Sector

In discussing the importance of the snow crab fishery to the Newfoundland economy, it is important to show the level of employment generated by both sectors of the industry (i.e. harvesting and processing). Employment in both sectors has become very competitive as other employment opportunities have diminished. This pressure was relieved somewhat due to the fact that more crab harvesting licences were issued. The wealth was spread around somewhat as smaller vessels were given an opportunity to obtain a quota (see Table 4.2, page 45).

In 1995, there were 360 permits granted to vessels less than 35 feet. This increased to 1805 permits in 1996, as all vessel owners in this category were given an equal share of the allocated resource for the given area. As well, in 1995 approximately 5,200 individuals (skippers and crew) participated in the harvesting sector of the fishery, compared to 8,000 in 1996 (DFO, 1997a). Both landings and landed value have increased in recent years (see Figure 4.4, page 41), signifying the importance of crab to the harvesting sector and the overall provincial economy.

During 1997 and 1998 approximately 3,300 enterprises with vessels less than 65 feet participated in the snow crab fishery in Newfoundland and Labrador (DFO, 2001a). Table 4.2, page 45, gives a summary of the number of snow crab licence holders for 2004. In 2004, over 3,400 enterprises with

Table 4.2: Number of Snow Crab Licences for 2004.

Area	Inshore	Supplementary		Full-time	4R[1]	4R[2]	4R[3]	4R[4]	4R[5]	Total
		Small	Large							
2J	65	31		4						100
3K	621	240		29						890
3LNO	821	246	79	38						1184
3Ps	725	95		-						820
4R	335			-	47	24	8	3	6	423
Total	2567	612	79	71	47	24	8	3	6	3417

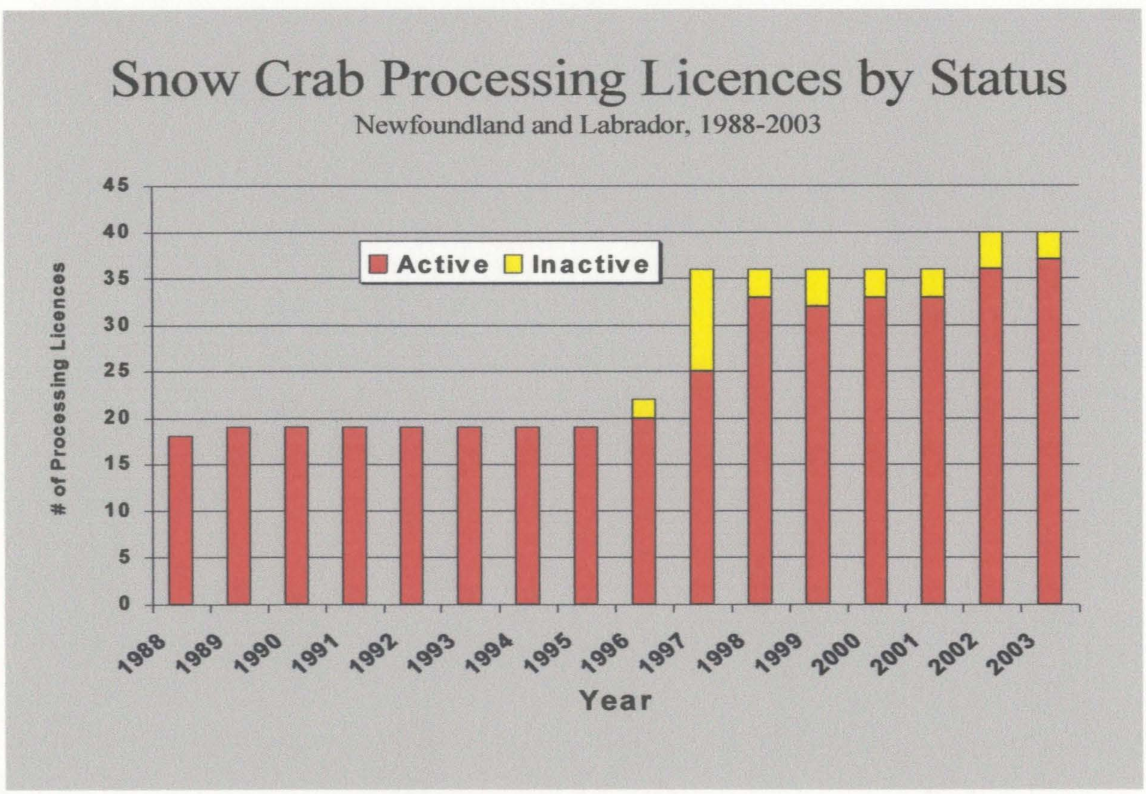
[1]Exploratory Converted
[2]Experimental Converted
[3]Bay of Islands
[4]Outside of 8
[5]Moratorium

Source: Department of Fisheries and Oceans

vessels less than 65 feet participated in the snow crab fishery in NL. At the time, the majority of licence holders were enterprises with vessels less than 35' (inshore). There are approximately 700 supplementary licence holders and 71 full-time licences.

4.2 Processing Sector

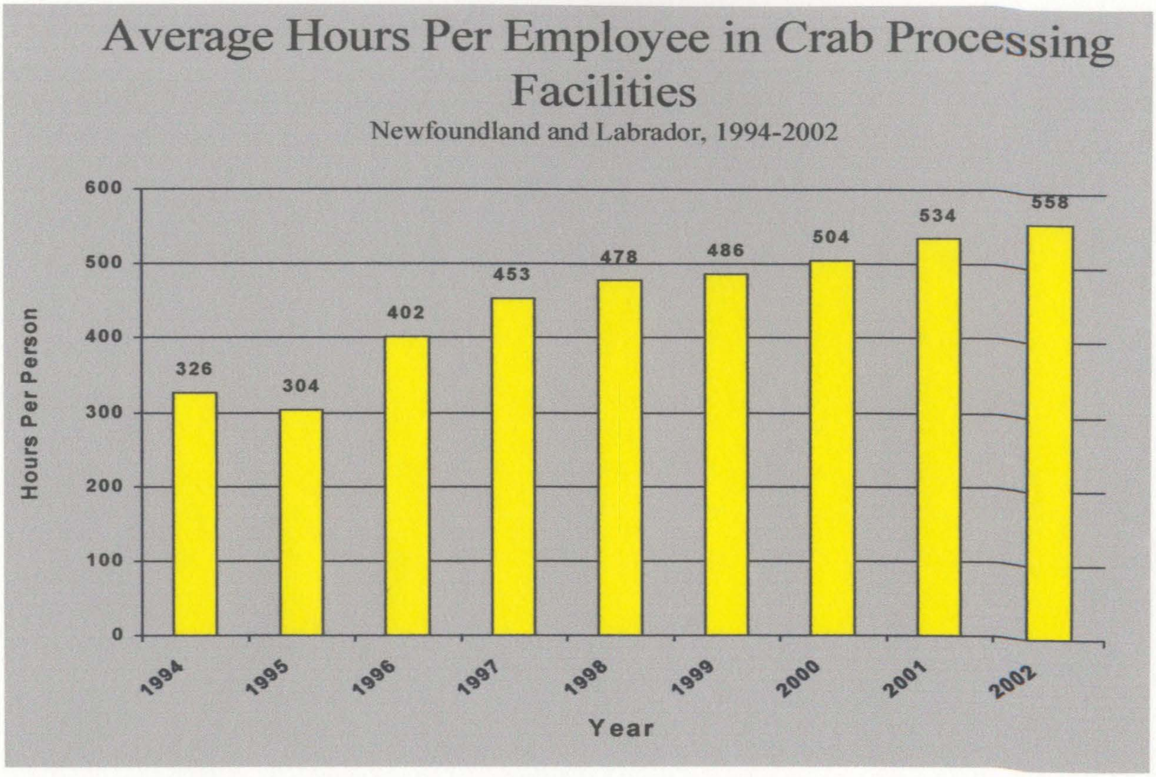
The expansion in the harvesting sector resulted in growth in the processing sector in the period 1994-2004. The number of crab processing licences was increased from 19 in 1995 to 36 in 1997. See Figure 4.6, page 46. The reason for this was two fold. First of all, it



Source: Department of Fisheries and Aquaculture
Figure 4.6: Snow Crab Processing Licences by Status

Source: Department of Fisheries and Aquaculture
Figure 4.7: Newfoundland and Labrador Snow Crab Plants 2003

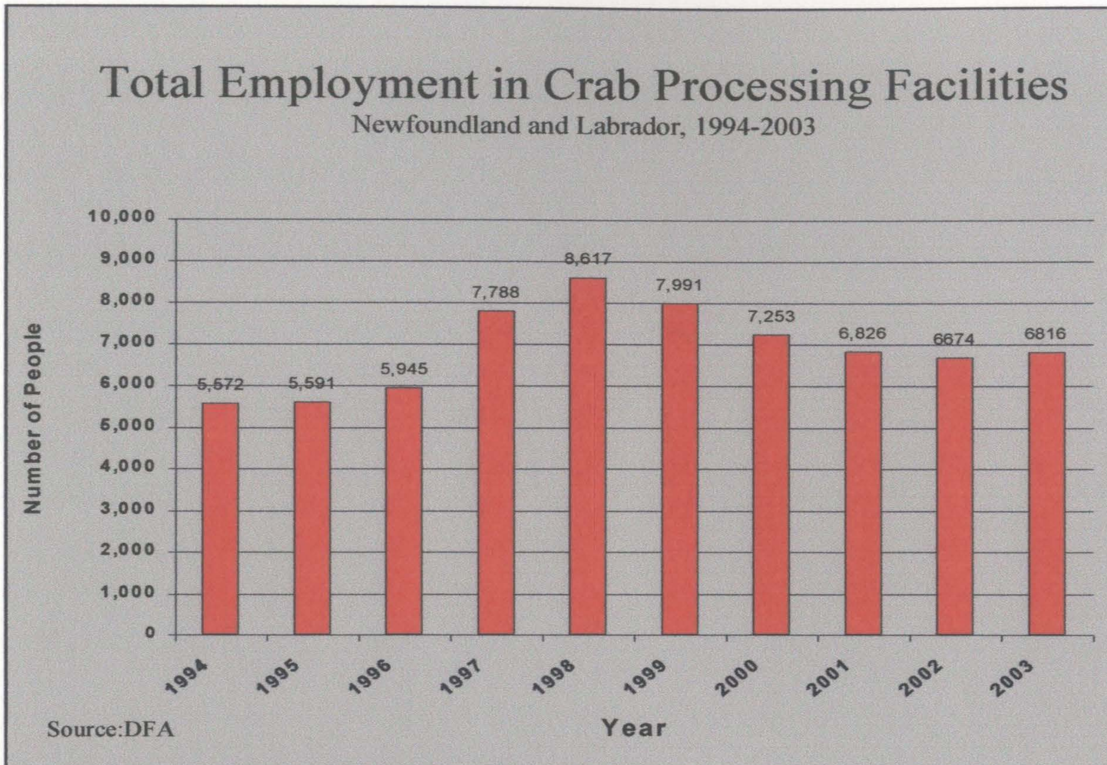
distributed the processing capacity around the province better (see Figure 4.7, page 47), which also enhanced employment. It also reduced transportation time for raw material to reach the plants, which has a positive effect on overall product quality. In 2003, there were 40 licenced snow crab plants, with one licenced being inactive.



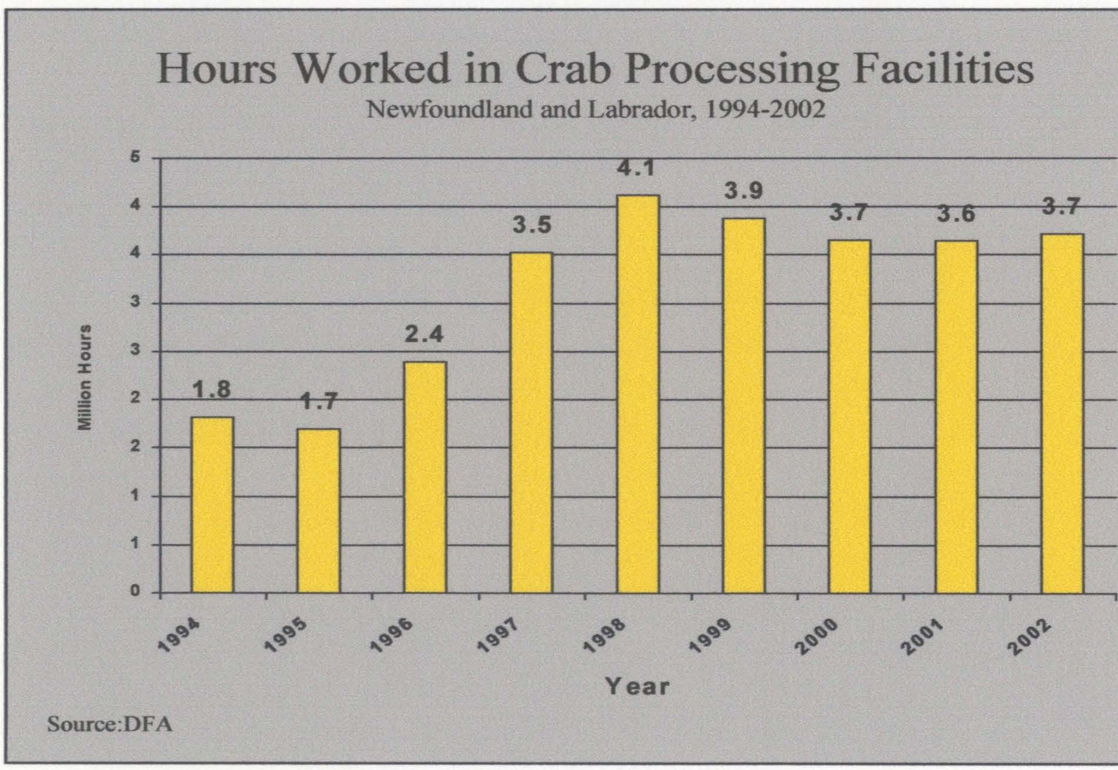
Source: Department of Fisheries and Aquaculture
Figure 4.8: Average Hours Per Employee in Crab Processing 1994-2002

The average hours per employee in crab processing has steadily increased over the years. In 1995 it was 304 hours per employee, in 2002 it was 558 hours per employee. See Figure 4.8, page 48.

Total seasonal employment in the crab processing industry averaged 6772 people in the period 2001-2003. See Figure 4.9, page 49. The market demand is for snow crab sections, the main form of product exported by the processing sector. It is a less labour intensive process than crab meat production. This has downsized the labour force needed in the crab processing industry (Dunne, 2003).



Source: Department of Fisheries and Aquaculture
Figure 4.9: Total Employment in Crab Processing Facilities, 1994-2003



Source: Department of Fisheries and Aquaculture
Figure 4.10: Hours Worked in Crab Processing Facilities, 1994-2002

In 2002, an employee in a crab processing facility averaged 558 hours of work (see Figure 4.8, page 48). A total of 6674 people worked in crab processing facilities in 2002 (see Figure 4.9, page 49). A total of 3.7 million hours was worked in Crab Processing Facilities in 2002 (see Figure 4.10, page 49), compared to 1994 where the total hours of work was 1.8 million.

In 1999, the production value for the Newfoundland and Labrador fishing industry (all species) exceeded $1 billion for the first time in it's history. Since then it has exceeded the $1 billion mark in four of the past five years (1999-2003), and is due primarily to higher market prices paid for crab (DFA, 2004).

In 2000, when the management plan included a 15,000 tonne reduction in quota, it was reported in "The Telegram" that the reduction would mean a loss of more than $100 million in export value to the Newfoundland economy (Barron and Whiffen, 2000) . The importance of this resource to NL economy should not be underestimated.

5.0 FISHING RELATED MORTALITIES

The aim of this chapter is to review the research literature that is available with regard to crab fishing mortalities, determine what has been done, identify what needs to be done within industry to avoid or lessen the impact on the resource, and then determine if any industry policies need to be changed, or if any new policies need to be added in order to accomplish the management objective. The following mortality factors will be discussed: discard mortality, the possible mortality due to shrimp trawling on crab grounds, the bycatch of crab in turbot nets and the ghost fishing of crab pots.

5.1 Snow Crab Discards

The method of harvesting snow crab (i.e. crab pot) is not 100% efficient in terms of legal size snow crab. Therefore, there will be a portion of the catch that must be returned to the ocean. According to Sainte-Marie et al. (1995), pre-recruits (i.e., 70-94 mm CW) are susceptible to being caught in the snow crab fishery for two to three years. This period represents the time it takes for those snow crab to reach commercial size. Studies indicate that discards may represent 5% to 80% of the catch in Newfoundland and Labrador's snow crab fishery, depending on time of the year, molt stage of the crab, age and size structure of the local crab population and previous exploitation history (FDP 2002e). Studies have also shown that snow crab may be caught several times in the same season, which decreases their chances of survival (Taylor et al. 1989; FDP, 2002c). The current methods used for sorting and discarding crab cause mortalities. It is estimated that 30%-100% of discarded crab die, depending upon crab condition, how the crab are handled and the discarding method (FDP, 2002e). This will negatively impact the availability of crab resources in the future (He, 2002). Therefore, it is clear that measures need to be put in place to protect and increase the survivability of released snow crab.

The following hypothetical example illustrates the importance of increasing the survivability of snow crab discards to the industry. In 2003, a total of 58,351 tonnes of marketable crab were caught and sold. The total landed value of this crab was approximately 277 million dollars. If 25% of the total crab caught were discarded, then 19,449 tonnes of crab were discarded in 2003. If 50% of the discarded crab died, 9724 tonnes of crab were destroyed. This represented approximately 46 million dollars worth of crab, based on 2003 prices, lost to the harvesting industry alone, within the next two to three years. This does not take into consideration the reproductive potential of these same crab over the coming years.

He (2002) identified several factors affecting survival of discards. Those included the fishing season, fishing area, air exposure, air temperature, water temperature, water depth and vessel size and construction. What crabs are exposed to from the time they leave the ocean floor, dumped and then sorted on the vessel, discarded back over the side of the vessel, and returned to the ocean floor, can be broken into two distinct environments. One is the ocean environment, the environment that the crab experiences in it's natural habitat, as well as while the pots are being hauled and when the discards are put back into the ocean and return to the ocean floor. The second environment is the one aboard the vessel, when the crabs are out of the water and exposed to sunlight, high temperatures and rough handling.

Exposing crab to different temperatures in a short period of time is a major concern for survivability. It has already been stated that crabs prefer water temperatures of -0.5^0 C to 4.5^0 C. During the winter the deep waters of the Newfoundland and Labrador coast consists of two layers. One is a cold low salinity surface layer at a temperature often below 1^0 C and the other is a layer of warm high salinity bottom water of 1^0 C to 5^0 C. This changes in summer to three layers. The layer at the surface is warm, a cold intermediate layer (CIL) often less than 0^0 C comprises the second, and the third is a warm layer at the bottom of 1^0 C to 5^0 C (He, 2002). Water warms and cools gradually. During the summer, surface temperature on the northeast and east coast of Newfoundland is about 8^0 C to 12^0 C. At the same time on the south coast it is about 12^0 C to 16^0 C. As crab are hauled from the bottom and discarded, they are exposed to different water temperatures as they move up and down the water column. Sometimes there is an abrupt change in temperature through the water column. This may be fatal to a crab.

Another factor connected to the ocean environment is water depth. Crabs are harvested from depths of 100 m to 400 m and when discarded have to return to that same depth. They sustain great pressure changes in this process. There are no studies related to this topic, but it deserves some further consideration (He, 2002).

The size and construction type of the vessel may determine the handling procedures that occur on board. Vessels were not and are not, specifically designed for the crab fishery, since those vessels prosecute other fisheries. Vessels range in size from less than 35 feet to just under 65 feet. Two areas of concern with the vessel are drop heights that crab experience while being handled and whether the sorting area is sheltered or unsheltered. Usually, the drop heights for sorting crab are much greater on larger vessels. With the smaller vessels, there is less of a chance for a sheltered sorting area. On larger vessels crabs are dumped in the hole where sorting takes place. Crab discards are held in the hold in tote pans until a convenient time to discard them, one to two hours is not uncommon. When this occurs they are dumped over the side of the vessel from deck height to water, which can be high enough to cause impact on the survival rate of the crab. For smaller vessels, sorting takes place on deck, where crabs are directly exposed to sunshine and to hot or cold air temperatures, depending on the time of year. Also, while on board the vessel crab discards are exposed to processes that may be damaging and fatal to them. Physical shock, rough handling, extended holding times (air exposure and air temperature), sorting and limb loss, are factors determining the survivability.

Snow crabs are highly susceptible to physical shock. Physical shock to the crab is caused by dropping the crab. This occurs first when the pot is taken aboard. The pot itself is sometimes dropped from the crab hauler to the gunwale of the boat, or to the deck of the boat and sometimes rather abruptly. The legs of some snow crabs are extending out through the meshes, and can get damaged during the process. The pot is shaken to release the crab from the pot and then the crab are dropped to a hard surface, whether on deck or down in the hole of the boat, for sorting. See figures 5.1 to 5.4, pages 56-58, to get an indication of how crab are handled coming on board a vessel. The representation shown in those figures is on board a 35-foot vessel. Drop heights of up to seven feet are recorded for some vessels (FDP, 2002e). When crab are being discarded, another drop height from the deck to the water is encountered. The height of the drop varies with size of the vessel.

Source: Personal Photograph
Figure 5.1: Crab Pot Coming Down from the Hauler

Source: Personal Photograph
Figure 5.2: Taking the Crab Pot to the Dumping Area for Sorting

Source: Personal Photograph
Figure 5.3: Preparing the Crab Pot to Dump it

Source: Personal Photograph
Figure 5.4: Dumping Snow Crab from the Pot to the Sorting Table

A study was conducted by DFO in 1994 to help determine the effect current crab handling procedures have on mortality of undersized/soft shell crab (DFO, 1995). The testing has indicated that mishandling undersized crab, such as dropping and holding them for long periods of time, will result in high mortality rates. Another study in 1998 by Tavel Ltd. and the Marine Institute investigated the affect of 'impact shock' on the liveliness of crab. The experiment illustrated that dropping full boxes of crab will have a detrimental affect on liveliness (Trenholm and Norsworthy 1999). Furthermore, in 2002, an experiment was conducted in a laboratory to determine if drop height would have any effect on the survival of undersized and highgraded crab. The study found that drop height alone has a significant negative effect on those crabs. (Grant et al. 2002; Grant 2003)

Another study conducted in 2002 (FDP, 2002e) investigated how to increase the survivability of crab that is discarded by reducing on-board holding times and physical shock caused by dropping. The project involved work on two different vessel sizes, 34'11" and 64'11". The project designed an on-deck sorting system. This system consisted of a raised sorting table equipped with discard chutes. The purpose of the raised table was to reduce or eliminate drop height of the crab being emptied from the pot. A spiral chute was developed to eliminate dropping crab directly down the hold. This chute delivered crab almost directly to the stowage box down in the hold of the boat without any drop impact. Another chute was developed to reduce the discard dropping distance to the ocean. Both chutes were connected to the raised table. The project showed that there were significant reductions in dropping, and holding times of crab that were to be discarded. Sorting and discarding of crab was quick and gentle. Discards were lively as they entered the water and sank immediately. By reducing the amount of time crabs are out of their natural environment increases the likelihood of survivability. In the current study, there were no mortalities in the control treatments, which suggests in principle that raised sorting tables and discard chutes could substantially reduce the mortality of discarded crab.

Miller (1977) conducted a study to examine undersized hard- and soft-shelled snow crab with respect to what effect would duration of air exposure have on discard mortality. For exposure periods of 3 and 35 minutes it was recorded that hard-shelled crab witnessed mortalities of 11% and 30%, respectively, and for soft-shelled crab mortalities of 20% and 64%, respectively, were recorded.

A more recent and very important study to determine whether height of drop and length of exposure to the air reduces the survival capacity of discarded snow crab was conducted in 2002 (FDP, 2002c). The study dealt with hard-shell crab only. It showed that if crab were handled gentle, and put back in the water within 10 minutes, their survival rate is likely to be close to 100%. However, the study went on further to demonstrate when crab are exposed to the air for as little as 10 minutes and dropped a distance of two feet, four feet or six feet, they are likely to experience mortality rates of up to 10%, 20% and 37%, respectively, after being returned to the water. See Table 5.1, page 61. Another example, when crab are exposed to the air for as little as 60 minutes, and dropped a distance of two feet, four feet or six feet, they are likely to experience mortality rates of up to 29%, 42% and 51%, respectively, after being returned to the water. Mortalities increased with increases in drop height and air exposure.

Table 5.1: **Total mortality as a result of drop distance and air exposure.**

Total Mortality				
	Air Exposure Duration			
Drop Distance	**10 min.**	**30 min.**	**60 min.**	**120 min.**
Two Feet	10%	16%	29%	30%
Four Feet	20%	27%	42%	44%
Six Feet	37%	46%	51%	51%
Source: Fisheries Diversification Program (FDP 433, 2002)				

From this study it is concluded that crab discards should be put back into the water in a quick and gentle manner, preferably under 10 minutes. If this process is not followed then a substantial impact on the availability of crab for the fishery will be seen. This study further supports the importance of the raised table with the discard chute for handling crab (quick and gentle).

Holding time of discards will depend on several factors. For instance, the number in crew, the size of the vessel, the number of pots in a fleet, etc. will determine how long this crab will be laying around out of the water, probably in overloaded tote pans before they are dumped over the side of the vessel. When crab are taken from their natural environment, certain conditions have to prevail for them to survive. They require a temperature of less than 4^0 C and a relative humidity of over 75% to provide moisture to their gills (FDP, 2002e). The air temperature plays a significant role while out of the water. Crab are exposed to colder air in spring (much colder than the environment they came from), warmer air in summer (much warmer than the environment they came from). This variation in temperature can be fatal. Exposure to cold air reduces the crab's vigour and feeding rates (FDP, 2002e). The air causes dehydration. The longer they are on board the vessel the worst this problem becomes and will become fatal for the snow crab (FDP, 2002c). When soft-shelled crabs are out of the water their bodies drain of water and air replaces in this space. When they are discarded they can't sink as quickly, and become more accessible to predators.

By rough handling crabs they can be physically damaged by fracturing the carapace and/or limb loss will occur. This will add stress and weaken the animal. Examples of rough handling would include filling tote pans with discards so full that the next pan rests on the crab in the pan beneath, and dumping them over the side of the boat from tote pans that are a considerable height from the water. Other ways would include grasping multiple crab at a time, or a single crab by the legs, and throwing them over board.

With regard to sorting, where they are sorted and how long before they are discarded back into the ocean are of concern. If the elements, sun and wind, are allowed to play on these crab, the rise or fall in temperature and drying will increase the mortality rate. In some cases crab may be retained on board for more than two hours (FDP, 2002e).

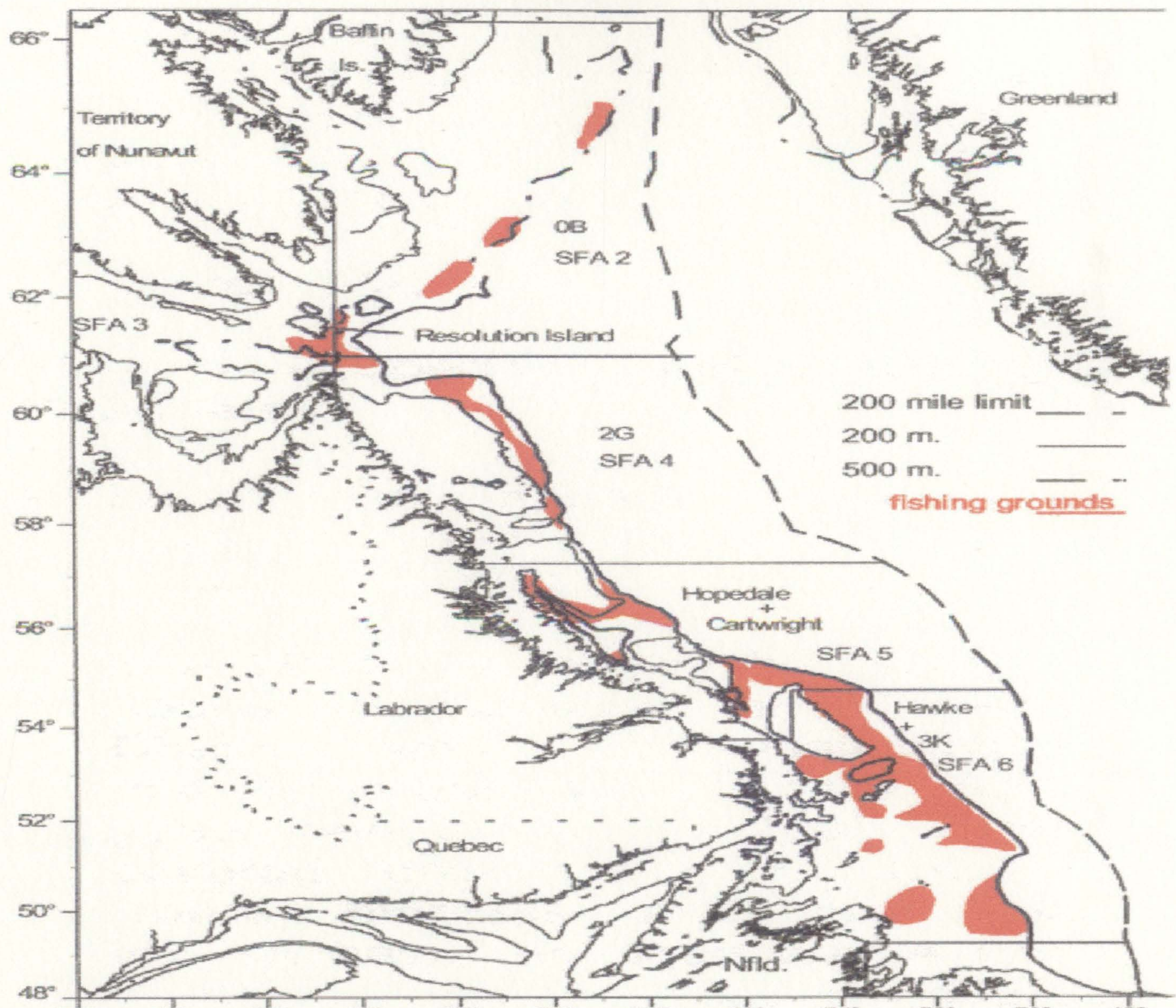
Limb loss from crab, which occurs through rough handling, becomes an important factor to their survivability. Examples would include multiple grasping and rough handling of the pot when crab legs are extending out through the meshes. They release their limbs as a defence mechanism when exposed to stress, extreme cold or shock (FDP, 2002e). With less limbs to defend themselves, they become more vulnerable to predation. Leg loss can also reduce reproductive performance. According to Sainte-Marie et al. (1999), male snow crabs missing more than one walking leg are reproductively less successful than males missing none. It was also shown by Abello et al. (1994) from field and laboratory experiments that for male green crabs the loss of a chelae (crusher or cutter chelae) provides a handicap, in both obtaining and defending a female while mating.

Clearly, research has shown that mortalities will prevail in the handling of discards unless they are handled in a gentle and swift method. It also provides evidence towards the fact that the safest way to protect the survivability of the snow crab is to enhance the harvesting method by leaving more unmarketable crab on the bottom in the first place.

5.2 Shrimp (*Pandalus borealis*) Trawling on the Snow Crab Grounds

The 2000 Crab Management Plan (DFO, 2000d), noted the need to conduct research to assess the impact of shrimp trawling on the crab resource. Fishers involved in the snow crab fishery have been voicing their concern with regard to the high number of crab that are caught with missing or broken legs. It is the opinion of some fishers that this damage is caused by shrimp trawling on the same grounds as where the crab fishery is conducted (FDP, 2002b).

On April 23, 1997, the Minister of Fisheries and Oceans announced increases in the TACs for Shrimp Fishing Areas 2, 5 and 6, and sharing of these increases with new, temporary entrants (DFO, 2003a). See Figure 5.5, page 65. In SFA 6, Hawke Channel plus Division 3K, some 363 temporary inshore shrimp licences have been issued (DFO, 2003a). From 1996 to 2003 the quota increased seven fold. With increasing quotas comes an increase in trawling activity. See Table 5.2, page 66. There is some debate to whether there is a correlation between the increased shrimp activity in this particular area and the damage of missing and broken legs seen by fishers.



Source: Department of Fisheries and Oceans
Figure 5.5: Shrimp Fishing Grounds

Table 5.2: Shrimp TACs – Hawke channel + Division 3K

	Catches	TAC
1987	1800 t	
1988	7800	
1989	5500-8000	
1990	5500-8000	
1991	5500-8000	
1992	5500-8000	
1993	5500-8000	
1994	11000	11,050
1995	11000	11,050
1996	11000	11,050
1997	21,200	23,100 increas. 100%
1998	46,300	46,200 increas. 100%
1999	51,232	58,632 increas. 27%
2000	63,300	61,632 increas. 5%
2001	52,600	61,632
2002	59,931	61,632
2003		77,932 increase 23%

Source: Department of Fisheries and Oceans

There is a regulation that shrimp trawlers be rigged with a sorting grate and 71 cm toggle chains to eliminate most bycatch (including snow crab) from shrimp trawls. This is considered to be effective in reducing the bycatch of crab. However, it is not known whether the footgear bridles and trawl doors that come in contact with the sea bottom pose a potential danger to slow-moving animals such as crab, resulting in either damage to or a decline in the crab resource (FDP, 2002b). Also, for a period when crab are moulting they are immobile and cannot get out of the way of gear that is in contact with the bottom.

To address the concerns voiced by crab fishers, a two-phase study was initiated to assess the condition of crab before and after trawling had taken place (FDP, 2002b). The primary objective of the research study was to determine if shrimp trawling has a negative impact on the snow crab resource by causing injury or mortality. Phase one of the project was undertaken in the fall of 2000 in Division 3K. Phase two commenced on July 6, 2001. Also, Dockside Grading Program Data from 1997 to 2001 was analyzed to confirm or disprove the finding of the two phase research study. (FDP, 2002b). The results suggested that shrimp trawling does not negatively affect the crab resource. However, the report also mentioned that conclusions drawn must be viewed with caution.

At an industry workshop in Gander on Feb. 27-28, 2001 two observations from attending fishers from northern areas were noted. One, based on fishers' reports (not supported by recorded data), indicates that there appears to be more crab with parts missing showing up at plants in NAFO Division 2J. A second was that crab stocks in the north, where most shrimp fishing occurs, appear to be declining faster than those in the south (FDP, 2001).

Being persistent fishers a proposal for a pilot project involving a "no-trawl" zone was received from Division 2J crab fishers in July of 2001. In

February, 2002, a working group concluded there was insufficient rationale to proceed with a closed area as proposed by the 2J crab fleet. The proponent group (fishers) did not accept the conclusions from the working group. In response, DFO committed to conduct work in 2J similar to that conducted in Division 3K. In Division 3K there are areas where shrimp trawling does not take place and crab fishing does. In 2J however, the two fisheries overlap significantly so the only alternative was to create a no-trawling area. In September 2002, the DFO implemented a 'no-trawling/no-gillnetting' study area in 2J to conduct work similar to that conducted in Division 3K. A small area, approximately 400 square miles, was closed to trawling and gillnetting in 2002 to allow an examination of the effects of trawling on crabs stocks. The area was closed to trawling and gillnetting effective September 26, 2002 to facilitate localized research. This area remained closed in 2003. (DFO, 2003a)

The Fisheries Resource Conservation Council (FRCC), in their advice to the Minister in 2003, recommended closing a wider area of the Hawke Channel to all commercial fishing activity with the exception of crab fishing, to protect spawning and juvenlle cod. The 2J snow crab fleets supported this recommendation and felt that this measure would also provide added protection to snow crab stocks (DFO, 2003a). To date this recommendation has not been implemented.

5.3 Snow Crab By-catch in Turbot Gillnets

When snow crabs are caught in gillnets the mortality rate is usually 100 per cent. Snow crabs have to be crushed first into smaller parts to effectively remove them from the gillnet. Crab and turbot distributions overlap throughout much of their range. Both species tend to prefer the soft bottom. For this reason it becomes a problem for harvesting. The landed value for turbot in 2003 was approximately $ 21 million and the landed value for snow crab was $ 277 million (DFA, 2004). It is obvious that the snow crab resource must take preference over the turbot to be protected.

On February 27-28, 2001, a workshop was held in Gander to discuss three important fisheries issues. One of those was snow crab by-catch in turbot gillnets (FDP, 2001). At the workshop, the DFO presented figures illustrating the potential impact of significant crab by-catch in the turbot gillnet fishery:

- Assuming that turbot vessels use, on average, 200 nets per vessel, and that there is a by-catch of one to three crabs per net for each day the nets are in the water (for a total of 30 days per season) – the turbot gillnet fishery could be resulting in the discard of 1000 to 2000 tonnes of crab in one season of fishing.

- This represents a potential loss of crab worth $6.4 million to $19.2 million. (The lower of these two figures equals nearly half the total landed value of turbot in 2000).

From the conference a clear consensus was drawn on several issues. There is a serious problem with snow crab by-catch in the turbot gillnet fishery in water depths less than 350 fathoms, crab by-catch levels must be reduced, and there is very little snow crab by-catch problem at depths greater than 350 fathoms. As a result, an action plan was developed that provided more consistent observer deployment in the turbot gillnet fishery in 2001.

An experimental fishery was conducted in September, 2001, in the Cape Freels area, to assess the effectiveness of a modified gillnet in reducing the by-catch of snow crab in the gillnet turbot fishery, by means of a test fishery using both standard and modified gillnets. The modified turbot gillnets were floated one foot off the bottom to determine whether that would reduce the snow crab by-catch. The snow crab by-catch was reduced dramatically. However, the turbot catch was also reduced, to a degree that the use of such modified nets would not be commercially viable (FDP, 2002f).

The 2003 licence conditions for Greenland Halibut (Turbot) contained the following (DFO, 2003b):

The total area was broken up into three zones:

- Inshore zone – waters outside the Inshore Crab zones and in water depths between 160 and 300 fathoms
- Midshore zone – water depths between 300 and 400 fathoms
- Offshore Zone – water depths deeper than 400 fathoms

Fishing Gear – gillnets

1. In NAFO Divisions 2GHJ3KL, in the inshore zone, the maximum number of gillnets permitted is 125 with a minimum mesh size of 6 inches.
2. In NAFO Divisions 2GHJ3KL, in the midshore zone, the maximum number of gillnets permitted is 200 with a minimum mesh size of 6 inches.
3. In NAFO Divisions 2GHJ3KLMNO, in the offshore zone, the maximum number of gillnets permitted is 500 with a minimum mesh size of 7.5 inches.

Fishing Restrictions:

When fishing in NAFO Divisions 2GHJ3KL, fishing is not permitted in water depths less than 160 fathoms. In NAFO Divisions 3NO, fishing is not permitted in water depths less than 400 fathoms. When fishing in NAFO Division 2J, south of 54 degrees 40' North latitude, fishing is not permitted within 20 miles from land.

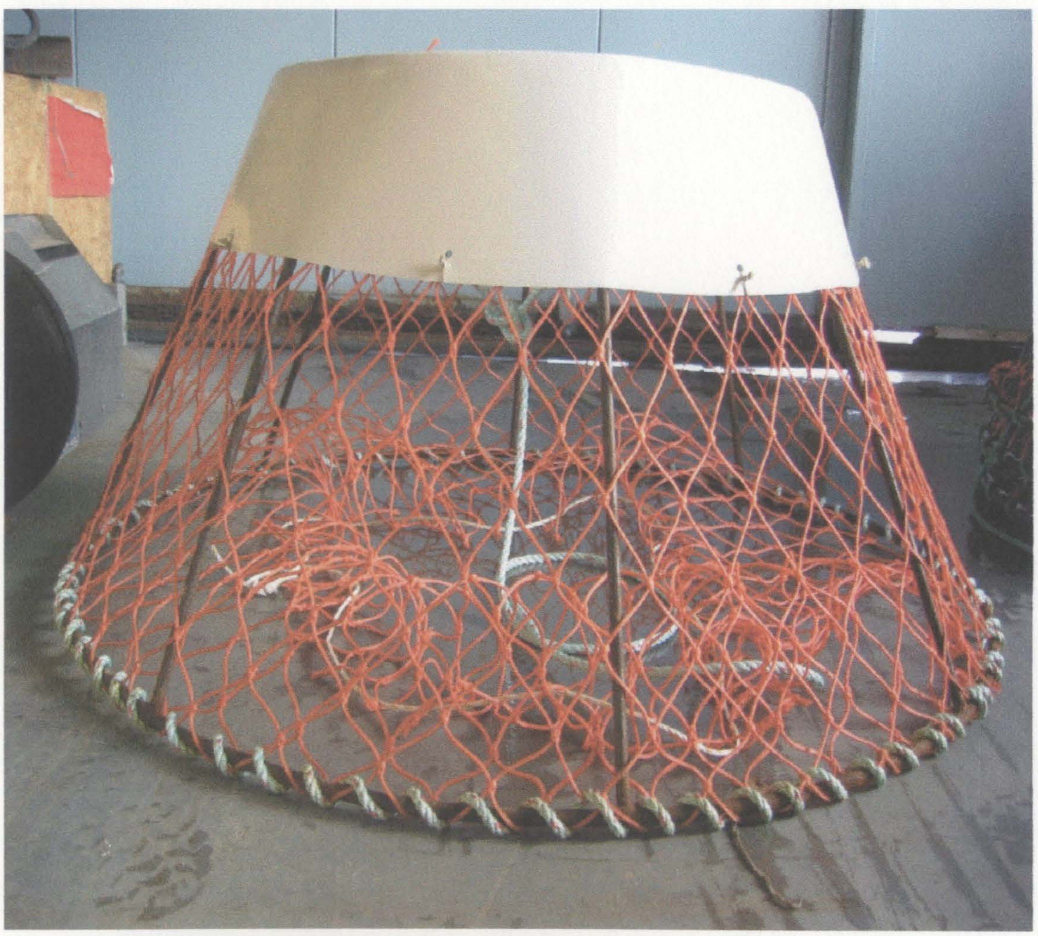
Incidental Catch:

The daily incidental catch of crab shall not exceed 5%.

5.4 Crab Pot - Ghost Fishing

The minimum legal mesh size for the crab pot used in the Newfoundland and Labrador crab fishery is 135 mm. This permits females that enter the pot to escape. This pot, based on its current design, catches undersized and soft-shelled crab. Catch performance and selectivity of snow crab pots are influenced by mesh size, type of bait, soak time, molt stage of crab and population structure (Hebert, 2001). The pot used in the Newfoundland and Labrador fishery needs to be more selective if it is going to catch less undersized crab and avoid soft-shelled crab.

To make the snow crab pot more selective there are at least three things that can be done. One is to increase the mesh size. Sinoda et al. (1987) conducted studies in the Japan Sea and found by increasing the mesh size smaller crab could be protected from the fishery. Some harvesters have voluntarily increased the mesh size on their pots to 140 mm (5.5") and greater to reduce the time spent sorting and culling small crab. Secondly, by attaching vertical plastic panels to the outside top of the pot can reduce the catch of undersized and soft-shelled crab. Figure 5.6, page 73, represents a similar version. Chaisson et al. (1993) used this technique in the Gulf of St. Lawrence and found that the number of undersized and soft-shelled crab caught decreased with the increase in



Source: Personal Photograph
Figure 5.6: Crab pot with plastic selectivity panel

panel height. DFA and Fishery Products International carried out a similar study in Newfoundland in 1997 to test the effects of a 7.5" selectivity barrier on a traditional snow crab pot. The study reported that the catch rate of undersized crab was reduced by 53.8%. Also, the study showed a reduction in the number of small crab between 3.75" and 4" (Hearn and Foster 1998). This demonstrates that the size selectivity of the snow crab pot can be significantly improved with a simple modification. Another study conducted by Hebert (2001) found that adding the plastic panel made the pot catch significantly less soft-shelled crab and sub-legal crabs than normal conical pots, while maintaining the same catch rate of commercial crabs. A more recent experiment in 2002 also showed that the experimental trap barriers do reduce the number of sub-legal male crabs entering the pots (FDP, 2002a). Third, it is suggested through anecdotal evidence that increasing the length of soak time on pots can reduce the catch rate of smaller crabs.

Another fishing related mortality that exists but does not seem to gather much attention in the NL crab fishery is the fact of ghost fishing by lost crab pots. There is no recorded data with regard to the number of crab pots lost in the Newfoundland and Labrador snow crab fishery. Studies have shown that lost pots will continue to fish. Results from Hebert's (2001) ghost fishing experiment demonstrated that lost snow crab pots continued to catch snow crab. The pots would reach their saturation level, then slowly decrease by cannibalism and predation. The catches would increase again to their saturation level. This type of scenario infers a ghost fishing cycle. Ghost fishing by pots will continue until pots are destroyed to the point where all captured crabs can escape. This emphasizes the need for escape mechanisms to avoid unnecessary mortality of crabs. In the southwestern Gulf of St. Lawrence a biodegradeable escape mechanism became mandatory in 1994, to avoid the unnecessary loss of snow crab by ghost fishing (Hebert 2001).

To reduce mortality among undersized and soft-shelled crab the most practical thing to do is to avoid harvesting them altogether. The introduction of a new trap, or modified conventional trap, in order to avoid soft-shelled and undersized crabs in catches may be a good conservation strategy for the snow crab industry. It was strongly recommended from the FDP 433 (FDP, 2002c) report to investigate harvesting strategies and gear selectivity devices that avoid catching undersized and soft-shelled snow crab.

6.0 CONCLUSIONS

The snow crab fishery of NL has been deemed the backbone of the fishing industry. The dependence on the resource today is unlike anything else that has been seen in the fishery of NL ever before. The past years have seen production values for the fishery exceed $1 billion. Over 50% of the total landed value for the NL fishery is from snow crab. The future health of the entire fishery is at stake and for the most part, either directly or indirectly depends on what will happen within the crab fishery. DFO managers, harvesters, and processors have a role to play in maintaining this resource so that Newfoundland and Labrador can maximize the benefits provided by this resource.

This paper has identified what affects crab in its natural environment. Crab prefer cold water, the colder temperatures during the late 80's and early 90's had led to exponential growth of this resource. Since the mid 90's the water temperature of the ocean has been warming, and this is not considered good for the reproductivity of snow crab. Bitter crab disease (BCD) has been identified and it is known that this disease is a contributing factor to the mortality of crab, yet it is not known to what extent it is impacting populations. Fishers must be able to identify diseased crab, dispose of them properly and not cull their catch while steaming. Cannibalism is another factor contributing to the mortality of crab and again, the known extent is undetermined. Predation, another mortality factor, is taking place in the habitat of the snow crab and once more, to what degree it is unknown. If groundfish, especially cod, a natural predator of small snow crab, is on the increase then it is expected that predation mortality is on the rise. All of the above factors are nature related and are uncontrollable by man. From an industry perspective, it can only hope that nature will be kind and treat this resource fairly.

This paper also identifies fishing related mortalities as factors affecting the sustainability of the resource. Those are man made and are controllable by the industry. Among the fishing related mortalities, the handling of discards is probably determined the most problematic for this industry, since this problem exists wherever the snow crab fishery is taking place. The ideal solution would be to have a pot that only takes marketable crab from the bottom. Undersized, females and soft-shelled crab would then remain in its habitat undisturbed. At this point in time the ideal pot for harvesting does not exist. However, knowing the consequences of poor handling practices on crab discards, the pot must be made more selective. Research by industry, DFO, DFA and Marine Institute have already identified ways to make the pot more selective.

To address the undersize crab issue, a number of steps may be possible. These include increasing the minimum mesh size, some fishers are already doing it to save time on sorting smaller crab from the catch. Mandatory soak times on gear, for at least 48 hours should be regulated. Although many harvesters already fish this way by choice, for others it may be difficult to police. But in some cases through the use of logbooks, extra observers and education, the measure may get implemented on a volunteer basis. For female crabs, which is not usually a problem due to the size of the mesh, an increase in soak time would prove to be beneficial. Pots can be made more selective by adding plastic barriers to the top edge of the pot. This has been proved to reduce the amount of undersized and soft-shelled crab from entering the pots. The gentle and swift method of discarding crab that was discussed earlier in this paper with the use of a sorting table on deck should be regulated, made mandatory and subject to inspection. Education has to be made a key factor. To maximize the benefits that can be attained from education, everyone should get the same message. This can be accomplished by requiring all licence holders to attend workshops. This could be made effective if the DFO had the mandate to make it a condition of licencing, that each licence holder must attend a workshop before the licence is granted. However, the only recourse is that the Professional/Certification Board make it a precondition of their certification.

To address the problem of highgrading, pot selectivity would no doubt play a significant role. But in the meantime industry has to come together on this issue. They have to increase the 20% tolerance that now exists for paying the top price for standard crab (crab under 4") or even better do away with it altogether and have one price for all legal size crab. The price of crab to the harvester may drop, but industry has to consider the impacts of the alternative, on the resource and the fishery. Again, education has to play a role. It has to be stressed that highgrading is having a negative impact on this industry, especially when the crabs being highgraded are discarded improperly. A further increase in observer coverage will provide a deterrence to highgrading.

The soft-shell discard issue is becoming very problematic. Soft-shell is occurring earlier in many areas and in greater abundance. Harvesting of soft shell crab has to be avoided because those animals are very susceptible to mortality. It has been proposed that an earlier start date for the fishery would help somewhat. The problem here is that industry lags in the spring on price negotiations, delaying the start. A timely price settlement is a key to get the industry off to an early start. Increase observer coverage to determine actual soft-shell catch rates would give resource managers information to act more diligently on the problem. Laying the management area out into grid sections and closing the grid section when catch rates exceed the soft-shell protocol would protect the animals and save the fishery at the same time. This has been done in this past year's fishery for NAFO Division 3K area. More discussion is needed with industry to have a protocol in place for the upcoming season that protects the soft-shell animal first and foremost and offers the harvester an alternative for him/her to still be able to harvest their quota. The length of the fishing season will have to be reviewed. Either lengthen the fishing season, so that when soft-shell occurs harvesters are not in a panic to catch their quota, sorting through massive amounts of soft-shell before the fishery closes. Or close the fishery when soft-shell occurs early in the season, to be reopened again after the soft-shell period, two to three months later (a fall fishery always occurred only until recent years). For the processing industry a consistent flow of raw material to the plants from start to finish would mean efficient operations cutting operating costs to a minimum. Profits gained by processing companies with a short crab season may not outweigh the price that may have to be paid by society when this resource declines. In addition, past studies have indicated that plastic panels on top of the pot have reduced the capture of undersized and soft-shell crab. Again, education has to play a key component. The how, why and significance of protecting the soft-shell crab must be reinforced again and again.

The harvesting method of trawling for shrimp is a very contentious issue throughout the world. The damage this type of gear inflicts on the resources and the habitat where the resource is found is quite controversial. Recent experiments of shrimp trawling completed in NL have revealed that no significant damage is done to the crab stock. This research was conducted on a limited basis, therefore more industry sponsored research is needed to assess damage. In the meantime, identifying separate zones for trawling is one way to protect the crab from this technology and over several years a comparison could be made between the trawling zone and the no trawl zone to determine if any difference occurs to the catch rate of crabs. Caution is highly recommended since the evidence that industry has on this issue is limited.

The turbot fishery is only one thirteenth of the snow crab fishery in terms of landed value. Nearly all the fishing enterprises in NL range from some to total dependence on the snow crab fishery (approximately 3400 licences). It has already been stated that the snow crab fishery is the new backbone of the fishing industry. Therefore, with regard to the bycatch of crab in turbot gillnets, maintaining the status quo is identified. Allow fishing with gillnets in deep water only, where crab are not so prevalent.

With regard to ghost fishing, escape mechanisms with biodegradable twine should be made mandatory. In the southwestern Gulf of St. Lawrence fishery, this has been a requirement since 1994. Some sort of mandatory reporting of lost gear should be put in place so that managers can get an idea of how much gear is being lost. It may be difficult to enforce, unless some deterrent measure is added, such as, random drags for crab pots at the end of the season. Sanctions against the harvester should be put in place if gear is found and the licence holder did not report it lost.

This paper has also identified the need for more research. Scientists, in consultation with fishers, need to develop a research program that will include information beneficial to the industry. Industry should bear the cost of the research. Since cost is always a factor, industry can contribute tremendously by contributing time. The exorbitant cost associated with hiring vessels and crews are already covered while fishing for their quota. This will give industry more ownership and demand higher expectations from the work being carried out. Also, increase observer coverage and train observers extensively to monitor and to collect data that scientists and fishers need to make their predictions.

No one within the industry is prepared to repeat the conditions of the groundfish closures. This may be inevitable regardless of what management measures are implemented. However, a very important lesson should have been learned with the closure of the groundfish and the times of hardship associated with the moratorium. This should be avoided from happening again, if industry knowingly can avoid it. The snow crab fishery is a renewable resource and it is man's duty to protect the reproductive potential of this resource for future generations to come.

One of the most disturbing findings of this report is that improvements through past experiments have been discovered but not implemented. For example, escape mechanisms in pots in the southwestern Gulf of St. Lawrence in 1994 (Herbert 2001), barriers on pots to reduce undersize and soft-shell crab in 1993 (Chaisson et al. 1993; Hearn and Foster, 1998), increasing the mesh size in 1987 (Sinoda et al. 1987), and sorting tables in 2002 (FDP, 2002a), but none of those were implemented. If they were adapted in the commercial industry, they may have lead to other discoveries that would curtail waste and/or lead to further improvements. Other measures have been put in place to curtail cheating, such as, dockside monitoring, observers, VMS, etc., but nothing new has been implemented to the actual harvesting method. Valuable research has been wasted that could be benefiting industry if implemented.

Education, from a scientific perspective, combined with the harvester's experience from fishing will provide a more knowledgeable group of individuals. This will enable them to be more forceful when it comes to managing the resource for the long-term benefit of the user. As a result, industry may be quicker to respond on a more positive basis. The speed to which decisions are made are sometimes as critical as the decision itself. Education has to make the resource users take ownership of the resource and by doing so, the users are more likely to protect it when they consider it their own. The common property mentality has to change to maximize effectiveness and efficiency of the resource.

7.0 REFERENCES

Abello, P., Warman, C.G., Reid, D.G., Naylor, E., (1994). Chela loss in the Shore crab (Carcinus maenas Crustacea: Brachyura) and its effect on mating success. Mar. Biol. 121, 247-252.

Barron, T., G. Whiffen. (2000). Crab quota cut by 25 per cent. The Telegram. 1-2.

Blanchard, T. (2004). Personal Interview – October 30. Staff Officer, Shellfish. Department of Fisheries and Oceans.

Brothers, G. and W. Barney. (1986). Exploratory Surveys for Snow Crab in Newfoundland and Labrador 1968 – 1985. Department of Fisheries and Oceans, Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1887.

Chiasson, Y. J., Vienneau, P. DeGrace, Campbell, R., Hebert, M., and Moriyasu, M. (1993). Evaluation of catch selectivity of modified snow crab Chionoecetes opilio conical traps. Can. Tech. Rep. Fish. Aquat. Sci. 1930: 21 p.

Dawe, E.G., H. J. Drew and R. T. Warren (2001). Trends in prevalence of Bitter Crab Disease (Hematodinium spp.) in snow crab (Chionecetes opilio) at Newfoundland and Labrador. CSAS Res. Doc. 2001/086, 13 p.

Department of Fisheries and Aquaculture. (2004). 2003 Seafood Industry Year In Review.

Department of Fisheries and Oceans. (1985). Atlantic Fishing Regulations, 1985, Section 54 (2)(b) and 54 (3) (a) and (b).

Department of Fisheries and Oceans. (1990). Underwaterworld: The Atlantic Snow Crab. Communications Directorate.

Department of Fisheries and Oceans. (1995). Undersized crab survivability project. Project Summary, I.D.D. #3. Industry Development Division of the Department of Fisheries and Oceans, St. John's, Newfoundland. 4 p.

Department of Fisheries and Oceans. (1996). 1996 Snow Crab Management Plan. Fisheries Management Branch.

Department of Fisheries and Oceans. (1997a). 1997/1998 Multi-Year Snow Crab Integrated Management Plan – Newfoundland Region. Fisheries Management Branch. pp. 1-19.

Department of Fisheries and Oceans. (1997b). 1997-1998 Snow Crab Management Plan. Backgrounder, B-HQ-97-21E. Retrieved February 10, 1999, from the World Wide Web: http://www.ncr.dfo.ca/communic/backgrou/1997/hq21e.htm

Department of Fisheries and Oceans. (1999a). DFO Announces Three-year Crab Management Plan Total Quota over 61,000 tonnes for 1999. News Release, NR-N-99-06. Retrieved October 10, 1999, from the World Wide Web:http://www.ncr.dfo.ca/regions/newfound/NewsRel/1999/nfld06_e.htm

Department of Fisheries and Oceans. (1999b). 1999-2001 Snow Crab Management Plan. Fisheries Management Branch.

Department of Fisheries and Oceans. (2000a). Dhaliwal Announces Reductions In Harvest Levels For Newfoundland Snow Crab. News Release, NR-HQ-00-15.Retrieved April 13, 2000, from the World Wide Web: http://www.dfo-mpo.gc.ca/COMMUNIC/NEWSREL/2000/hq15_e.htm

Department of Fisheries and Oceans. (2000b). Newfoundland and Labrador snow crab. DFO Science Stock Status Report C2-01 (2000).

Department of Fisheries and Oceans. (2000c). Newfoundland Snow Crab Management. Backgrounder, B-HQ-00-15(131). Retrieved November 27, 2001, from the World Wide Web:http://www.ncr.dfo.ca/COMMUNIC/BACKGROU/2000/hq15(131)_e.htm

Department of Fisheries and Oceans. (2000d). Newfoundland Snow Crab Management. Backgrounder, B-HQ-00-15(131). Retrieved January 8, 2003, from the World Wide Web: http://www.ncr.dfo.ca/media/backgrou/2000/hq-ac15(131)_e.htm

Department of Fisheries and Oceans. (2000e). Newfoundland Snow Crab Science. Backgrounder, B-HQ-00-15(132). Retrieved July 01, 2003, from the World Wide Web: http://www.dfo-mpo.gc.ca/media/backgrou/2000/hq-ac15(132)_e.htm

Department of Fisheries and Oceans. (2001a). DFO announces 2001 management measures for Supplementary and full-time snow crab fleets. News Release, NR-N-01-05. Retrieved November 11, 2001, from World Wide Web: http://www.nfl.dfo-mpo.gc.ca/media/release/2001/NR-N-01-05_E.htm

Department of Fisheries and Oceans. (2001b). DFO Correspondence to NL Snow Crab Fishers.

Department of Fisheries and Oceans. (2001c). Newfoundland and Labrador snow crab. DFO Science Stock Status Report C2-01 (2001).

Department of Fisheries and Oceans. (2001d). Small Increase in 2001 Harvest Levels for Inshore Snow Crab.News Release, N-NR-06-01. Retrieved May 15, 2001, from the World Wide Web: http://www.nfl.dfo-mpo.gc.ca/media/release/2001/NR-N-06-01.htm

Department of Fisheries and Oceans. (2002a). DFO announces 2002 management measures for snow crab fishery. News Release, NR-N-02-09. Retrieved May 09, 2002, from the World Wide Web: http://www.nfl.dfo-mpo.gc.ca/media/release/2002/NR-N-02-09_E.htm

Department of Fisheries and Oceans. (2002b). Newfoundland and Labrador snow crab. DFO Science Stock Status Report C2-01 (2002).

Department of Fisheries and Oceans. (2003a). Integrated Fisheries Management Plan: Northern Shrimp Northeast Newfoundland, Labrador Coast and Davis Strait. Retrieved September 10, 2004, from http://www.dfo-mpo.gc.ca/communic/fish_man/ifmpns-pgipcn/index_e.htm

Department of Fisheries and Oceans. (2003b). 2003 Groundfish Licence Conditions Newfoundland and Labrador Region.

Department of Fisheries and Oceans. (2003c). Newfoundland and Labrador snow crab. DFO Science Stock Status Report 2003/021.

Department of Fisheries and Oceans. (2003d). Newfoundland & Labrador Snow Crab Management 2003 – 2005. Backgrounder. Retrieved April 24, 2003, from the World Wide Web:http://www.nfl.dfo mpo.gc.ca/publications/backgrounders_fichesBGNL0302.asp

Department of Fisheries and Oceans. (2004a). Newfoundland and Labrador snow crab. DFO Science Stock Status Report C2-01 (2004).

Department of Fisheries and Oceans. (2004b). 2004 Newfoundland and Labrador Snow Crab Management. Backgrounder, BG-NL-04-03. Retrieved April 22, 2004, from the World Wide Web: http://www.nfl.dfo-mpo.gc.ca/publications/backgrounders_fichesBGNL0404.asp

Department of Fisheries and Oceans. (n.d.). Snow crab by Francois Plante. Retrieved April 12, 2002, from the World Wide Web: http://www.glf.dfo-mpo.gc.ca/sci/crab-crab/bio-bio-e.html

Dunne, E. (2003). Fish Processing Policy Review.

Fisheries Diversification Program. (2001). Gear and By-catch Concerns: Interactions in the Turbot, Crab and Shrimp Fisheries in 2J3KL. Environmental Awareness and Conservation Technology Component, Department of Fisheries and Oceans, St. John's, Newfoundland. Project Report: EACT-4.2001.DFO (FDP 334). 4 p.

Fisheries Diversification Program. (2002a). Experiments on Trap Modification Toward Reducing Discarding in the Newfoundland and Labrador Snow Crab Fishery. Fisheries Diversification Program, Environmental Awareness and Conservation Technology Component, Department of Fisheries and Oceans, St. John's, Newfoundland. Project Report: FDP Project No. 390. 4 p.

Fisheries Diversification Program. (2002b). Interaction between shrimp trawling and the snow crab resource. Fisheries Diversification Program, Environmental Awareness and Conservation Technology Component, Department of Fisheries and Oceans, St. John's, Newfoundland. Project Report: EACT-15.2002.DFO (FDP 281). 6 p.

Fisheries Diversification Program. (2002c). Mortality of Snow Crab Discards: At-sea Experiments on the Effect of Dropping and Air Exposure. Fisheries Diversification Program, Environmental Awareness and Conservation Technology Component, Department of Fisheries and Oceans, St. John's, Newfoundland. Project Report: EACT-21.2002.DFO (FDP 433). 9 p.

Fisheries Diversification Program. (2002d). Onboard handling and discard systems for snow crab vessels. Fisheries Diversification Program, Environmental Awareness and Conservation Technology Component, Department of Fisheries and Oceans, St. John's, Newfoundland. Project Report: EACT-3.2002.DFO (FDP 283). 8 p.

Fisheries Diversification Program. (2002e). Onboard handling of snow crab to optimize the survival of discards:Today's crab discards are tomorrow's harvest. Fisheries Diversification Program, Environmental Awareness and Conservation Technology Component, Department of Fisheries and Oceans, St. John's, Newfoundland. Project Report: FDP Project No. 283. 12 p.

Fisheries Diversification Program. (2002f). Reducing Snow Crab By-catch in Turbot Gillnets. Fisheries Diversification Program, Environmental Awareness and Conservation Technology Component, Department of Fisheries and Oceans, St. John's, Newfoundland. Project Report: EACT-10.2002.DFO (FDP 299). 4 p.

Fisheries Diversification Program. (2002g). Snow Crab Quality Initiatives. Fisheries Diversification Program, Environmental Awareness and Conservation Technology Component, Department of Fisheries and Aquaculture, St. John's, Newfoundland. Project Report: FDP Project No. 64, 89 &330. 4 p.

Grant, S. M., Keats, C., and Blackwood, G. (2002). Survivability of snow Crab discarded from the pot fishery: experimental cage design and preliminary drop experiments. A report submitted to the Canadian Centre for Fisheries Innovation and the Fisheries Diversification Program, Environmental Awareness and Conservation Technology Component, Department of Fisheries and Oceans, St. John's, Newfoundland. 25 p. + App.

Grant, S. M., (2003). Mortality of snow crab discarded in Newfoundland and Labrador's trap fishery: At-sea experiments on the effect of drop height and air exposure duration. Can. Tech. Rep. Fish. Aquat. Sci. #2481: vi + 28 p.

He, P. (2002). Survivability of Snow Crabs Discarded from the Pot Fishery: Protocol for Conducting Experiments at Sea. Fisheries Diversification Program, Environmental Awareness and Conservation Technology Component, Department of Fisheries and Oceans, St. John's, Newfoundland. Project Report: EACT-1.2002.DFO (FDP 307). 17 p.

Hearn, D., and Foster, D. (1998). Snow crab selectivity experiment F.V. Eastern Challanger, October – November 1997. Government of Newfoundland and Labrador Department of Fisheries and Aquaculture Fisheries Development Division. 18 p. + App.

Hebert, M., Miron, G., Moriyasu, M., Vienneau, R., DeGrace, P., (2001). Efficiency and ghost fishing of snow crab (Chionoecetes opilio) traps in the Gulf of St. Lawrence. Fisheries Research 52 (2001) 143-153.

McLeod, D. (1969, April). Hant's Harbour Crab Industry: experiment yielded bonanzas. The Daily News. P. 5.

Miller, R.J. (1977). Resource underutilization in a spider crab industry. Fisheries 2: 9-13.

Noting the news of 1997: History – making crab strike. (1998, Winter). The Union Advocate. Vol. 5. No. 2. 34.

Offshore/Inshore Fisheries development & Technologies: Species – Atlantic Snow Crab. Retrieved April 12, 2002, from the World Wide Web: http://www.mi.mun.ca/mi-net/fishdeve/crab.htm

Sainte-Marie, B, Raymond, S., and Brethes, J. C. (1995). Growth and maturation of the benthic stages of male snow crab, Chionoecetes opilio (Brachyura: Majidae). Can. J. Fish. Aquat. Sci. 52: 903-924.

Sainte-Marie, B., Urbandi, N., Sevigny, J.M., Hazel, F., Kuhnlein, U., (1999). Multiple choice criteria and the dynamics of assortative mating during the first breeding season of female snow crab (Chionoecetes opilio Brachyura, Majidae). Mar. Ecol. Prog. Ser. 181, 141-153.

Sinoda, M., Ikuta, T., and Yamazaki, A. (1987). On changing the size Selectivity of fishing gear for Chionoecetes opilio in the Japan Sea. Nippon Suisan Gakkaishi 53: 1173-1179.

Tavel. (1998). Snow crab size and quality determination. A handbook prepared for the Fisheries Association of Newfoundland and Labrador and the Fish, Food, and Allied Workers Union. 16 p.

Taylor, D.M.,Marshall, G.W., and O'Keefe, P.G. (1989). Shell hardening in snow carbs *Chionoecetes opilio* tagged in soft-shelled condition. N. Am. J. Fish. Manag. 9: 504-508.

Trenholm, R., and Norsworthy, P. 1999. Snow crab research project. A report submitted to the Canadian Centre for Fisheries Innovation and Newfoundland Department of Fisheries and Aquaculture, St. John's, Newfoundland.

Wellman, J. (2004, August). Shockwaves in NL Crab Fishery. The Navigator, 9-10.