USING HARVESTERS KNOWLEDGE TO DEVELOP AN INDIVIDUAL BASED COMPUTER SIMULATION MODEL OF THE ST. JOHN BAY, NEWFOUNDLAND LOBSTER (Homarus americanus) FISHERY

JENNIFER WHALEN

Using Harvesters Knowledge to Develop an Individual Based Computer Simulation Model of the St. John Bay, Newfoundland Lobster (*Homarus americanus*) Fishery

By

Jennifer Whalen

A thesis submitted to the School of Graduate Studies

in partial fulfillment of the requirements for the

degree of Master of Science

Geography Department

Memorial University of Newfoundland

October 2004

St. John's Newfoundland

0-494-06671-7

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

Abstract

This thesis draws on fish harvester Local Ecological Knowledge (LEK) to develop a historical reconstruction of the St. John Bay lobster fishery on the west coast of Newfoundland on Canada's east coast. This LEK is then used as a basis to develop an individual based computer simulation model of this lobster fishery that runs from the early 1970s until present.

The lobster fishery in Newfoundland has been in existence for over one hundred years and it has been heavily managed for many years. LEK, biological information on lobster populations, data on lobster landings, and license data from DFO are used to explore changes in all aspects of the fishery over the past 40 years. A particularly important change was the transfer of many licenses into the Bay in the mid 1980s caused, in part, by the decline in the inshore cod fishery along the west coast of Newfoundland. License transfer contributed to a rapid increase in effort in the Bay, which has translated into interesting changes in terms of the spatial dynamics of the fishery, community structure, and harvesters' behavior and strategies.

To replicate these changes a model based on individual boats in the fishery was developed. Each boat was assigned individual characteristics and strategies based on information gathered during the fieldwork portion of the research. This model was then used to develop "what-if" scenarios in which I could explore the possible effects of communication between harvesters, changing environmental conditions, and new management initiatives on harvesters' catch, behavior and strategies. The approach developed in this thesis is a first step toward providing a useful technique for evaluating the possible impacts of potential initiatives in fisheries management.

Acknowledgements

I would like to express my highest appreciation to my supervisors Dr. Barbara Neis and Dr. Roger White, MUN for their patience, guidance, and support. I would also like extend a special thanks to the harvesters who participated in onboard observation and interviews. I am also indebted to the SSHRC for their financial support of this research. In addition, I thank Jerry Ennis, DFO for answering all my lobster questions and Dave Schneider, MUN for his support. I would also like to thank my family and friends for their support and encouragement.

Table of Contents

List of tables

List of Figures

Chapter 1: Introduction

This thesis explores the potential utility of using fieldwork to inform the development of an individual based model (IBM) to study a lobster fishery. Can an individual based computer simulation model replicate the changing dynamics of such a fishery? For this study, the IBM was developed with the aid of information on lobster behavior and lobster fisheries in the literature, as well as fish harvesters' Local Ecological Knowledge (LEK) collected as part of this research in the study area of St. John Bay, Newfoundland, on Canada's east coast. LEK was collected on all aspects of the fishery in order to carry out an historical reconstruction of the fishery over the past 30-40 years, and to inform the development of the model. The St. John Bay lobster fishery has been under tremendous fishing pressure since the collapse of the cod fishery in the Northern Gulf area off Newfoundland's west coast. The increase in fishing pressure came in two forms: from the influx of new licenses to the area starting in the mid-1980s and from increased time and fishing efficiency within the lobster fishery after the cod collapse.

The focus of the model is on the individual harvesters involved in the fishery rather than on the lobsters. We use this model to try to replicate the changing spatial dynamics of the lobster fishery in St. John Bay over the past 30 years. We also use the model to test individual reactions (in terms of strategies) to changing environmental circumstances. For example, what happens when an increasingly patchy lobster distribution (something to be expected in response to the intensification of fishing effort) is introduced into the model? The model also explores the effectiveness of communication among harvesters within the fishery, under conditions reflecting both a relatively even distribution of lobsters and a patchy distribution of lobsters. What effects will communication have on harvesters' catch in this context? The model is then used to test new management initiatives such as the implementation of community territories, future trap cuts and the implementation of minimum numbers of traps per line and closed areas. At a more general level, I was interested in exploring the possibility of using such models as a future management tool.

Most fisheries research is based in the biological science that informs management strategies. In this research the focus is on the effect of harvesters' behaviors on catch (number lobsters caught/year, where they were caught and where they remain) and not on the lobsters. The effect new management initiatives can have on harvesters' behavior is also an important focus of this research. Management of the fisheries should be based on the human aspect because it is in fact the harvesters who are being managed, not the lobsters.

1.1 Background and context for the research

St. John Bay has hosted a longstanding, well-known, productive American lobster (*Homarus americanus*) fishery for over a century. It is located on the west coast of Newfoundland's Great Northern Peninsula beginning in the south at Point Riche and extending north to Ferolle Point. It is approximately 32 kilometers in length and 16 kilometers wide and is shaped like a semicircle. St. John Bay is in Local Fishing Area (LFA) 14B but it does not comprise the entire area; LFA 14B extends north to Big Brook. There are approximately 15 fishing communities within St. John Bay, including a few islands on which harvesters live and fish lobsters during the lobster season.

Lobsters in St. John Bay are fished in open boats that are less than 35 feet (10.67 m). Traps are strung out in lines with a buoy attached at the end so the harvesters can identify their lines by color and the pattern of their buoys. The lines generally consist of between 6 and 10 traps per line with approximately 7 or 8 fathoms (12.8 – 14.6 m) between traps. Harvesters use landmarks, GPS systems, sounders and nautical charts to set and check their lines. The traps are hauled up over the side of the boat using a hydraulic trap hauler; lobsters are taken out of the traps and measured to make sure they are within legal size limits (82.5mm carapace length); the traps are then re-baited with mackerel or herring and returned to the water.

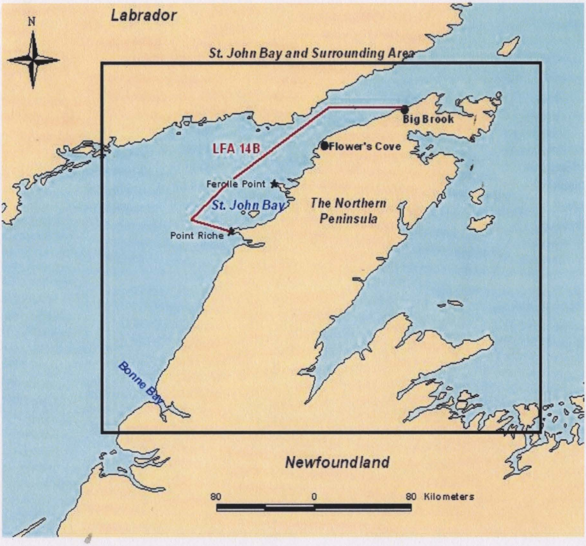


Figure 1.1. St. John Bay and surrounding area.

From the early 1980's up until the mid 1990's the lobster fishery on the west coast of Newfoundland was managed as part of the Gulf region, with headquarters located in Moncton. At this time there were no restrictions on transferring lobster licenses from one LFA to another. In the mid 1980s, in response to declining landings in the Northern Gulf Atlantic cod stocks (Palmer and Sinclair, 1997), there was an influx of fishers into the LFA 14B lobster fishery. Many of these were former cod harvesters (who had never fished for lobsters) from communities north of St. John Bay, as well as some harvesters living in the Bay who had never fished for lobsters. A majority of the harvesters who transferred lobster licenses into 14B began fishing in St. John Bay.A lobster license restricts lobster fishing to a season usually starting early in the spring and ending in July; each license has a specified trap limit and only one license is allowed per person.

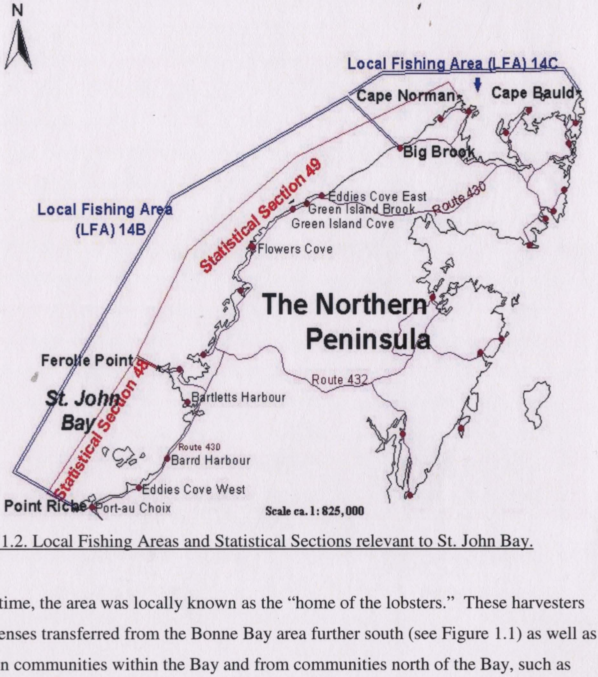


Figure 1.2. Local Fishing Areas and Statistical Sections relevant to St. John Bay.

At the time, the area was locally known as the "home of the lobsters." These harvesters had licenses transferred from the Bonne Bay area further south (see Figure 1.1) as well as between communities within the Bay and from communities north of the Bay, such as Flowers Cove.

Prior to the mid 1980s, reports from harvesters and buyers suggest that there were approximately 75 lobster fishing licenses being fished in St. John Bay. After the transfer of licenses was completed the number of licenses being fished in LFA 14B increased drastically to approximately 250. Although area 14B is larger than St. John Bay, and some harvesters are fishing lobsters from their home communities north of St. John Bay, a majority of licenses are being fished within the Bay. In 1993, the cod fishery in the Northern Gulf of St. Lawrence was closed. However, inshore cod landings had declined well before this time. During the 1990s and extending until present, the federal government introduced several license buyback programs to the Newfoundland lobster fishery (Personal communication Ennis, March 2, 2004). The federal Department of Fisheries and Oceans (DFO) would offer the harvesters lump sums of money and, in return, harvesters would discontinue fishing lobsters, relinquishing control of their license to DFO. Despite these buyback programs, in 2002, there were still between 155 and 165 licenses actively being fished for lobsters in St. John Bay. The number of traps present in the Bay prior to the 1980s would have been approximately 33,000 based on an estimate that each of the 75 licenses would have fished approximately 440 traps. This trap average of 440 is derived from interview data. However, it should be mentioned that some harvesters had far fewer and others far greater numbers of traps at that time. There was no trap limit at this time and harvesters reported using different numbers of traps. Presently, there are an estimated 70,000 traps (165 licenses) being fished for lobster in St. John Bay. Under current policies, lobster harvesters licensed for LFA 14B are not permitted to fish outside of this area and, in addition, they are no longer permitted to transfer licenses between areas (Integrated Lobster Management Plan, 1998-2001).

The increased numbers of licenses and pots in use in the area have contributed to high levels of fishing pressure on St. John Bay lobsters. Another factor contributing to increased pressure in the 1990s was the fact that many harvesters began fishing longer for lobster than in the past when they would have transferred effort over to the cod fishery after a few weeks fishing lobster. Thus, whereas in the past, many would fish for lobster for only four to five weeks of the season, at present lobster are fished intensively for the entire eight weeks of the season. Since St. John Bay is understood by most to be the best lobster fishing area in 14B, a majority of the harvesters will remain inside the Bay instead of moving to the northern portions of LFA 14B, outside St. John Bay. A third factor contributing to increased fishing pressure on the St. John Bay lobsters is management policies that have prevented these lobster fishers from obtaining crab and shrimp licenses.

In 1997, the Northern Gulf cod fishery was reopened with a small quota of 10,000 tons (CBC news on line, March 9 2004). However, in 2003, the federal fisheries minister announced that this small-scale cod fishery which most of the harvesters counted on to supplement their incomes was to be closed once again (CBC on line news, 2004). Mid-1980s license transfers, subsequent policy changes preventing further transfers and limited access to alternative fisheries mean that these harvesters are trapped inside a crowded St. John Bay lobster fishery with their future becoming more unpredictable every year. In recent years, increased fishing pressure has threatened local lobster stocks and reduced individual lobster landings, thereby threatening harvesters' social and economic futures. It is important to understand how and why this situation emerged, its effects on lobster fishing strategies, and what might be done in the future to lessen its effects on the lobster stocks and on harvesters' incomes.

This thesis provides a historical reconstruction of the St. John Bay lobster fishery from 1972 – 2002 based on fish harvester LEK. Their LEK was collected during interviews and on board observations with local lobster harvesters. Through interviews and onboard observation critical factors affecting harvesters' strategies and behavior were identified. In addition, harvesters' attitudes towards and ideas about the effects of management initiatives from the past, present, and future were explored. The remainder of the thesis uses an IBM of the fishery during this time, developed with input from the LEK, to explore the changes that have occurred in this lobster fishery and uncover and model explanations for those changes. In this model every individual (in this case a boat) is modeled and has set characteristics unique to that individual. The boat agents are guided by logic (sets of rules within the model) and input data used by the boats.

One focus of this research is using fish harvesters' Local Ecological Knowledge (LEK) to document the changing spatial dynamics of lobster fishing areas within St. John Bay as a result of interactions between several factors, such as the increase in the number of harvesters, the breakdown of community structure, and increased effort. LEK is a form of knowledge gained through experience (Franklin, 1990). Local Ecological knowledge in this context means knowledge gained through fishing in a particular locality with distinct social and physical environmental characteristics at a particular time (Kloppenburg, 1991). The IBM model developed for the study was used to run simulations in order to see if it would produce changes in fishing practices and territories similar to those described by harvesters. In addition, by extending the model to run until 2012, the model has been used to test the potential impacts of alternative, new management initiatives and their effects on individual behavior using "what if scenarios".

1.2 Why is it important to study this lobster fishery using LEK and IBM?

The harvesters from the St. John Bay area are under tremendous stress because all of the fisheries to which they have access seem to be in decline. In 2003, announcements by the federal fisheries minister of the complete re-closure of the northern Gulf cod fishery devastated harvesters from the area. Although not as lucrative as it once was, many harvesters still depended on the extra money that the cod fishery provided to supplement their income from lobster. In 2003, their futures looked very uncertain due to reported declines in their individual lobster catches and the closure of the cod fishery. Their desperation and frustration have been illustrated in news broadcasts showing harvesters burning their boats and cod gear, and even slashing tires on Department of Fisheries and Oceans' (DFO) vehicles.

LEK research and onboard observation can provide us with information related to changes in the numbers of boats, changes in lobster catch rates and abundance, demographic information, information on harvesters' strategies, information on communication between harvesters, spatial changes in their fishing effort, and information on attitudes towards conservation initiatives. It can sometimes be difficult to assemble LEK in a manner that is easily interpreted since it groups large amounts of information based on many participants. Using an IBM is one possible way to present some LEK in an easily interpreted manner and once harvester-lobster interactions are better understood to model the potential impacts of alternative management initiatives.

Studying a fishery such as the one in St. John Bay using an IBM makes it possible to explore the effects of many factors on individual behavior and landings. Since traditional management has focused on the effects of fishing on the species and not on the individuals who depend on the species, management initiatives have often had unforeseen negative impacts for the harvesters. In addition, because managers often have poor knowledge of harvester behavior, this behavior can result in unanticipated negative consequences for fish stocks. By developing a generic model of the fishery with a focus on boat-boat interactions, I am exploring a possible new way to study the effects of new management initiatives on individuals before they are implemented.

1.3 Relationship to existing research

This research draws on a variety of different types of existing empirical knowledge. The development of the lobster distribution component of the model used biological studies on Newfoundland lobsters, landings and logbook data from DFO, and findings from the Fisheries Resource Conservation Council of Canada report on the state of lobster stocks in the Canadian lobster fishery (FRCC, 1995). Information from nautical charts (no. 4180) of St. John Bay was used to develop a digital bathymetric model and a digital bottom type map on which the lobsters were overlain during the simulation (Reproduction of British Admiralty Chart, 1976). These maps provide a digital representation of the Bay as a grid of cells. The lobsters are distributed and move on the grid of cells during the simulations. Lobster management plans were used as a guide to incorporate management changes into the model at the appropriate times. For example, the trap limits implemented for many LFA's including St. John Bay, were implemented in the model in 1996 after consultation with integrated Lobster Management Plans. The modeling of the individual boats draws on fisheries research as well as empirical data collected within this study. Collecting the LEK using interviews and informal discussions with harvesters identified critical factors, strategies and behaviors for inclusion in the model. Existing literature on other computer simulation models and IBM's (including one used to study a fishing society) was used to: (1) gain an understanding of how these tools work; (2) identify what, if anything, was missing from previous models; and (3) identify their capabilities for use in this kind of application.

The biology of the American lobster is well documented in Newfoundland. Templeman (1940) was the first to do extensive biological study of lobsters in Newfoundland. Ennis (1984a), and Ennis *et al.* (1989, 1997) have studied biological aspects of lobsters within many locations in Newfoundland. Rowe (1999) completed some recent studies on the effects of closed areas, and larval drift of lobsters.

Landings data provided by DFO were used to estimate trends in the population of lobsters. The populations of lobsters in the model are all mature, legal-sized individuals. Since the focus of this research is on the harvesters and not the lobsters, and there is inconclusive literature on larval drift and settlement of lobsters to the bottom, I chose to use mature lobsters only. Whale and Steneck (1991) studied the distribution of lobsters in terms of the availability of suitable habitat. I used their research findings to inform the way lobsters would be distributed and move in the model. Depth was also used in the model because it seems lobster are more active and tend to move toward shallower, warmer water later in the summer (Ennis 1984a). Bottom type is also used to determine where the lobsters will be located. For example, larger lobsters are said to prefer rocky bottom as opposed to mud or sand. All this information was used to ensure that the population of lobsters in the model mimicked as accurately as possible lobster distributions that would be predicted by existing scientific research and LEK.

The Fisheries Resource Conservation Council (FRCC) report (1995) highlighted recruitment overfishing as a problem within the Atlantic Canadian lobster fishery. Recruitment overfishing means that the majority of lobsters being caught are immature and do not get sufficient opportunities to spawn and reproduce. The current exploitation rate (percentage of commercial size lobsters caught) for most Newfoundland lobster fisheries is 85% although numbers vary depending on effort and local conditions (Personal Communication Ennis, October 15 2003).

The lobster fishery in Newfoundland has had some management initiatives in place since the early years of the fishery. The current fishery is managed using such input controls as limited entry licensing, the organization of the coastline into LFA's and, within these, limits on the number of traps per license and limited lobster fishing seasons. At present, the Newfoundland season length is approximately eight weeks and usually begins in May but the exact opening date depends on local ice conditions. Other controls include minimum and maximum legal size limits and returning egg-bearing females to the ocean. At present, the minimum carapace length for lobsters in Newfoundland is 82.5 mm and the maximum is 126 mm. In recent years, many harvesters have begun to v-notch egg-bearing females. V-notching involves cutting a shallow triangular notch in one (second from the right) of the five elements of an egg bearing female tail fan (FRCC, 1995). The v-notches are retained through 2 molts of the female. When a v-notched female is later caught she is returned to the water thus protecting known spawners. V-notching is done on a voluntary basis, but it is illegal to be in the possession of or sell v-notched lobsters. DFO collected logbook data from the St. John Bay lobster fishery in 2000 and 2001 but this project was discontinued because of funding difficulties in 2002.

The division of management zones into LFA's highlights the importance of locality in managing the lobster fishery. At present St. John Bay is in fishing area 14B and no license can be transferred from or to another fishing area. The number of allowable traps per license in 14B is 425 and is the highest in the province. All traps must be tagged with tags provided by DFO. Traps also have to a have an escape mechanism of 3 ¾ inches (95.25 mm) so small lobsters can escape.

Acheson (1981; 1987) highlights the importance of studying territories in the context of fisheries management. In the Maine lobster fishery, harvesters defended their traditional lobster fishing territories for generations. In 1995 a Zonal management system based on these traditional territories was implemented. Each of the zones has their individual regulations, such as the number of traps per license and the number of traps per line. Acheson's research on the lobster fisheries of Maine has provided the present research with some alternative management schemes, for example the use of community territories as possible management areas. Using the IBM to test new management initiatives may shed some light on the effects such future management initiatives would have on the lobsters stocks and on individual's landings. DFO does not recognize any traditional fishing territories and treats St. John Bay, and other LFA's as single large fishing areas where license holders can set wherever they want within the areas.

Palmer (1992; 1993) writes about the role of folk practices in the development of new formal regulations in the lobster fishery. In his work on the west coast of Newfoundland he highlights the importance of examining the motivations behind harvesters' acceptance of management initiatives and the socioeconomic context within which they are presented. He concludes that the motivation of the individual replaces that of the group when his or her best interest is not accounted for by the initiative. This emphasizes the importance of dealing with individuals and their behavior and strategies within a lobster fishery context and thus is a new and interesting way to model a fishery.

Literature on the modeling of social systems such as fisheries is sparse. Bousquet and LePage (2004) have reviewed the literature on multi-agent simulation and ecosystem management. Bousquet *et al.*, (1994) have produced a model of a fishermen's society in the central Niger delta region. Findings from that study report the influences on individual behavior in terms of how fishermen occupy space (for example do the individuals occupy a pond, a channel or a river). In the present research on the dynamics of individual behavior attention is extended beyond the use of space (in this case fishing areas), to include information such as individual landings. The model also has the capability to examine the effects of different management initiatives on communities or certain groups of interest.

Since the model was meant to be as generic as possible such that (with few adjustments) it could be applied to lobster fisheries in other locations, this research also draws on findings from a study of other lobster fisheries in Newfoundland. The lobster fishery and the lobster stocks on the Eastport Peninsula in northeast Newfoundland are healthier than those in St. John Bay. In response to the collapse of the northern cod stocks in the early 1990s, the harvesters of the Eastport Peninsula started utilizing their lobster licenses throughout the full season, but there was no major influx of large numbers of new harvesters and they took steps to prevent encroachment on their grounds. In addition, some Eastport Peninsula harvesters have been able to obtain crab licenses to supplement their incomes. In this area, the establishment of the Eastport Peninsula Lobster Protection Committee (EPLPC) in 1995 tackled problems with non-harvester poaching and the disregarding of local rules. The Committee took steps to conserve the lobster resource as harvesters were encouraged to police themselves, get other harvesters to abide by the rules, v-notch berried females, complete logbooks and at-sea sampling programs, implement two closed zones around Round Islands and Duck Islands and an exclusive fishing zone around the Eastport Peninsula. This committee has formed a partnership with the Department of Fisheries and Oceans and is seeking Marine Protected Area status for the closed areas around the islands.

The situation around the Eastport Peninsula is starting to look up with reports of better catches in recent years (Rowe and Feltham, 2000). As indicated below, reports from St. John Bay are quite the opposite with individual catches down overall and reports of fewer small and spawny lobsters. In St. John Bay, v-notching, the filling out of logbooks, and at-sea-sampling were also carried out for a few years but the funding was terminated as of 2002. When the harvesters of St. John Bay were asked if they thought an arrangement like the one present at Eastport would work in St. John Bay, many thought anything was worth a try. Several people pointed to a fundamental difference between the two areas: the number of harvesters in St. John Bay is much higher than in Eastport and they have fewer alternative fisheries. This could make it very difficult to get everyone to agree on new management initiatives.

It is clear that something has to be done quickly if the St. John Bay lobster fishery is to survive. Comparison of the findings of the present study area with those from the

Eastport Peninsula suggests an innovative management initiative (closed areas) might be helpful. This was tested with the model.

Traditionally, lobster management has largely been based on lobster biology without much reference to the effects of management and on changes in fisheries on individual's behavior. In this study, current management initiatives are added to the model in addition to new management initiatives. Results of model experiments are used to see how these new rules might influence changes in strategy and behavior in the future.

1.4 Organization of the Thesis

The second chapter begins with a review of existing research on American lobster and its fisheries. This includes biological studies of lobsters, research on fish harvester LEK and how this information was used to inform the IBM of the St. John Bay lobster fishery. Chapter 3 then describes the methods used during the fieldwork component of the research and how these methods were used to retrieve information used in the model. Chapter 4 is a summary of the results found from the fieldwork component of the research. Demographic, strategy information, and composite maps of fishing areas utilized by lobster harvesters are presented here. A discussion of fieldwork results is presented at the end of the chapter. Chapter 5 focuses on the modeling methodology and background information on this field of study. A literature review of computer simulation models includes a description of what simulation models are and some of the most frequently used types of models. Computer simulation models have been used to model urban growth in the past and are now beginning to be used to model socio-ecological systems such as fisheries. The use of these models provides a new way to study fisheries, one that's based on individuals within the fishery and is focused on the harvesters and their interactions with the lobsters and each other rather than with the lobster population alone. These are alternatives to biologically based statistical methods often used by DFO and other governing agencies worldwide to inform managerial decision-making in the fishery. A diagram of the model interface and an explanation of all its components can be found here. The features of this model are also exemplified through the use of maps and interfaces available in the model. This chapter also includes a substantial section on the calibration of the model to the empirical data. Calibration is carried out to make sure the model is producing results similar to those found in reality. Calibration is done both with quantitative data comparisons, and qualitative calibration to see how the model results compare to reports in the fieldwork data and data from DFO. A baseline scenario is used to compare maps produced with the model and the empirical composite maps of the changing spatial dynamics of lobster fishing areas (historical reconstruction).

Chapter 6 provides a summary of results from the experiments performed using the simulation model. These experiments included the effects of communication between harvesters on landings; the effects on fisheries of seasonal variability in the lobster distribution; as well as the effects of the implementation of community territories, new trap limits and minimum allowable number of traps per line and closed areas on the fishery. The development and importance of the experiments are explained, followed by the results.

Chapter 7 discusses the results from the model simulations. This chapter is meant to emphasize the overall themes and points of interest and refers back to specific examples from the fieldwork and model results. Concluding remarks highlight the strengths and weaknesses of the research and areas for future research.

Chapter 2: Literature Review and Fieldwork Methods

2.1 Introduction

This thesis proposes a different way to study a fishery, by using both the results of biological studies and local ecological knowledge (LEK) to inform the development of an individual based model (IBM) of the fishery. Researchers have developed a wealth of information on the biology of lobster in Newfoundland related to standing stock, landings, reproduction, as well as growth, distribution and movement patterns of lobsters (e.g. Templeman, 1939 and 1940, Squires, 1970, Ennis, 1982, Ennis *et al.*, 1982, 1989 and 1994).

American lobsters are long-lived, bottom-dwelling invertebrates. Part of the reason for lobster longevity is that they have few predators and the majority of their mortality results from the commercial lobster fishery (Fogarty, 1995). American lobsters are generally found on narrow bands of rocky bottom and they are distributed from the Strait of Belle Isle in northern Newfoundland to Cape Hatters, North Carolina (Lawton and Lavalli, pp.49, 1995).

The standing stock of lobsters or the number of commercial lobsters in Newfoundland has been estimated using the Leslie and Peterson Methods. Recruitment is the most important factor involved in the year-to-year fluctuations in the numbers of commercial lobsters (Ennis *et al.*, 1982). Recruitment is determined every year by the numbers of pre-recruit sized lobsters and the percentages of these lobsters that molted in the pre-recruit size range the previous year.

A historical reconstruction of Atlantic Canadian lobster landings was provided by the FRCC report on the Atlantic Canadian lobster fishery (FRCC, 1995). In the late 1890's, Canadian lobsters landings showed an increase to approximately 45, 000 tons. From the late 1890's until the 1920's lobster landings declined. Landings showed long term fluctuations with peaks in the early 1930s and in the 1950s. A dramatic increase in landings occurred beginning in the 1970s (15, 000 tons) and extending until 1991 (peak 48,000 tons). In the years following 1991 the landings declined to 39,000 tons in 1994.

The Atlantic Canadian landings then showed a gradual increase to approximately 52,00 tons in 2001 (Johnson, 2002). These macro-level landings mask, however, localized trends.

Landings data for Newfoundland had to be calculated in pounds because the earlier data could only be obtained in that form. Data from the 1970s onward were converted from metric tons to pounds to permit the assessment of long-term trends. The overall trends for Newfoundland are as follows. In 1874 (the year official records suggest the Newfoundland lobster fishery started) there were 150, 000 pounds of lobster landed in Newfoundland (Ennis, 1982). Landings increased to the peak year 1889 when 17.5 million pounds of lobsters were landed. Despite short-term fluctuations in landings there appears to have been a downward trend from 1889-1924, when landings were at a low of 750,000 pounds. During 1925-1927 the fishery underwent a closure. Following a one-year recovery (1928= 4.6 million pounds), landings fluctuated and by 1949 (when lobsters were starting to be shipped live to the US) landings totaled almost 5 million pounds. Ennis (1982) explains that this increase was likely due to the increased recruitment resulting from the newly enforced regulations (minimum size and restriction of berried females). Another peak was experienced in 1955 when 5.5 million pounds of lobsters were landed in Newfoundland. Landings declined during the 17-year period prior to 1972 to 2. 7 million pounds, increasing again to 5.7 million pounds in 1979, and increasing to a high of 7.0 million pounds in 1992 (peak for the 20th century) (Ennis *et al.*, 2003). After this peak, landings declined to 3.8 million lbs in 2000, a pattern of decline that is evident across Atlantic Canada. From early reports landings increased again 2001 and 2002 (4.6 million pounds and, 5.0 million pounds respectively). It is important to note that data from these last two years are from a quota report and are subject to substantial revision.

Effort in terms of number of traps could not be obtained prior to the early 1900's. In 1900 the number of traps utilized in the Newfoundland lobster fishery was approximately 250,000. The number of traps started to decline by 1914, although there were some fluctuations, this pattern of decline continued until 1939 to 125,000 traps. In the period from 1939 to 1957 there were no measurements of effort reported. In 1957 the number of traps increased to approximately 300,000 traps. The number of traps increased to 575,000 traps in 1965 followed by a decline to just over 400,000 in 1972. The number of traps continued to rise to over 750,000 in the mid 1970s. By 1982 the number of traps had declined slightly to approximately 650,000. Following this decline effort increased to a peak in 1992 of 1,188,292 traps.

Despite a nominal effort decline (measured as number of licenses times number of traps per license) from 1,188, 292 traps in 1992 to 656, 690 traps in 2002 and a 25% reduction in nominal effort from 1998-2002 exploitation rates in Newfoundland are still extremely high in all areas (Ennis *et al.*, 2003).

In the study area of St. John Bay, landings from 14B increased during the 1970s and 1980s with a large peak in 1989 at just over 1.26 million pounds of lobsters (23% of the Newfoundland total for that year). After this peak year landings show a downward trend continuing to present.

Lobsters show delayed reproduction (Wilder, 1953). Sexually mature (5-8 years) females will mate in the summer after they molt (shed their shell). Female lobsters on the west coast of Newfoundland are generally mature once they reach 80mm (FRCC, 1995). The eggs are extruded and attach to the underside of the tail the next summer. The female then carries her eggs for another 10-12 months before they hatch. Fecundity, or the number of eggs a female produces, is larger with large more mature individuals (Ennis, 1982). In addition, larger females produce eggs that have higher survival rates (Affard and Hudon, 1987).

Planktonic larvae (6-8 weeks) live and feed near the surface of the water before settling to the bottom to find shelter (Ennis, 1995). For the first two to three years of their lives these young lobsters spend most of their time hiding from predators. As they grow larger they begin to move from their burrows.

Lobsters grow (both in length and weight) through the processes of molting. The amount of growth is calculated by examining the relationship between premolt and postmolt carapace length (Hiatt growth diagram) (Fogarty, 1995). Studies done across the geographical areas where lobsters are found show little variation in the relationship between premolt-postmolt sizes. In Bellburns, Newfoundland, Ennis *et al*., (1994) developed growth equations for sphyrion tagged lobsters that were analyzed by the Hiatt program developed by Somerton (1980). These following equations are derived from least squares regression of postmolt carapace length (CL) on premolt CL. The units of CL = mm. Males: $y = 1.1197x + 2.0619$ ($n=91$, $r=0.92$). The slope of this line is significantly greater than one according to an analysis of covariance ($p = 0.02$, $n= 91$). This means that in males in this particular area, molt increment increases with premolt size. For females y: $1.0017x + 8.7651$ ($n=199$, $r=0.95$). The slope of this line suggests there is no significant difference from one, which means female growth increments are constant with premolt size, in this area ($p = 0.94$, $n = 199$). Males molt more often than females, especially after maturity, thus achieving larger sizes over their lifetime (Collins and Lien, 2002).

Although some research (Rowe, 1999) has been done on spawning locations, and larval drift, no strong consensus has been reached about how lobsters populations settle to the bottom and form distributions. There is a tendency in nature for populations to have patchy distributions. In other words the population of natural species is variable (concentrated in smaller areas) rather than scattered at random across the habitat (Horne and Schneider, 1995). In addition, the degree of patchiness changes with spatial scale, such that at scales of a few meters the distribution may seem random but at larger scales the population is back to the patchy distribution (Horne and Schneider, 1995). Wahle and Steneck (1991) have found that the distribution of lobster is also dependent on the amount of suitable habitat and the competition for that habitat with large lobsters.

During the early years of a lobster fishery when the population would be dominated by large, older lobsters, there would likely be little year-to-year variation in the distribution of lobsters. There would also be multiple larval patches where they dropped to the bottom with multiple year classes spread out throughout the lobster habitat. With an increase in fishing effort and an increase in the ability of harvesters to cover more lobster ground, and with natural population fluctuations, this situation would change. At present, it is likely that the fishable population of lobsters in many parts of Newfoundland is comprised of only one-year class (those individuals that have just matured to legal sizes). Lobsters also tend to converge into good habitat with many crevices and food. Lobsters will spread into poor habitat if crowded. Heavy fishing reduces crowding, hence convergence. In the context of annual variations in recruitment that are probably enhanced with the elimination of larger, older and more fecund lobsters from the population, it is possible that the distribution of lobsters is much more patchy now than in the past.

Research on lobster movement has been undertaken in many localities in Newfoundland, including Bellburns, Bonavista Bay, and on the west coast of the Island (Ennis *et al*, 1989, Ennis *et al*, 1994, Rowe, 1999, Templeman, 1940). Researchers track the movement patterns of lobsters by tagging and recapturing individuals within the study areas. Although the amount of lobster movement seems to be driven at least in part by the habitat, lobsters tend to move only short distances. The majority of lobsters in Bellburns, for example, where the habitat is considered suitable for lobster movement (straight rocky bottom with gently sloping bottom topography), did not move considerable distances. Ennis *et al.* (1994) found that of the lobsters at large (time between tagging and recapture) between 11 and 13 months, 39% were recaptured in the immediate vicinity (non movers), and 20% of the reminder were recaptured no more than 1 km away. In Bonavista Bay, where lobster habitat is characterized as poor in terms of lobster movement (narrow bands of steeply sloping rocky bottom), the lobsters also appear not to move great distances. Of the lobsters at large between 11 and 13 months 53% were recaptured in the immediate vicinity of where they were initially tagged, and 88% of the remainder were found no more than 1 km away (Ennis *et al.*, 1989). Results presented by Rowe (1999) support previous findings that lobster movements in Newfoundland waters are confined to small geographical areas. In addition, Rowe found that lobster movements are possibly impeded by excessively deep water or the presence of seasonal thermoclines. This phenomenon has also been described in other work (Ennis 1984b, Ennis *et al.*, 1994, Comeau *et al.*, 1998). However, in other areas, "While generally lobsters are found in commercial numbers at depths less than 35m, they are also fished by the offshore fleet along the outer Scotian shelf at depths to 450m" (FRCC, 1995).

Lobsters also seem to move seasonally into warmer, shallower water (Ennis 1984a). This movement is influenced, however, by the bottom topography and the exposure to storm waves. Females that are about to start hatching the broods they have been carrying since spawning the previous summer are known to actively seek out higher temperatures to speed up embryonic development. For this reason and because fisheries target male lobsters, mainly female lobsters are found in shallower water at the end of the fishing season, many of them spawny. Any shifts in distribution would be related to habitat quality, i.e. at low levels of population abundance marginal habitat areas would very likely have much lower densities than they would at high levels of abundance (Personal Communication Ennis, September 4, 2003). In contrast density would not change to the same extent in areas of prime habitat. That is not to say that some lobsters would not occupy that marginal habitat either continuously or periodically at some time of the year even during periods of low abundance.

2.2 Management Considerations

The Canadian lobster fishery has been heavily managed for many years. This management has largely been based on the wealth of biological information collected to date. The first conservation measure introduced into the Canadian lobster fishery was the protection of the egg bearing females (FRCC, 1995). This conservation measure was implemented in the early 1870's. Also during the early years of the fishery (1874 onward) there were regulations on minimum carapace size. The minimum size implementation experienced many problems with enforcement, however, and was abandoned in most areas before being reintroduced in the 1930s and 1940s (FRCC, 1995). In Newfoundland, a minimum size limit of 78mm was reintroduced in 1939. Overall, these two regulations were not strictly enforced until the 1930s (Ennis, 1982).

In 1949 a trap lath spacing regulation was implemented (FRCC, 1995). This implementation was to ensure that sub legal-sized lobsters could escape from the traps while still on the ocean floor thus minimizing any harmful effects on the lobster and allowing them to grow into larger, legal-sized lobsters.

Limits on effort (number of licenses and number of traps per license) were introduced in 1969 along with licensing. If a fisherman fished fewer traps in 1968 than the lower limit for his district he could not add any additional traps in the future. Class B licenses were issued to harvesters utilizing less than 100, 75, or 50 traps (differed depending on district), and they were not subject to renewal upon the retirement of the fishermen. Class A licenses were issued to all other boats and were transferable.

In 1976, after a report from the Lobster Fishery Task Force, the government implemented a buyback program in order to eliminate harvesters who earned their living outside the fishery (FRCC, 1995). These buybacks were implemented in Prince Edward Island, and later in Nova Scotia and New Brunswick. Buyback programs stared in the 1990s in Newfoundland and continue to present.

Prior to 1976 the overall number of licenses and the number of traps per license in the Newfoundland fishery were uncontrolled (Ennis, 1982). In 1976 a trap limit was introduced and harvesters were limited to the number of traps they had fished the year before. In the years between 1976 and 1981, it was the consensus that harvesters were actually utilizing higher numbers of traps than were allowed under the licensing agreement (Ennis, 1982). In 1977, if a harvester had more than 100 traps there was no increase allowed. If a harvester had less than 100 traps they could increase to a maximum of 100 traps per license. From 1978 to1982 there were no increases in trap limits.

In Newfoundland, starting in 1982, licenses were issued according to eleven management areas. The west coast of Newfoundland was not included in these management areas at this time. The DFO mandate for the west coast was transferred from Newfoundland Region to the then newly created Gulf Region (Headquarters in Moncton) in the early 1980s (Personal Communication, Ennis, March 16, 2004). Although local responsibility remained with the Area Office in Corner Brook, these officers reported to senior managers in Moncton rather than St. John's. The mandate for lobster management was transferred back to the Newfoundland Region in the early 1990s and the area was then brought under the Local Fishing Area (LFA) management zone structure. In 1983 and 1984, full time fishermen could be granted a 100 trap limit if they had been licensed for less than this the previous year (Ennis, 1982). Between 1985 and 1990, the trap limits remained the same. In 1991 each management area was granted its own trap limit and these ranged from 100 traps per license to 300 traps per license. In 1996 implementations for trap limits differed depending on the Local Fishing Area (LFA). In St. John Bay, the trap limit was set at 425 traps per license at that time.

In Newfoundland, by 1983 restrictions were implemented preventing the transfer of licenses from one district to another. Prior to 1982 the transfer of licenses was not restricted to the same management district. In 1984 the transfer of licenses between full time and part time lobster harvesters was permitted. The license transfers had to be to full time harvesters who were resident of the community or an adjacent community within the fishing area for which the license was issued. While the west coast of Newfoundland was part of Gulf Region (early 1980s to early 1990s), there were some major diversions with respect to licensing policy, some of which still persist (Personal Communication, Ennis, March 31, 2004). The senior DFO personnel in Corner Brook at the time are all retired which made it difficult to contact anyone about examining this further. This is likely what produced the situation of licenses transfers between Bonne Bay and St. John Bay.

A meeting with Tom Perry of Science management division at DFO in March of 2002 provided some information on regulations concerning the practice of fishing two licenses (twice as many traps) from one boat. This practice is referred to as "buddying up". Although buddying up has legally occurred in the lobster fishery for many years, in 1997 harvesters were required to fill out a "license condition for buddy-up arrangement" form. The form stated that, in any LFA, two harvesters (no more) could fish 850 traps in one boat. Harvesters must have their own vessel registration number on their respective buoys. Changes in carapace sizes have been implemented in different fishing areas at different times. For example, in west Cape Breton in Local Fishing Area (LFA) 26B the measure was increased to 70mm by 1990. There was a proposal to increase the minimum carapace size in Newfoundland and Scotia Fundy (83mm) because of changing U.S. regulations pertaining to Canadian imports. These changes did not occur because all sectors in the industry were not in agreement (FRCC, 1995). In 1998 the minimum carapace size was increased to 82.5 mm for all LFA's in Newfoundland. In the same year, following the recommendations of the FRCC, two closed areas were implemented in Bonavista Bay and Trinity Bay (LFA's 5 and 6). During the period from 1998 to 2002, there were no major trap cuts (except for a reduction from 200 to 150 traps in LFA 7).

In the 1970s and 1980s the fishing season for Newfoundland generally opened around April 20 and closed the first or second week in July (~12 weeks). In 1997, a reduction in season length was implemented in most fishing areas. This implementation is intended to ensure minimal removal of lobsters when reproduction and molting occurs. The opening of the fishing season depends on local ice conditions. In 1998, In St. John Bay (LFA 14B) the season was 7.9 weeks long from May 9th to July 2nd. In subsequent years the opening of the season has been between early and late May depending on these ice conditions, but the season remains at 7.9 weeks long.

DFO started developing Integrated Fishery Management Plans in 1996. In 1996, the v-notching of egg bearing females was started on a voluntary basis. It subsequently became illegal to keep or sell a v-notched lobster. In the same year, a pilot project in LFA's 13A 13B, 14A, 14B, and 14C started whereby the retention of males or females in excess of 120mm carapace size became illegal. In response to a significant catch decline in some localized areas of 13B, the maximum carapace size was increased to 127mm for areas13A, 13B, 14A, 14B, and 14C.

2.3 The FRCC report on a Conservation Framework for Atlantic Lobster

The Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) responsible for providing scientific advice to fisheries managers, was formed in the late 1970s and continued until the early 1990s (Gendron *et al.*, 2000). The Fisheries Resource Conservation Council (FRCC) replaced the CAFSAC in 1992. The FRCC meets with industry stakeholders in public meetings where scientists have a chance to present their stock assessments and conservation measures to give the harvesters a chance to be more involved with the recommendations that affect their futures in the fishery. The FRCC provides a report usually including recommendations for total allowable catches (TAC's) and other management initiatives to the Minister of Fisheries and Oceans.

A report from the FRCC (1995) raised concerns about the future of the lobster fisheries in Atlantic Canada. One of the main reasons cited was that the majority of the legal sized lobsters that comprised the fishery at that time were immature individuals. Reports from all over Newfoundland suggest that lobsters caught during the season are primarily newly matured individuals (for example Ennis *et al.*, 1994). This means that under unfavorable environmental/ ecological conditions and increased effort, recruitment failure could occur. Instead of suggesting specific management initiatives, the FRCC suggested several possible, rather general, conservation strategies that could deal with these problems and they encouraged local stakeholders and management officials to work together to develop programs for specific local regions.

The 1995 FRCC Report has formed the backbone of policies in the Atlantic Canadian lobster fisheries in recent years. The conservation strategies outlined by in this report included measurements to increase egg production through reduction of exploitation rates, closed areas, increased minimum carapace size, and v-notching of egg-bearing females. Suggested measures to reduce exploitation rates included reducing the number of licenses, reducing the number of trap hauls, shortening the season, reducing the number of fishing days (for example banning Sunday fishing), reducing illegal fishing by increasing enforcement, limiting the transfer of licenses and, limiting the reactivation of inactive licenses. Measurements to improve stock structure included reducing exploration rates, in addition to protecting certain components of the lobster population, allowing them to grow through v-notching, establishment of Marine Protected Areas (MPA's), and maximum size limits. The last measure suggested was to minimize waste through targeting lobsters at "optimal" size, targeting seasons to periods when lobsters are at their best (full of meat as opposed to full of water as they build their new carapace) and better handling of lobsters.

In addition to proposals for a new conservation framework, the FRCC recommended program improvements in three areas of DFO: enforcement, science and education. Enforcement was to be improved through improved enforcement visibility (increase the time Fisheries officers spend on the water, encourage community watch programs) by involving harvesters more directly in enforcement activities, and by improving penalty systems.

The FRCC suggested recommendations on science priorities and research activities included improved definition and assessment of conservation measures. It recommended steps be taken to achieve a better understanding of the effects of v-notching, validity of protecting large animals, the limiting effects of increased egg production (capacity of the bottom environment as a bottleneck). The FRCC also recommended the definition of Lobster Production Areas LPA's based on the hypothesis that lobster production is influenced over a larger area than LFA's (conservation measurement is implemented at this level) because measurements at the LFA level could possibly affect other adjacent areas. They suggested that oceanic research could be used to more accurately determine LPA boundaries. This would also involve developing better understanding of migration patterns and larval drift. Monitoring of stock assessments (for example the impacts of escape mechanisms and entrance ring sizes) and understanding long-term trends were two other science priorities suggested by the report (FRCC, 1995). Finally, the FRCC highlighted the importance of communication between scientists, mangers and stakeholders and better education of the stakeholders related to such issues as how scientific data processing works, how the resource is doing in the environment through the gathering of biological and ecological data, and improved explanations for policy initiatives

The influences of the FRCC report can be seen in subsequent implementations of changes in season length, trap limits, new minimum and maximum carapace sizes, the implementation of closed areas that differed depending on regional areas, and in the efforts of the Eastport Peninsula Lobster Protection Committee. Closed areas have also been implemented in Leading Tickles, Trout River, and Summerford, Newfoundland.

2.4 Using Local Ecological Knowledge to study fisheries

With the development of such projects as the Coasts Under Stress (CUS) Research Project, the focus is shifting away from using biological science to understand fisheries to focusing more on interactions between fishery resources and the people involved in and depending on these fisheries for their livelihoods. The CUS mandate is to identify important ways in which changes in society and the environment in coastal British Columbia and Coastal Newfoundland and Labrador have interacted to affect the health of people, their community and the environment over the long run.

Researchers involved in CUS have been using interview techniques, historical archival data and scientific data to develop historical reconstructions of various fisheries across coastal Newfoundland and Labrador. By collecting local ecological knowledge (LEK) on all aspects of fisheries they are adding a human dimension to fisheries research. Davis and Wagner (2001) highlight the importance and challenges associated with identifying local experts when collecting LEK.

A study on the evolution of lobster fishing practices in the Magdalen Islands, Quebec and their influences on the stock assessment process was undertaken by scientists at Maurice Lamontagne Institute (one of DFO's research facilities incorporating fisheries biologists and harvesters) and an anthropologist from Laval University (Gendron *et al.*, 2000). As part of this research a biologist and anthropologist interviewed forty lobster harvesters using semi structured interview schedules. One of the main interview topics was the dramatic increase in lobster landings from 1,000 tons in 1976 to 2,800 tons in 1992 in the Magdalen Islands. This increase in landings was believed by many in the field to have been influenced by favorable environmental conditions in addition to increased effort and improved efficiency of fishing practices. The scientists classified data on the changes in fishing equipment (vessels, traps, sounders, navigation equipment), as well as fishing practices (number traps per line, spatial distribution of lines, etc) and strategies. These data were classified into 50 variables in a Microsoft Access database that could be queried in many valuable ways.

Results from this research found that larger, faster boats and new navigation equipment (including color sounders and GPS systems) had increased the fishing capacity since the mid 1970s. Larger traps also increased efficiency but were banned by the mid 1990s. Harvesters reported that fishing a smaller number of traps per line (presently an average of six as opposed to ten - twelve traps per line used in the 1970s) and thus larger numbers of lines allowed them to fish larger areas of lobster ground. The increase in the distance between traps (from 8-9 meters to 12.5-14.5 meters) on a line has allowed them to reduce the competition between traps and increase their efficiency. The shorter length of the trap lines (because of reduced numbers of traps per line) in conjunction with information received from color sounders allowed harvesters to strategically place lobster lines in more effective locations on the lobster grounds. Strategies by harvesters had also shifted from a focus on the interception of lobsters as they moved into shallower water to the pursuit of the species with new technologies and faster boats. In the past harvesters would wait for the lobsters to be intercepted on lobster grounds closer to shore, which in some cases, meant not all lobsters would be intercepted by the end of the season. During the period under study, harvesters began fishing in deeper water (new offshore areas) and pursuing lobsters early in the season resulting in higher catches.

The ethnographic approach taken in this research helped the researchers understand the evolution of fishing strategies and harvesters' goals and concerns and how they had affected fishing habits and strategies. "The importance of common fishing grounds, competition, and the relationships among fishers, as revealed in the interviews, helped us to understand better the changes that had occurred and also revealed local differences" (Gendron *et al.*, pp66). In the Magdalen Islands although only one fishing area is recognized harvesters divide the lobster grounds into two sections: the north area and the south area. Although some tolerance is allowed due to the difference in catch rates over a season (the south area experiences declining catches later in the season and the north area experiences a more stable catch rate throughout the entire season), for the most part harvesters fish one area or the other. In the northern areas each fishing wharf has its own set boundaries and only fishers from that particular wharf are allowed to fish. On the offshore grounds (in the north and south) the area is governed on a first come first served basis and this is the area where competition for lobsters is the strongest. It is in this area that fishing efficiency has increased most rapidly.

Findings from this research were considered during the stock assessment process of 1994 (Gendron, 1997). Biological observations on the decrease in small lobsters, and in egg production per recruit, as well as catches with few large individuals had resulted from increased fishing pressure over the previous ten to fifteen years. Findings on increased fishing efficiency were also used as background information and brought into discussions about the increased catch per unit effort (CPUE) from the late 1980s until the mid 1990s. The early season CPUE increased as a result of larger lobster biomass, harvesters' ability to locate and catch lobsters at this time, their improved ability to position the traps and increased performance of the traps themselves. In other words, improvements in technology permitted the lobsters that were available to be caught faster and earlier in the season. This information helped explain why, despite improved catches during the early part of the season, overall declines in landings had been experienced.

The research by Gendron *et al.* (2000) uncovered two processes that need to be addressed by biologists and managers in the future lobster fishery. First it highlighted the importance of monitoring the development of new fishing practices and strategies that can develop even with the effort controls implemented by managers. In addition, it also highlighted the fact that managers need to take into account improvements in fishing efficiency.

Rowe and Feltham's (2000) research on the Eastport Peninsula in Newfoundland drawn from the conservation strategies suggested by the FRCC report. After the downturn in the cod fishery in that area, inactive lobster fishing licenses were activated and those harvesters who originally fished lobster during the first of the season (before the cod opened) began fishing the entire lobster season. A disregard for management regulations was also present in the form of fishing higher numbers of traps than the legal limit, the retention of sub legal sized females and egg bearing females. This increased effort and disregard for management regulations eventually resulted in reported catches in 1993 that were the lowest in harvesters' memories.

In 1995 the Eastport Peninsula Lobster Protection Committee (EPLPC) was formed. The Committee held meetings to inform individuals about the negative impacts disregarding the regulations would have on their catches for future years. They also explained that by protecting the smaller individuals they would reap larger benefits in years to come since they would be allowing the lobsters to mature into larger individuals that are worth more money. In 1996 v-notching projects were started whereby over 1,500 female lobsters were v-notched (on a voluntary basis) and the retention of v-notched individuals was prohibited. In 1997, a co-management agreement was signed for 5 years between DFO and the EPLPC. The committee undertook additional management initiatives when they applied to DFO to implement an exclusive fishing zone around the Eastport Peninsula whereby only traditional harvesters from the seven Eastport Peninsula communities were permitted to fish inside the zone. In the same year the committee also applied to DFO to close the areas around two islands (Round Island and Duck Islands) to commercial fishing. A partnership was formed between the committee, DFO, Memorial University and Parks Canada and together they integrated scientific methods (to gain quantitative data from the areas) into the LEK base (qualitative data). Harvesters helped identify which areas should be closed to commercial fishing. The areas were chosen based on the quality of bottom type as good lobster habitat, and the fact that not many harvesters fished these grounds. Students from Memorial University were hired to conduct catch-mark-and release biological sampling in order to determine the extent of movement in and out of the closed areas. A research assistant from Memorial University was also hired to join harvesters (who fished in the closed area before the implementation) and together they measured, sexed and determined the reproductive condition of the lobsters. As harvesters had indicated, these areas were found to be capable of ideal egg production. Harvesters were asked to monitor these tagged lobsters wherever they showed up in their lobster traps during the fishing season. The data were analyzed at Memorial University and later presented at a meeting in Eastport. Harvesters had a chance to compare the fall research and monitoring results to their own personal predictions.

In addition to fall research fishing and the monitoring projects, analysis of the overall population of lobsters in the area was done by participating harvesters collecting logbook data (daily catch by category and number of traps). The authors explain: "The information pertaining to catch rate is being used to generate indices of abundance for commercial-sized lobsters in order to monitor exploration rates and annual variability in production"(Rowe and Feltham, pp. 243, 2000). Research assistants also joined these harvesters to take more detailed information on population structure (for example percentage of legal and sub legal sized males and females, legal sized and sub legal sized egg bearing females etc). This information can help predict landings in future years of the fishery.

In addition to the innovative management initiatives described above, the committee has also taken an important role in policing their peers. Any harvester who disregards regulations is now reported to the committee and a group warning is given to the individual. The fisheries officers are informed and they either take appropriate legal action where it is warranted or they enhance patrol around problem areas and monitor traps to ensure they are registered to licensed harvesters. The committee has also been involved with educating harvesters and non-harvesters on the benefits of conservation efforts. The education program has extended to include the incorporation of school children into the analysis of lobster fisheries management data as part of a class project.

The efforts of the EPLPC have been successful in integrating local knowledge with fisheries science and management. In recent harvesting seasons reports of increased landings in Eastport (while other areas are reporting declines) have supported high expectations for the future of this lobster fishery. The no take reserves implemented in Eastport will ideally provide a sustained supply of lobsters through protecting against high exploitation rates and increased levels of egg production (Collins and Lien, 2002). Efforts have been underway for other areas of Newfoundland to start investigating how they could implement similar committees and no-take fishing zones in their own areas.

At sea sampling and collection of logbook data in Eastport is continuing. The closed areas are in the later stages of being established as Marine Protected Areas (Personal Communication, Annette Power, March 22, 2004). The Eastport closed areas have been through 4 out of 6 steps of the framework for establishing and maintaining MPA's. They are in the process of going through the public meetings as part of the 5th designation stage. In 5th stage, the MPA also needs to go through the legislative process in Ottawa, which could take approximately 12-18 months. Once the MPA is designated, the sixth stage is maintenance of the MPA.

Research undertaken during the winter of 2001 by Davis, Whalen and Neis has produced a report that summarizes research documenting the history of the EPLPC on Newfoundland's northeast coast, and Eastport harvesters' LEK regarding the relationship between changes in the lobster resource, regional lobster fisheries and the conservation initiatives of the EPLPC (Davis *et al.*, 2002). This research was developed to explore the impact of the Committee's initiatives on fish harvesters, fishing strategies, conservation practices and attitudes towards conservation. Findings from interviews with key informants involved with the development and activities of the committee, phone interviews with local harvesters and, career histories with local harvester experts identified by their peers are used to document the processes associated with the development of the committee and the impact of developments in the 1990s on lobster fishing strategies, conservation practices and attitudes in the area. A mapping component was used to explore changes in fishing areas as a result of the downturn of the cod and increased pressure on lobster stocks.

Neis and Kean (2003) have highlighted how LEK research done in Newfoundland indicates a pattern of spatial, temporal, ecological and social expansion and intensification in northeast coast Newfoundland fisheries in the period between the 1970s and the 1990s. One of the reasons this present research has a strong and important mapping component is to see if these twin processes of intensification and expansion can be seen in the lobster fishery of St. John Bay. One potential constraint on expansion is the presence of enterprise or community territories similar to those identified by James Acheson in the lobster fisheries of Maine.

Acheson (1975; 1980; 1981; 1987 and 2003) highlights the importance of territories in the management of Maine lobster fisheries and in protecting lobster resources and sustaining landings. Based on his work in Maine, Acheson identified two types of lobster harvesting areas, nucleated and perimeter-defended, based on the amount of mixing within the territories that is tolerated. In nucleated areas the lobster harvesters have a strong sense of territoriality (and defense of this territory) around the mouth of their Harbour, with sense of territory decreasing with distance away from home Harbour. In the perimeter-defended areas, the sense of territory (usually an Island) and defense of that territory does not decrease with distance. Acheson found that those harvesters who fished perimeter-defended areas were usually kin-based and had historical connections to the lobster fishing area. They were often referred to as "lobster gangs" and defended the boundary, sometimes through trap degradation, making it hard for new entrants to enter into the area. By examining the nucleated and perimeter-defended areas the economic effects (e.g. catch rates) of territoriality can be discovered. Acheson found that lobster harvesters from the perimeter-defended areas had higher catch rates than those in the nucleated areas. Territory also affects the ecology of the lobster stocks, since the amount of effort is lower in perimeter-defended territories, allowing higher numbers of lobster to mature into larger sizes. In Acheson's work, a regression analysis showed that from a list of factors affecting the catch of lobsters, territoriality was in the middle of the list, placing before depth and bottom type, but after seasonality (Acheson, 1987).

From a management perspective, it is important to examine changes such as expansion into offshore lobster grounds and increased time spent in the lobster fishery that might increase pressure on the lobster resource and sustain catch per unit of effort despite resource decline. Acheson recently updated his research on Maine's lobster fisheries. He found that although some island areas have managed to defend their traditional territories, other areas have seen increased mixing in the inshore territories since retaliation has been discouraged by threat of loss of license, a fine, or time spent in jail (Acheson and Brewer, 2003). Harvesters in other perimeter defended areas such as Swan's Island and Monhegan have been successful in lobbying the government to implement conservation zones around the Islands. Harvesters from these Islands have convinced the government to defend their traditional territories by using state wardens and agreeing to the strictest conservation measures in Maine.

In Maine, technological change, the introduction of new boats, competition between harvesters, an increase in the number of full time lobster harvesters, and the collapse of the groundfish fisheries have led to an explosion in the numbers of traps on Maine's lobster fishing grounds, and expansion into offshore areas (Acheson and Brewer, 2003). In 1995, a Zonal management system was implemented whereby the coast was divided into seven zones that modeled the traditional territories, each governed by elected harvesters. Each zone has trap limits, limitations on the number of traps allowed per line, and on the hours of the day when fishing is allowed. The license holders from the zones vote on these implementations. The government did not expect implementation of these zones to cause major problems because they were based on traditional territories and because the harvesters were allowed to fish on both sides of the zone boundary, following the restrictions of the strictest zones.

Since these changes were implemented there have been disputes in five out of seven management zones. Many people in Maine believe that the longstanding traditional territories of the Maine lobster fishery, through pressure from new formal management strategies, are undergoing serious changes. There is some evidence to support these concerns. For harvesters in nucleated areas, barriers to entry have been lowered and more mixed fishing is allowed making it easier to gain entry into harbour gangs (Acheson, 2003). Harvesters in perimeter defended areas believe that the territorial system is intact. However, Acheson argues that their views were clouded by a siege mentality and that they hoped they would retain these territories. These harvesters were clearly worried about increased incursion by mainland boats and were finding that increased patrols made defending their areas through illegal acts more difficult. Some believe the traditional spatial distribution of territories will be erased in the future. These developments highlight the possibility that even management initiatives modeled from indigenous practices can have detrimental effects (Acheson and Brewer, 2003).

Based on fieldwork on Newfoundland's west coast, Palmer (1992) worked on the role of folk practices in developing new formal management initiatives in the lobster fishery. He states that on the surface, formal management strategies modeled from folk practices appear to have a conservation effect for the benefit of the larger social group. Maine has excellent examples of formal management rules used to model indigenous practices. In Newfoundland, however, according to Palmer, indigenous practices did not conserve the resource for the long term good of the social group. In both areas harvesters realized that the indigenous management systems did not prevent declines in lobster populations.

Palmer criticizes the idea that indigenous conservation practices have evolved from group selection (Palmer, 1993). Many authors argue that the assumptions about the "adaptation" and "evolution" of such practices do not hold up when made explicit (see for example see Hames, 1987).

Berkes (1989b: 74) explores the unanswered question of how to incorporate local cultural practices into the field of evolutionary biology. The idea of group selection borrowed from evolutionary biology has been dismissed in that field, and replaced by individual selection, highlighting the fact that when the two are contradictory, individual selection choices will override group selection (McCay and Acheson, 1987). Palmer

(1992) explains that the acceptance of formal rules cannot necessarily be taken for granted even if they are based on indigenous rules. He highlights the importance of examining the motivations behind harvesters' acceptance or rejection of formal rules and the socioeconomic context within which they are presented. In the case of the Newfoundland west coast lobster fishery, for example, he finds harvesters were motivated to accept the formal regulations because they realized the instability of the resource associated with folk managed fisheries. In this context, motivations that benefit the individual replace any that benefit the group. For example, he argues that the recognized taboo on Sunday fishing on the northwest coast of Newfoundland was not practiced because it benefited the social group; rather it was based on religious and social motivations. According to Palmer, "the future of the Newfoundland fishery does not hinge on the incorporation of folk practices, but on the incorporation of fishers into the decision-making apparatus of the Canadian Government" (Palmer, 1992, p.49). This is not to say that that the future of the fishery depends on either/or but it could depend on a combination of incorporation of fishers and support for folk practices. Palmer's research, however, was conducted in a place and a time when conflicts between government policy and local practice were particularly strong in his study area. Palmer concludes that if it is to be effective, indigenous practice needs to be supported by formal rules.

As can be seen from previous work done on lobster fisheries, research has started to focus more on the people involved in these fisheries and the importance of bringing their knowledge to the management table. Previous research also highlights the importance of studying local management practices (such as territories) and knowledge when developing new management initiatives. It also, however, points to some constraints associated with such practices. This research proposes to use some scientific information on the biology of lobsters, but is more focused on how LEK can be collected to inform the development of an IBM computer simulation model. This model also brings to light the incorporation of the harvester's decision-making processes and the effects management initiatives can have on their behavior and strategies. A further discussion of this IBM and what this model can bring to future management policies will be presented in chapter 4. Chapter 3 explains how the LEK for this project was collected and how the information collected will be used to develop a model based on the individuals within the fishery.

Chapter 3: Fieldwork Methods

The purpose of the fieldwork component of this study was to inform the development of the IBM. The fieldwork had four main components: preliminary and follow-up phone interviews, onboard observation, demographic and strategy interviews, and expert/retired interviews with lobster harvesters who fish in St. John Bay. This is the first time most of the harvesters from this area have been interviewed about their fishery. Detailed and extensive amounts of information stand to be learnt from such a project.

Preliminary phone interviews were completed in the winter of 2002, and follow-up phone interviews were completed in the fall of 2003 (see Appendix A). The preliminary phone interviews gave me a basic understanding of the lobster fishery in St. John Bay. This allowed me to make a first attempt at developing code for the model. In turn this code made it evident what other types of information would be required from the face-to-face interviews for development of the models. The follow up phone interviews involved short, informal questions on the number of licenses in each community and the Bay as a whole. There was no formal interview schedule for these follow-up interviews. Results from both sets of phone interviews were recorded in a notebook.

Fieldwork was undertaken during the 2002 lobster fishing season from early May until early July. Additional face-to-face interviews were carried out in October of 2002. A local woman named Megan Coles was hired as my assistant as part of a joint partnership between Coasts Under Stress and the Conservation Corps. Megan's father fishes for lobster in St. John Bay and over the past several years she has accompanied him during the fishing season. We started spreading the word about the project through word of mouth and an ad in the local newspaper as soon as I arrived in the area.

3.1 Preliminary and follow-up Phone interviews

In the winter of 2002 I completed four telephone interviews with harvesters who had participated in the at sea sampling project with DFO in 2000 and 2001. I retrieved their names from the onboard observer and contacted them to see if they would be interested in helping me with my project. The four participants had different levels of experience within the lobster fishery; some had been fishing lobsters since they were children and others joined the fishery after the collapse of the cod stocks in the mid 1980s. I asked them general questions about how and where they fished for lobsters (see Appendix A). Since I had little information on how lobsters were fished I asked them to take me through a typical season and explain to me how they set their traps and moved them as the season progressed. I used a sketch map of St. John Bay provided by the fisheries observer and a nautical chart to record information. The information obtained (maps and hand written notes) gave me ideas on how I would start to model the harvesters' behavior.

Every harvester seemed to have certain areas where they would fish and they all reported moving into shallower water as the season progressed. Depth and bottom type were both cited as important factors they used when deciding where to fish over the course of the season. They also highlighted the use of test lines, whereby they would set a few lines in shallower water to see if they could "find where the lobsters were." Wind was identified as a driving force in their decision-making influencing what routes they would take and what sequence of areas they would go to on a given day. They were also asked about what equipment they used to find lobsters, for example, GPS, compass, charts and sounders.

These harvesters reported changes in the number of traps per line they used. They also reported that they used different strategies for finding good lobster areas. These included using traditional areas that were handed down to them from their fathers, following harvesters that had been fishing there for a long time and knew the lobster area well, and they also reported using trial and error to find new "special spots" for fishing lobsters. The information obtained while conducting these interviews helped me develop the questions I would need to ask the harvesters I would be interviewing during the fieldwork in the spring.

After the preliminary phone interviews were completed questions on all these aspects were added to the demographic and strategy interview schedules (Appendix A). I also started to write the preliminary code for the model. While I was writing the code it became apparent that additional questions would have to be investigated in order to model the situations that the harvesters were reporting. I needed to find out where and when the harvesters obtained their licenses and how long they had been fishing in St. John Bay. In addition, I needed to know how many test lines they would set, what the beginning and ending depths for fishing lobster would be and when and how they would decide to move their traps into shallower water. When and how would they decide to take their traps in at the end of their season? How many traps would they check in a single day and what this depended on? How did they decide what areas to fish i.e. did they fish traditional areas, follow others, or use trial and error? We also need to explore communication among harvesters and how that affected their fishing strategies. Additional questions on buddying up (fishing two licenses out of one boat) and why they would do this were needed. It was also important to find out who was fishing with these harvesters, i.e. about crew structure. The effects of other fisheries on the effort put into the lobster fishery were explored further. At this point, I decided that I would need to bring a nautical chart with me since the harvesters seemed to use these and were very familiar with them.

Through this initial attempt to model the fishery based on these preliminary interviews the demographic and strategy interview schedule and expert interview schedule were developed.

3.2 Onboard Observation

The onboard observation consisted of joining 10 lobster harvesters for a day of lobster fishing. I joined harvesters for a fishing trip and sometimes Megan joined us as well. Informal discussions took place during the trips and I recorded handwritten notes in a waterproof notebook related to these. These notes were used along with interview data to define strategies and decision-making within the model. Several other fishermen invited me to take a trip with them but weather and time did not permit me to do any additional onboard observations.

The ten harvesters who participated in this part of the fieldwork were fishing from different communities within St. John Bay. This was important since there could have been significant differences in fishing practices and strategies between different communities. This sampling strategy also ensured I would gain an understanding of fishing activities in most of the general fishing areas of St. John Bay. These were important elements for input into the model during the modeling aspect of the methodology.

Since I had never fished for lobsters before, the first thing harvesters had to explain was exactly how they fished for lobster. They showed me how they string several traps (the number of traps differs among harvesters) in a line and attach a buoy onto each line so that they can find them when they return to check their lines. I asked them questions concerning changes in technology and how these have affected their fishing strategies and behavior. Questions were also asked about how much they rely on technologies such as sounders, and how long these technologies have been used in this lobster fishery. I watched them check their traps and return them to the ocean floor. I made notes on exactly how they fished for lobster so that there would be no miscommunication when talking about the lobster fishery during interviews. The harvesters thought the best way for me to learn about how to fish lobster, in addition to all the questions I asked, was to take part in the activity myself. During the several weeks of onboard observation I helped the harvesters haul traps, check for lobsters, measure the lobsters, band the lobster claws, bait traps, and return the traps to the water.

After I had an understanding of how lobster was fished, I needed to understand the fishing strategies and behavior of the harvesters that I would be modeling. These questions generally focused on how they decided where they would fish for lobsters. For example, did people inherit berths in certain fishing areas, did they follow other people or did they use trial and error? In addition to observations on how they would decide to move their lines, I was interested in what depths, bottom types and bottom type configuration they were looking for in order to set and move their lines. How low would the catch on one line (catch threshold) have to be before they would move it, and how did they decide where to move it? Answers to these questions helped me establish critical factors that were affecting the harvesters' strategies and behavior.

Figure 3.1. Onboard observation: banding lobster claws.

Documenting the crew structure of each boat was another important component of the onboard observation. These social aspects of the fishery were important to understand since they would be used to model individual behavior. Did many people fish with relatives? How many of the boats had buddied up so that more than one license was being fished from the boat? Did the harvesters have sharemen (paid crew members who may or may not have been related to the skipper) fishing with them? Had there been any changes in crew structure over time and did these affect fishing strategies? For example, did the introduction of many harvesters' wives onto the fishing vessels have any effects on fishing strategies?

Questions were also geared towards figuring out the levels of communication among harvesters from the same and differing lobster fishing communities within St. John Bay. In the context of the lobster fishery, community means the place they fish from, whether it be a community such as Port aux Choix or an Island such as St. John Island. During the onboard observation, I noted the number of boats in any given area where the harvesters had taken me. I also noted any communication between boats and if this differed depending on their relationship to each other. I also noted the information they verbally exchanged with these people. I was trying to observe whether the information was more accurate and detailed between harvesters with close family relationships. I also tried to see if there was communication shared among harvesters fishing from the same community and if this differed across the bay as a whole. If there was communication, was it as accurate and detailed as that shared between family members? The purpose of this exercise was to establish if communication affected the harvesters' strategies and behavior and, if so, what information would be shared, and by whom in the model.

Crowding of the lobster fishing areas was also investigated as another factor affecting fishing strategies and behavior. I asked them if the number of boats in the harvester's fishing area had changed over the course of their fishing careers. When and why did this change occur, and what was the extent of the change? If areas became more crowded, how had this affected their fishing strategy? For instance, did newer harvesters watch where other harvesters were moving their lines in order to follow them? If this was the case, were there any conflicts between newer and older harvesters?

At the end of every onboard observation the harvesters and myself would draw the routes we had taken that day on a waterproof copy of nautical chart no. 4680. They were then asked if they took this route every day. Were there differences in the routes taken and, if so, why? Then the harvesters were asked if they had always fished these areas. If there had been a change in their areas then they were asked to indicate this change on the map along with any reasons they could provide for it. All maps were studied in detail, and I defined the factors responsible for any spatial changes in fishing areas. These factors were then implemented either directly or indirectly within the model, so that the model could produce a situation that resembled reality.

3.3 Demographic and Fishing Strategy Interviews

During the same time period as the onboard observations were being conducted I also interviewed harvesters who currently fish for lobsters in St. John Bay. These demographic and fishing strategy interviews were intended to provide me with an understanding of who fished for lobster in St. John Bay, what strategies they used while fishing for lobster and their ideas about past, present and future management initiatives. The interviews were originally supposed to be completed over the phone, but I completed the first one in person at the request of the participant and then decided, due to the length of the interview, and due to the fact that the interviews really needed a face-to-face mapping component, that I should perform the interviews in person. We began this component with a complete list of 242 license holders for statistical sections 48 and 49 (includes St. John Bay and all communities to the tip of the Northern Peninsula). In order to narrow this list down to current St. John Bay harvesters, Megan and I talked to lobster buyers and harvesters resulting in a list of 160 names. Fifty names of participants were chosen at random from those identified as fishing in the bay using the SPSS random function.

Forty-three of the fifty people whose names were randomly selected were interviewed, one fourth of the overall population. Four other participants were willing to participate, but our schedules conflicted, and time didn't permit the interviews to be completed. The remaining three participants simply said they did not think they would have time for an interview during the fishing season. In addition to the 50 names chosen by the random sample, there were several additional harvesters who wanted to be interviewed, but time didn't permit an interview. However, I spent some time talking to these harvesters on the wharfs, telling them about my project and taking suggestions regarding ways to improve my interview questions.

These interviews ranged from 1 ½ hours up to four hours, depending on how much the harvester decided to talk. Information was recorded in the spaces provided on the interview schedule. Information on spatial changes was also recorded on the maps.

These interviews were not tape recorded. As each interview was completed, especially the first few, additional questions and points of clarification were added to the interview schedule (see Appendix A). Additional questions were needed in order to be able to model the fishery, and thus the interviews evolved into the version in Appendix A. Questions were added on exactly how they decided to move their lines, what proportion of their lines they would move, etc. In general the questions on strategy were expanded to make sure we had a good understanding and these could be modeled. The addition of the mapping component meant that the harvesters could draw on the maps themselves, and this was easier than drawing the changes in areas while they communicated to me over the phone (as was done in the preliminary phone interviews). Both my assistant Megan and myself conducted interviews in the homes of participants and in their fishing cabins. The information from these interviews was coded and then entered into an Excel spreadsheet for later analysis.

The interviews focused on demographic information, fishing experience, experience with the lobster fishery, fishing licenses, fishing activities affecting strategies and decision making, competition for lobsters, and lobster conservation. Information on all the aforementioned aspects of the lobster fishery was needed in order to develop the IBM. The demographic section (section 1a) was used to acquire an understanding of who fished for lobsters in St. John Bay. These structured questions focused on the participant's age, community they were from, their spouse's occupation, if their children fished for a living, and their level of education. Analysis of these data, completed the following fall, included: average age of a St. John Bay harvester, the percentage of women fishing in the lobster fishery, the percentage of harvesters who fish with their children, and the average level of education.

Section 1b included questions dealing with the participants' experience fishing. They were asked general questions about where they had fished from, and about who they fished with for lobsters. The crew composition information provided an understanding of who was on these boats and what relationship they had with the license owner. Since the lobster fishery comprises many different families, community groups, friends, and individuals coming from different backgrounds, it was important to start the interviews with these types of questions in order to understand relationships and communication that would later be modeled. This information was also stored in the database under the 'Relations' variable.

Section 1c dealt with the participants' experience in the lobster fishery. Earlier reports from CUS interviews the previous year suggested many harvesters had transferred licenses into St. John Bay in the mid 1980s. We needed to figure out if this influx actually happened, and if so, the percentages of harvesters from each group (those fishing before 1985 and those who started after 1985) currently fishing in the Bay. We accomplished this by asking structured questions on when and where they obtained their lobster license.

Section 2 of the interviews shifted focus to information on fishing practices, strategies, and information used in decision-making. Within this section there were seven subsections covering different aspects of harvesters' strategies. Questions were semi structured and open ended, so that the participants could share as much information as they felt comfortable with sharing. A few harvesters felt that answering a few of the questions related to moving lines would give away their individual strategy. Information on strategies was coded and put into the database. The data were then analyzed to investigate such factors as the average wind limits and catch thresholds of participants, average numbers of traps per line, the distribution of harvesters fishing between fishing areas, etc. It was important to discover the critical factors that affected fishing behavior and that are used in their decision-making processes in order to include these factors in the simulation model.

Subsection 2a focused on general strategy questions such as the number of traps per boat and the number of licenses per boat. Participants were also asked if they knew what proportion of people from their community, and from other communities, buddy up (fish two licenses from one boat). This was asked to ensure we had an accurate picture of the distribution of buddying up and to see if there was likely any difference between communities. We also asked the harvesters to tell us how they decided where to fish at the beginning of their careers.

Subsection 2b was developed to investigate lobster-fishing areas. A nautical chart was used to map changes in their lobster fishing areas over time. Since the model was to simulate the changing spatial dynamics of fishing areas within the Bay, I needed a clear picture of how the harvesters had changed the position of their lines both within a season and over their careers. This was accomplished by first asking them in what areas they had fished for lobster at the start of their career. The general areas indicated were drawn on the map. If they went to new areas or abandoned old ones, this was also indicated on the map. Lastly I asked them if they traveled to these areas in the same sequence everyday, or if this depended on wind conditions, and past days' catch. If any changes were described, I also asked them when and why these changes occurred.

Subsection 2c dealt with the importance of the lobster fishing to the harvesters' overall income. We needed to see if there had been changes in the importance of income from lobster after the cod fishery decline. Differences were explored between harvesters who had always fished for lobsters in St. John Bay and those who started fishing there after 1985.

Subsection 2d investigated other fishing licenses that each participant owned. Were there any alternatives for these people if the lobster fishery failed? Did they have access to crab licenses? Were there any differences between harvesters in this regard?

Subsection 2e focused on fishing activities and associated strategies. Two critical factors were explored: wind speed and catch per line per day. Participants were asked how much wind would keep them from fishing lobster and this was called the wind limit. They were also asked how low their catch per line would have to go before they decided to move it and this was called the catch threshold. They were asked if there had been a change in this catch threshold over the course of the season and over their careers.

Participants were asked how they decided where (general areas, depths, bottom types and configuration) to fish for lobsters. The number of traps each participant fished per line and any changes in this were also explored. We also investigated if the harvesters would put test lines in shallower or deeper water just in case. The number of lines each harvester checked each day, and any changes that had occurred in this over a season and over their careers were explored. When and why these changes occurred was also important in identifying factors that affect strategy and behavior.

Subsection 2f focused on trends in competition for lobsters after the influx of new licenses into St. John Bay. The participants were asked how it was decided where people would put their pots, whether it would be on a first come, first served basis, community fishing territories, individual territories, following others or something else. I asked them if the number of boats fishing the same areas as they were fishing had changed over the course of their careers. If so what communities did these new boats fish from? They were also asked if there was ever a situation where it would be too crowded to set lines. If so what would they do? Responses to these questions were coded and added to the database. These questions were important to establish how new harvesters would affect the decision-making processes related to setting and moving lines in the simulation model.

Subsection 2g was used to uncover any other fisheries that would overlap either spatially or temporally with the lobster fishery. For example, did the opening and closing of other fisheries and the abundance and price of these fisheries have any impact on the effort that the harvesters would invest in lobster fishing? This information may be used in future versions of the model to detect how other fisheries affect effort put on the lobster fishery.

The third section of these interviews dealt with lobster conservation. Questions focused on changes in landings over their careers. The intent was to compare this information with that we obtained from DFO in order to add lobster population to the model. Harvesters were also asked what would need to happen in order for them to stop fishing in St. John Bay and about their optimism for the future of the lobster fishery. Finally, they were asked to rank the present management initiatives they thought would best protect the lobster stocks. The interview ended with a few open-ended questions about the health of the lobster stocks, and the management of lobster in their area. Using this information an interesting comparison can be made between the initiatives the harvesters think would work (for example trap cuts) and the model's predictions.

At the end of each interview the participants were asked to recommend 3 people who fish from the same community who in their opinion would be most knowledgeable about the lobster fishery. This was used to develop a peer recommended list of expert harvesters ranked on the basis of the number of votes they received, for the final component of the study.

3.4 Expert Interviews

From this peer recommended list, harvesters were chosen to take part in the final round of interviews. From the list of the top ten peer recommended harvesters, eight were contacted. Unfortunately time allowed only seven of these participants to be interviewed. These interviews (see Appendix B) were from 2 hours to 5 1/2 hours in length. I recorded information directly on the interview schedule, while Megan took additional notes in a notebook. As with the demographic and strategy face-to-face interviews, information on spatial changes was recorded on a map. These interviews were tape-recorded in case we lost information during the recording of our notes.

The purpose of the expert interviews was to explore changes in all aspects of the fishery over the thirty-year study period. For this reason participants in this part of the study were people who had been in the fishery for at least thirty years. A few participants had already retired and the rest were still currently fishing lobster in St. John Bay. Participants were also chosen on the basis of what community they fished from. I tried to interview at least one participant from each of the main fishing communities within the Bay. Two of the seven recommended participants turned out not to have fished in St. John Bay for the entire duration of the study period. However, they still provided information on changes in the fishery for the years they had participated. One of the remaining harvesters fished from a community that was not included in the demographic and strategies interviews. Since we were missing information on the demographics and strategies of this community this participant agreed to do both interviews in order to give me a complete picture of the fishery, and changes in this fishery from this community's perspective.

Some of the participants had already completed the demographic and fishing strategy interview. Those who had not were taken through any questions that were not repeated on the expert/retired interviews. This meant that data from the experts and retired harvesters could be compared to data from the fishing strategy interviews.

Section 1 of the expert interviews (see Appendix B) gave an idea of how long people had been fishing lobster in St. John Bay. I also established a time line, which we could refer back to when figuring out the dates when changes had occurred. To accomplish this we asked them about the boats (boat size and engine) they had fished in over their careers and the changing dimensions of their boats as reference points.

The remainder of the interview was divided into several sections. Section 2 included questions on their fishery (2a); management (2b); economics (2c); events leading up to and after the cod moratorium (2d); and ecological changes (2e). After each section was completed the interview focused on changes to this particular area of the fishery over their careers. During this change component part of the interview, we asked when changes occurred, why they occurred, how long they lasted and whether they occurred quickly or slowly. Where applicable we asked how these changes had affected their lobster fishery (for example boats, gear navigation equipment, fishing areas etc), the lobster resource, lobster management in the area, their income, relationships within communities, new entrants, and their individual strategies.

Section 2a included questions on all aspects of the participants' fishery. They were asked about the number of traps in the water, number of times they would check their traps, trap design, bait, navigation equipment, hydraulic trap haulers and how these things had changed over the course of their careers. We also asked questions on the number of harvesters per boat, buddying up, the number of harvesters that fished alone from each community, crew structure, and cooperation among harvesters, again focusing on changes over time.

Section 2b consisted of questions surrounding how the lobster fishery has been managed over the thirty-year study period. The participants were asked about local rules as well as DFO regulations that have influenced the lobster fishery. Enforcement, including the number of DFO officers in the area and the number of times the participants had been checked over a season, completed this section. Since there is a management component in the model I needed to have the background information on this aspect of the lobster fishery. As with the previous section, they were asked to describe changes and impacts of these changes outlined in the change component part of the interview.

Section 2c concentrated on the economics of the lobster fishery. Questions relevant to the price of lobster, proportion of fishing income from lobster, catch per unit effort (CPUE) in good, medium, and poor seasons, size of lobsters, and landings over a season. They were then asked to describe any changes and the impact of those changes on the economics of their fishery.

Since the cod moratorium has been inadvertently affecting the lobster fishery, section 2d focused on the events prior to and following this major event in the history of the lobster fishery in St. John Bay. The participants were asked to describe other fisheries they participated in and how important they were in terms of overall income and in relation to lobster income. They were asked if there were spatial or temporal overlaps between cod and lobster fisheries. The areas where they fished for other species were drawn on nautical charts in green lead pencil. Lastly they were asked to describe any conflicts that may or may not have occurred between different fisheries.

As a sub-component of the model, the lobster population and movements had to be modeled. This was done by using scientific information on landings and reports on movement, in addition to information obtained from section 2e dealing with ecological questions. The participants were asked when they thought the number of lobsters in St. John Bay had peaked and how the lobster population had changed, and these observations were compared to landings data obtained from DFO. Their observation of the numbers of small and spawny lobsters and any changes were also noted. Lastly, the types of environments (depths, bottom types, bottom structures) that they associated with lobster were also explored.

Section 3 was the mapping component, and it focused on changes in lobster fishing areas within St. John Bay over their careers. Questions on the lobster fishing areas within St. John Bay were followed by questions that were subdivided into three sections: expert fishing areas (3a), community territories (3b), and new entrants (3c), i.e. harvesters entering the fishery after 1985. I wanted to compare community-fishing territories before and after 1985 and map these changes. Each participant's fishing areas, their community fishing areas, and new entrant's fishing areas were drawn on a nautical chart, numbered and the number was then spoken into the tape. The numbers were spoken into the tape to ensure no details from the map were lost. In order to know what spatial patterns to expect from the model, I needed to figure out what had happened to the lobster fishing territories over the 30-year study period. Composite maps from the both expert participants and the participants from the demographic and strategy interviews were produced to show changes over time.

During section 3a on expert fishing areas we wanted to understand how people tended to divide up lobster fishing areas in the past as opposed to the present. For example was it on the basis of berths, family or community areas, first come first served, a share system or something else? Did they have any areas that they considered their traditional fishing areas; areas they went with their father or grandfather? The expert fishing areas were mapped in blue pencil. Changes in fishing areas over a season and over their careers were indicated on the maps as well. Usually movements were shown as arrows with short notes attached to describe what the arrow meant. As with the first round of interviews these participants were asked about routes taken and sequences of areas. Then each participant was taken through a season in terms of depths fished, movement into other general areas, and reasons for these movements. If there had been any changes in these strategies over their careers, they were asked to explain when, how, and why these had occurred. They were also asked how the cod collapse affected the way they divided their lobster fishing areas. During the last part of this section we asked them if there were any areas they were more likely to see small lobsters. These areas were indicated using brown pencil and by attaching a symbol 'SM" to the areas.

Section 3b explored community-fishing territories. Since we could not interview everyone from each fishing community we asked our participant to try to give us an idea of where others from their community fish for lobster. The community fishing territories were indicated in purple. The general numbers of boats on these territories and any overlapping territories were also investigated. Again changes in these territories were discussed and mapped when appropriate.

Section 3c related to the introduction of new entrants after the collapse of the cod fishery. Since this was a major change in the lobster fishery, any spatial changes that had occurred as a result of this were tracked. These areas were indicated in red in order to distinguish this group from other harvesters. They were asked when the new entrants began to start fishing in St. John Bay, how many new entrants came, the reaction of other harvesters, and how they decided where to fish. In addition we also needed to know how these new entrants affected pre-existing community boundaries and how the situation was handled. In other words, did DFO or local harvesters enforce these boundaries? At the end of this section we mapped any areas where poaching was identified as a problem.

Section 4 focused on the relationship between DFO management and the lobster fishery. Throughout this section the effectiveness of rules and enforcement were explored. They rated DFO's level of enforcement as adequate or not adequate. They were also asked if they knew how DFO assessed the lobster stock,s and if so, could they think of any improvements to this process. In addition, they were asked if they thought the current level of enforcement was enough to adequately protect the lobster stocks, and what would be an effective way to provide feedback to DFO. They were asked if they thought more could be done to incorporate local knowledge into the stock assessment process.

Section 4b of the interviews focused on the participants' ideas on management initiatives. They were asked if they thought initiatives such as the ones taken by the Eastport Peninsula Lobster Protection Committee would work in St. John Bay. Since the model will implement one of the Eastport management initiatives (closed areas) it will be interesting to see if the results comply with harvesters' expectations. In addition, each participant was asked to talk about the pros and cons of preexisting and new management initiatives. They were asked if they thought that the general fishing population was concerned about the future of the lobster population. The level of fishing effort and ideas on how to reduce it were also discussed. The model also tested some of these ideas, such as a trap reduction. There was also an open question in which the participants were asked if there were any additional conservation measures that they would like to see implemented.

Using these methods, I obtained information regarding the individual characteristics and strategies needed to inform the development of my model. Results from this portion of the research are found in the following chapter.

3.5 Integration with the model

The fieldwork and model components of this research were developed and reworked interchangeably in light of each other. As the logic and input data for the model were being developed alongside the completion of interviews, questions were fine-tuned to obtain information needed to model the situation accurately. Information on such factors as community the harvester fishes from, number of boats fishing from that community, number of traps they used, beginning and end dates of fishing careers, and catch thresholds were input into the model.

A simulation model takes a real life situation, in this case a lobster fishery, and translates it into a computer environment. Harvesters are the basic unit of the simulation and boat agents represents each of the harvesters involved in the lobster fishery. The model structure reflects the structure of the lobster fishery in general.

After the interview data were collected, coded and summarized in the database the code for the model was further developed. During this process several things had to be explored in order to make sure the ideas I had were consistent with what the harvesters were actually doing. For example, it was thought that they would move their lines into shallower water as a result of poor catch. A few follow up phone discussions were made to confirm that this was actually the case. I also wanted to confirm the types of information that would be shared and with whom. These follow up phone discussions were very useful in the code development and in defining what information should be used as input into the model. Questions were asked about how and when they decided to move their lines over a season. This was to confirm what I thought was the case and to make sure it was correct before I modeled the behaviors. I also wanted to confirm the changes in the number of boats from the different communities so that I could add appropriate numbers of boats to the model.

After the first versions of the model were completed, additional follow-up phone interviews were conducted in the fall of 2003. The purpose of these interviews was to confirm the number of active fishing licenses within St. John Bay, and within each community. We also wanted to find out if any changes had occurred in these numbers in 2003. In addition, questions were asked about relations among harvesters so that this could be more accurately modeled. Additional harvesters from the Ferolle Point areas were contacted to fill in the number of licenses fished from that community and the changes that had occurred there.

With the aid of information obtained in the fieldwork component, digital maps of St. John Bay, seasonal length data, management data, lobster population data, characteristics of harvesters themselves, calibrated parameters, and through further follow up interviews, the model was used to ground the simulation agents in the empirical data patterns found in St. John Bay. The simulation model, defined in chapter five, runs through every day of the lobster season, the boats setting lines and returning each day to check and possibly move their lines. The boats move their fishing lines from one area to another as they look for and follow the lobsters.

3.6 Ethics

According to the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* prior to any fieldwork dealing with humans the research must have approval from a Research Ethics Board. The Interdisciplinary Committee on the Ethics of Human Research (ICEHR) at Memorial University approved this project. Participation in the study was free and voluntary. Potential participants were given a description of the CUS project, my research and the types of questions to expect. This information was reviewed before they were asked to sign a consent form (See Appendices C-E). For the on-board observation component, prior to leaving the wharf each harvester signed a consent form (See Appendix C) that explained the nature of the project, and any risks or benefits that may arise as a result. It was explained that the risks in such a project are seen as minimal. The benefits were limited to the opportunity for each of them to influence the findings of this research. We explained to them that participation in this research was voluntary and they could withdraw from the study at any time. Each participant was told that his or her name would not be used. Instead each participant was given a number to protect anonymity, but it was also indicated that in the case of onboard observation, we could not guarantee their anonymity since other harvesters may have seen me onboard the participant's boat or known that I had interviewed them. This meant it might be possible for someone to associate particular observations with a particular person. In these cases the participants will be given an opportunity to review the information containing their observations in the form of a report, which I will present to all St. John Bay lobster harvesters during a follow-up meeting. It was also explained that they could feel free to decline any question given to them without having to justify their decision.

Participants were also asked to sign a consent form prior to taking part in the demographic and fishing strategy interviews (see Appendix D). The consent form repeated all the issues from the onboard consent forms. For the expert/retired interviews (see appendix E), in addition to the outline of the project and description of any risks and benefits they could expect, I also had to ask their permission to tape these interviews.

Taping of the interviews was imperative to permit me to focus on what they were saying instead of trying to write notes to capture everything that was being communicated to me, and to ensure that none of the information they provided was lost. Each participant was told they could request a copy of the research from the Coats Under Stress office in St. John's. As part of the consent process, the participants agreed that the transcripts and tapes would be stored in a locked cabinet at the Coast Under Stress office in St John's.

3.7 Conclusion

Although biological science was used in the development of the model, the collection of LEK allowed me to explore the lobster fishery in depths not possible through biological science alone. Having a presence in the community, meeting people on wharfs, in their homes, at their cabins and interviewing them has permitted me to gain a better understanding of the lobster fishery. This is very important in developing a good model. A model based on a well-understood fishery will more accurately simulate reality. The following chapter will present the results of the data collected in the field and show how that data was used to inform the model.

Chapter 4: Fieldwork Results

4.1 Introduction

This chapter summarizes the results from the interviews and onboard observation conducted while in the field. Results from expert interviews provided a snapshot of the fishery up to 30 or more years past and were used to help develop a historical reconstruction of all aspects of the fishery. Expert interview results also helped confirm results from demographic interviews expanding on those findings in terms of changes over time. The demographic interviews contributed a profile of the fish harvesters fishing for lobster in St. John Bay in 2002 and information on fishing strategies used by harvesters. Issues surrounding the influx of new licenses in the mid-1980s were explored in relation to strategies used by harvesters. Changes in areas fished and responses to the crowding situation were also documented. During the onboard observations, information on how harvesters in St. John Bay fish for lobsters, their fishing strategies and information on communication among harvesters was collected.

4.2 Expert/Retiree Interviews

These interviews focused on changes in all aspects of the fishery over the 30-year study period. A time line was established by asking each expert to describe the different boats they had fished from over their careers. Throughout the rest of the interview this timeline helped the harvesters recreate the history of their fisheries. Seven expert and retired harvesters were interviewed. Of the seven harvesters participating in the expert/retired interviews, 6 were fishing lobster in St. John Bay at the beginning of the study period in the early 1970s.

During the 1970s there were no limits on the number of traps harvesters were allowed to fish. Of the six harvesters who were fishing in the 1970s, all reported having a lower number of traps than they acquired when the first trap limit of 600 traps was imposed in the 1980s. Those harvesters involved with the fishery at this time reported fishing between 200 and 500 traps. After the trap limit was imposed they all went up to the total allowable number of traps. Only one harvester reported using 650 traps in the 1970s. He cut down to 600 when the limit was imposed.

All expert harvesters reported that, in the 1970s, the traps were larger than they are today and that they fished more traps to a line (10-15 traps per line as opposed to 6-10 traps per line presently). In addition they fished fewer lines than today (25-40 lines as opposed to 50-60). They checked their lines as frequently as today, poor weather or poor catch being the only factors that would affect this. The bait they used was the same except that at that time, they would often catch their own bait. When bait was scarce they bought it. Bait was very cheap to buy in these early years.

Five harvesters reported they used mostly landmarks and compass to fish for lobsters in the 1970s. The GPS systems discussed in the demographic interviews were not introduced into the Bay until the 1990s; sounders were around but not in large numbers until the late 1980s and early 1990s. Harvesters used jigger lines (with weights attached to them) to determine the depths of the wate,r and they reported hauling their pots by hand until the introduction of hydraulic motors in the 1970s. Reports suggest that people fished alone more often than today but sometimes they would take on a shareman. In the 1970s and 1980s it was more common to take a shareman than it is today. Of the people who did not fish alone or have a shareman, crews were mainly composed of family members. The majority of reports suggest that people did not begin to buddy up until the mid1980s.

All expert harvesters reported that there were local rules about not eating spawny lobsters in the past. They reported a decrease in season length and two increases in carapace sizes over the course of their careers, although they were not sure about the exact timing of these changes. They all seemed to know that the last reduction in the trap limit (down to 425 traps per license) was implemented in 1996. They all reported that the number of times they were checked by DFO officers had increased since the early 1970s.

The price of lobsters in the early 1970s was between $2.90 and $3.50/pound. Prices increased steadily to about $5.50-$6.00/pound at the time of the interviews in 2002. The average catch in the 1970s was between 60 and 100 crates of lobsters (6,000 lbs-10, 000lbs). Because the minimum size for lobsters then was smaller than today, it would take about 90 lobsters of approximately one pound each to fill a 100 pound crate at that time. Today, it takes 70-75 lobsters to fill a crate.

Table 4.1. Lobster catch (pounds) and effort (traps) of expert and retired harvesters interviewed in St. John Bay, Newfoundland and Labrador.

Fisher ID No.	Year Initial	Traps	Initial Catch /season (lbs)	CPUE (catch/trap/season)	Year Final	Traps	Final Catch/season (lbs)	CPUE (catch/trap/season)	Δ CPUE (%)
1	1950	400	8,000	20	1980	300	4,250	14.	-29
2	1985	400	6,000	15	1996	1700	9,000	5	-65
3	1967	200	5,000	25	1994	450	3,750	8	-67
4	1950	300	7,000	23	2001	850	5,000	5.8	-75
5	1950	200	4,000	20	1987	600	5,500	9.2	-54
6	1965	325	5,500	17	2002	850	3,000	3.5	-79
7	1967	650	10,000	15	2002	850	4,700	5.5	-64

Individual landings have declined over the past 50 years; however landings alone do not provide an accurate picture of the changes being experienced in St. John Bay. The catch per unit effort (CPUE), i.e. the catch per trap per season, was calculated for all expert/retired harvesters both for the year they started fishing and the last year they fished before the interview was conducted (Table 4.1). The CPUE has declined since the early 1950's. The CPUE in the 1950's was between 20 and 23 lbs per trap per season. By the 1980's the CPUE had declined to between 9.2 and 15 lbs per trap per season. The CPUE dropped again in the 1990's to between 5 and 8 lbs per trap per season. The latest data recorded for 2001 and 2002 showed a continued drop in CPUE, to between 3.5 and 5.8 lbs per traps per season. In addition, harvesters also reported having to travel farther and fish a much larger area than in the past, for lower catches.

The change in CPUE (Table 4.1) was calculated using formulas described in Neis *et al.*, 1999. It is clear from these calculations that the major changes in CPUE occurred after the mid 1980's. The two harvesters who stopped fishing before the mid to late 1980s had lower percent CPUE change values (-29% and -54%). The remaining harvesters had greater declines in CPUE values, ranging from -64% to -79%. These values mean that the CPUE has continued to decline, more drastically after the mid 1980's, with increased effort. The decline has become much more drastic over the past 15 to 20 years after the influx of harvesters and subsequent increases in effort.

Overall recent catch rates are about one-third the 1970s level. Rates might be even lower if changes that have contributed to efficiency in the fishery could be quantified. These include the expansion of fishing areas, improved abilities to monitor the bottom and locate traps, increases in efficiency related to increased horsepower, and likely changes in the number of hauls per trap per season. Thus, fishing effort has drastically increased but the individual catches have declined despite this increase in effort.

The expert harvesters reported that, in the past, a majority of their landings was caught in the first half of the season after which landings declined until the season closed. Reports from the harvesters who participated in the demographic interviews suggest that a majority of their landings are still caught during the first half of the season.

There were varying answers to the question: when do you think the lobster population peaked? Two experts were not sure, one said the 1950s and 1960s, one said 15-16 years ago (mid-1980s) and one said before the early 1980s. On average, the number of small and spawny lobsters per line was reported to have been between 40 and 50 in the early years of the harvesters' careers (1960s-1970s) and to have declined over the thirty year period. In the present fishery reports suggest harvesters are seeing an average of eight to ten small and spawny lobsters per line. There are always slightly higher numbers reported at the end of the season. There were no reports that, at the time of the interviews, any one location in the Bay had higher concentrations of small or spawny lobsters. A few reports suggest that, in the past, the area around Squid Cove had higher concentrations of small and spawny lobsters than other parts of the Bay. The number of large lobsters intercepted appears to have remained similar over the study period but the trap design (entry ring size and overall size of traps decreased) has changed to prevent large lobsters from being caught.

Cod and herring were fished at the same time as the lobster in the past, but there does not appear to have been much of a problem with gear conflicts. Herring and lobster were often fished at the same time without affecting the effort put on either fishery. There were no gear conflicts reported between these two fisheries. Cod could be fished at the same time, but cod usually opened between the middle and end of the lobster season. When the cod fishery was good harvesters reported only checking lobster traps 2-3 times a week. They all reported lobster becoming a larger part of their income after the mid 1980s, when cod landings declined. Historically, lobster was important because it gave them the cash they needed to purchase supplies to participate in other fisheries. In addition, it was the first fishery that opened up after their unemployment benefits ran out in early spring. They all reported that these benefits usually took them up to the opening of the lobster season again the next year. Harvesters reported that, in recent years, their employment insurance benefits often do not take them up to the opening of the lobster fishery.

Seasonal movements of lobster gear consisted of movement into shallower water later in the season when the water became warmer. This had not changed over the careers of the expert harvesters. Their selection of a route and the sequence of areas fished were determined by wind speed and direction. Usually they needed to haul their lines and travel in a direction that would place the wind at their backs.

Fishing areas were defined as certain stretches of water between two points on the coastline, areas around islands, and areas of shallower water, which the harvesters refer to as shoals. The harvesters have local names for almost all these areas.

The results from the mapping component were similar to those that emerged from the other interviews (see Figure 4.3: a composite map based on all interviews). In the past most experts utilized fishing areas where their fathers or grandfathers had fished. They noted, however, that new entrants did not recognize these traditional areas and that the entire bay was now working on a first come first served basis. The new entrants started off fishing the community areas of the community they were fishing from.

Harvesters already fishing these areas knew there was nothing they could do about this and were quick to point out that everybody had to make a living.

Five of the six experts were fishing larger areas than when they started fishing; one had fished the same amount of lobster ground throughout his fishing career. As with the other harvesters interviewed, the experts described increased crowding and spatial intensification and expansion of effort as a result of increased crowding on the grounds. Most of the changes in the harvesters' fishing grounds occurred with the influx of new harvesters after the cod collapse. As areas to the south around Barr'd Harbour started becoming crowded, another large-scale move down to the bottom of the bay (offshore from Bartletts Harbour) appears to have taken place around 1997.

The expert harvesters were asked to rate DFO enforcement in the fishery as adequate or not adequate. Three of seven rated DFO as doing an inadequate job and the remaining four rated them as doing an adequate job. Three of the harvesters did not understand the stock assessment process; one of the harvesters who did suggested that DFO should look for advice from the harvesters about where to take their samples. Five harvesters said that they thought the rules in place now should protect the stocks and that the harvesters themselves should look after the fishery. Four expert harvesters suggested additional conservation measures such as closing the fishery down for a few seasons. Six experts also suggested more buyback programs and a reduction in the number of traps (350-400 traps per license). Five experts also wanted to see more meetings and better communication between harvesters and DFO. Once told about the efforts of the Eastport Peninsula Lobster Protection Committee they thought anything was worth a try. One harvester thought that there were just too many people in St. John Bay for such an initiative to work.

Expert harvesters were asked to outline any pros and or cons they associated with a list of conservation measurements (see Appendix B). They generally agreed that most of them are helping protect the stocks. One implementation a few harvesters deemed less important was the implementation preventing the retention of large males. One harvester did not agree with the most recent increase in carapace size because, he suggested, the big lobsters cost a lot more on the market and he didn't think there was a viable market for the larger lobsters. One harvester said he thought that v-notching should always be in place, but all the rest thought v-notching was a good idea but "could be cut out after a while." Unlike some of the harvesters in the demographic interviews ,a few experts thought v-notching might actually harm the lobsters.

Two experts thought that there might be an odd person who disregards the rules, but they added that this was an individual attitude problem to do with an inability to see very far into the future. Three harvesters suggested that the harvesters should have more say or voice when it comes to management decision-making. There were isolated reports of poaching but in general, the experts did not see poaching as a problem in St. John Bay.

4.3 Demographic and Strategy interviews

The demographic and strategy interviews (participants from these interviews are referred to below as demographic harvesters) produced important information on the demographics of the St. John Bay lobster harvesters, as well as fishing strategies and attitudes towards conservation. The average age of the participants was 45 years (ages ranged from 32 to 60 years). Ninety-three percent of their fathers were also fish harvesters, although not necessarily in the lobster fishery. Seventy-seven percent of harvesters came from families where three or more generations had been in the fishery. Their fathers taught 77% of these harvesters to fish. Eighty-eight percent of harvesters were married, and 28% of their wives were fishing lobster with them. All women had started fishing lobster after the downturn in the cod in the mid-1980s. Harvesters had, on average, two children and 18% of these had children who fished with their parents.

Eighteen percent of participants had graduated high school, 42% had a level of education between grades nine and ten, and 40% had an education level of grade eight or below. In comparison, the results of the expert interviews showed an average age of 65, only one participant fished with his wife, and all had less than grade eight educations.

The results from section 1b focused on the harvesters' fishing experience. A map of all communities occupied by harvesters who fish for lobsters in St. John Bay is presented below in Figure 4.1. Seventeen out of 43 harvesters interviewed had always fished out of the community where they presently live. These communities included Port aux Choix, Eddies Cove West, Castors River North, Castors River South and Bartletts Harbour. Twenty-six out of 43 fished from communities or islands they only occupy during the fishing season. These communities included Doctors Brook, Tilt Cove, St. John Island, Hummocky Island, Eastern Twins (or Fox Islands), Whale Island, Barr'd Harbour, Josephine's Cove, and Long Point.

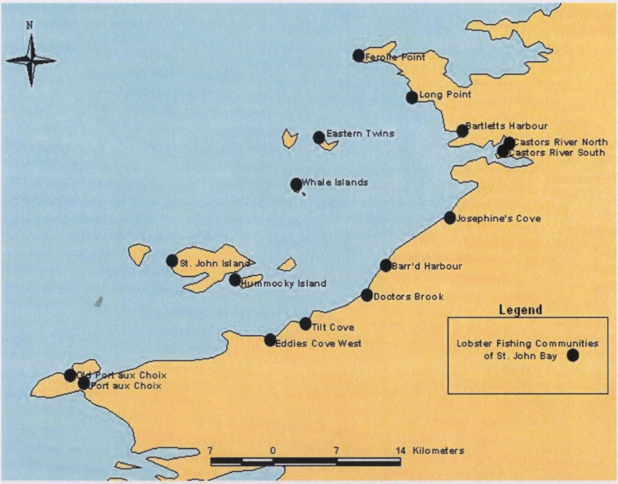


Figure 4.1. Spatial distribution of communities of origin for study participants.

Sixteen out of 43 had fished only inshore; 23/43 had fished inshore and on longliners, and 7/43 had fished inshore, on longliners and offshore. In terms of crew sizes, 8 of 43 harvesters fished for lobster alone, and 35 of 43 boats had 2 or more harvesters on board. Thirty-three out of the 43 crews had crewmembers who were related. These relations were most often brothers, fathers, sons, uncles and wives.

Subsection 1c focused on where and when licenses for lobster were acquired. Fifteen had lobster licenses before the mid 1980s (Table 4.2). Of these, seven harvesters obtained their licenses from a fisheries officer prior to 1985 and eight obtained licenses from their fathers when they retired. The remaining 28 harvesters obtained licenses after the mid 1980s. Eleven of these harvesters transferred licenses from the Bonne Bay area after 1985. Seven harvesters obtained their licenses from some other community within the bay. Six harvesters obtained their license from communities to the north of the Bay and three harvesters obtained license from Port Saunders (community south of Port aux Choix).

Table 4.2. Origin of lobster licenses held by sampled harvesters in St. John Bay.

Number of interview participants	**Where licenses came from**	**Year License purchased**
7	Fisheries Officer	Prior to mid 1980's
8	Retired father	Prior to mid 1980's
11	Bonne Bay area	Mid to late 1980's
7	Communities within St John Bay	Mid to late 1980's
6	Northern communities	Mid to late 1980's
3	Port Saunders	Mid to late 1980's

Participants were asked about the number of licenses presently being fished from their communities and how this had changed from when they started fishing. In some cases follow-up interviews had to be completed in order to get a more accurate picture of the changing number of licenses in St. John Bay as a whole. The results (Table 4.3) suggest that the increase in the number of licenses has affected most of the communities in St. John Bay over the thirty-year study period. Only three communities experienced no change in the number of licenses.

Table 4.3. Change in number of active lobster fishing licenses in St. John Bay from the 1970's to 2003.

Community	Number Licenses in 1970s	Number of licenses in 2003	Percent change	Comments
Port aux Choix	10	25-30	+ 47%	Increase (Includes old Port aux Choix)
St. John Island	3-4	8	+ 40%	
Hummocky island	4	6	+ 20%	
Eddies Cove West	5-6	11	+ 33%	
Tilt Cove	1	7	+ 75%	
Doctors Brook	2-3	6	+ 41%	+ 4 licenses have cabins in Doctors Brook but launch boats in Barr'd Harbour
Barr'd Harbour	5	33-36	+ 75%	
Josephine's Cove	6	11	+ 29%	Josephine's Cove (Some fish from here but are from Castors River
Castors River South	5	5-7	~ + 9%	
Castors River North	8	8-10	~ + 9%	
Bartletts Harbour	12	12	0	
Long Point	8	0	0	All licenses now gone
Ferolle Point	6	9	+ 20%	
Eastern Twins (Fox Islands)	2-3	6	+ 33%	

Note: Data on the number of licensees per community was requested but not provided by DFO for all years between the 1970's and 2002. Data on number of licenses in 2002 was taken from a list provided by DFO. Data for the early 1970's was collected as part of the interviews and in conversations with harvesters. Data on the current (2003) number of licenses was estimated after several follow up phone interviews in 2003.

The number of harvesters fishing for lobster in St. John Bay was approximately 75 in the 1970s and increased to over 200 by the mid 1980s. After the initial influx in 1985 there was a steady increase until the late 1990s. After this there were buyback programs but reports suggest this did little to lower the number of licenses. Reports from harvesters suggest some people have now moved north of the Bay but are still fishing inside LFA14B. Some additional licenses have been sold back and a few have retired in the past few years. Reports suggest, however, that in the 2004 fishing season the number of licenses is still between 160 and 190. These estimates of the number of fishing licenses were also checked for accuracy by figuring out the number of harvesters fishing from each community (interviews, follow up phone interviews); the sum of licenses for all the communities was 165 in 2004. It is obvious that efforts to date to reduce the number of licenses have had only limited success.

As can be seen from Table 4.3 most of the increase in licenses occurred in the southern and central sections of St. John Bay. Port aux Choix experienced a 47% increase in the number of licenses and Tilt Cove and Barr'd Harbour experienced 75% increases. The communities in the northern sections of the Bay did not experience such a high increase in the number of licenses (between %33 and 0% change). It may be that the crowding in the south and central portions of the Bay and subsequent expansion into northern areas of the Bay has, in part, caused harvesters in northern sections of the Bay to move north out of St. John Bay and into St. Margaret Bay.

Section 2a focused on harvesters' strategies. The depths in which demographic harvesters reported they would set their lines at the beginning of the season were between 20 fathoms (35.6 m) and 10 fathoms (18.3 m). The end of season depths ranged from 7 fathoms (12.8 m) to 0.5 fathom (0.9 m). Bottom types best for lobster fishing were generally reported to be rocky bottom, but some harvesters would set anywhere at the right depths.

The number of traps used per line varied between harvesters. During recent years the range for the number of traps fished per line was between 6 traps per line and 10 traps per line (average 7 traps per line). The number of traps per line has decreased from a range of between 10 traps per line and 14 traps per line in the 1970s (average 10 traps per line). Changes in the number of traps per line were linked to the imposition of trap limits. The last cut to the limit was implemented in 1996 and set the limit at 425 traps. This is still the highest trap limit in Newfoundland.

The number of traps per line at the beginning of the demographic harvesters' careers ranged from 14 to 6 depending on when they started. An average of 10 was used by most harvesters prior to the 1996 cut to the trap limit. The expert harvesters reported increasing the number of traps they used after the trap cut so that they could stay competitive with other harvesters. As the subsequent reductions in the trap limit were implemented, both expert and demographic harvesters tended to fish fewer traps per line so they could "cover more area". Since the cut to the trap limit would typically reduce the number of lines, without this strategy the harvesters would lose the ability to spread their lines over as many different areas, or spread them out within a particular area. In addition, reducing the number of traps per line means the lines are shorter and easier to move and position strategically thus offsetting the risk of reduced catches associated with lower trap limits. The distance between traps on a line ranged from 7-10 with an average of 8 fathoms (14.6 m). Most (41/43) demographic harvesters reported using test lines that they placed in shallower water.

Those harvesters from onboard observation and the demographic interviews who fished alone reported that they fish fewer numbers of traps per line than the harvesters who fish with others. Most demographic harvesters who fish one license fish 6 or 7 traps per line, since it's easier to handle shorter lines when you are fishing by yourself. This is logical since it is easier to haul a line with six traps than a line with ten traps when there is only one person onboard. It is also more efficient fishing fewer traps on a line when the harvester fishes alone because although he may have a few extra lines to haul it takes him less time to haul each line. When harvesters are buddied up they tend to use more traps per line (average 7-8 traps per line). This works efficiently for them because they have two and sometimes three people onboard to lessen the workload and ensure they can fish in an efficient manner.

Sixteen out of 43 harvesters reported fishing 2 licenses from their boats; all except one had only been doing this since the mid-1980s. Most of these buddied pairs were brothers. Table 4.4 provides an approximation of the number of buddy pairs in each community based on responses to the question what proportion of harvesters from your community buddy up? The most notable result of this part of the research was the number of buddy pairs in Barr'd Harbour. Barr'd Harbour had over three times the number of buddy pairs as any other community within the bay.

Results from the demographic interviews show the majority (81%) fishing with more than one person on a boat (usually wives or children) or, in the case of buddied up enterprises, other adult males. The persistence of multi-person crews despite technological innovations that have reduced the physical demands of lobster fishing could be partially due to the fact they now have larger areas to cover, and a higher number of lines to fish than in the past. In the case of household-based crews, this may be due to the need for more than one member of the household to qualify for Employment Insurance benefits (EI) in order for the enterprise to survive and in the case of buddied up crews to the need to keep costs down.

The harvesters were asked how they had decided where to fish for lobsters when they first started fishing in St. John Bay. Twenty of 43 harvesters reported using traditional knowledge; a father, grandfather or some other relative showed them the areas where to fish lobsters. Eleven followed other people from the community and fished in the same areas as were fished by them. Five used trial and error in addition to another strategy such as traditional knowledge or following others. Seven used trial and error alone or a different strategy classified as 'other'.

Many harvesters (47%) reported that when they first started fishing they went to areas that had been shown to them by their fathers or grandfathers. This traditional knowledge had, in some cases, been handed down over several generations. Many of the harvesters who entered the fishery during the mid 1980s had no experience lobster fishing and were not familiar with the area; these harvesters tended to follow others. Most reported that after a few years of following others they felt comfortable enough to explore new areas on their own.

The harvesters who reported using trial and error in addition to other strategies most likely followed others and used trial and error to explore other areas or to look for 'good fishing spots'. An example of one of the strategies classified as "other" would be taking over fishing areas fished by the previous license holder. In some cases the previous license holder would take the new entrants out and show them exactly what areas to fish for lobsters.

Table 4.4. Spatial distribution of buddy pairs in the St. John Bay Lobster Fishery in 2002.

Community	**Approximate Number of Harvesters in 2002**	**Number of Buddy pairs**
Port aux Choix	35	3 buddy pairs
St. John Island	8	3 buddy pairs
Eddies Cove West	11	0 buddy pairs
Tilt Cove	7	2 buddy pairs
Doctors Brook	6	2 buddy pairs
Hummocky Island	6	1 buddy pair
Barr'd Harbour	35	10 buddy pairs
Whale Island	4	0 buddy pairs
Josephine's Cove	11	0 buddy pairs
Castors River South	8	1 buddy pair
Castors River North	9	1 buddy pair
Bartletts Harbour	12	2 buddy pairs
Long Point	0	0 buddy pairs
Ferolle Point	8	2 buddy pairs
Eastern Twins	4	2 buddy pairs

Section 2B focused on changing fishing areas over the harvesters' careers. The major changes reported occurred after the influx of new entrants after 1985. The new entrants' presence meant intensification in fishing effort on existing individual and community territories within the Bay. In general the areas fished prior to the mid 1980s were smaller and closer to the harvesters' home communities, and there were only small areas of overlap between community territories. Presently, the fishing areas are larger and more ground is fished in the bay where most of the available lobster fishing areas is now being exploited. A detailed discussion of the spatial changes in fishing areas is presented in Figure 4.3 in the section on changing spatial dynamics.

The results of section 2c (on the importance of lobster to income) are summarized in Table 4.5. Almost equal numbers of harvesters reported a decrease or an increase in the importance of lobster to their income over their careers. A majority of the harvesters who reported no change in its importance to their incomes did not start fishing in the bay until after the mid 1980s.

Table 4.5. The importance of lobster to the harvesters' income.

Nature of change in importance of lobsters to income	**Number of harvesters**	**Proportion Change**
Decrease in importance of lobster to total income	11/42	26%
Increase in importance of lobster to total income	12/42	28%
No change in importance of lobster to total income	20/42	46%

Section 2d solicited information on the other licenses to which these harvesters had access (Table 4.6). Thirty-eight of 43 harvesters had bait (herring, mackerel) licenses. A majority of harvesters (41/43) still had groundfish licenses which meant they could fish for cod (if this fishery was not under a moratorium) and often for turbot and halibut. Thirteen still had capelin licenses, and nine had a lumpfish license.

Table 4.6. Other licenses held by St. John Bay lobster harvesters.

License	**Proportion of harvesters interviewed**
Bait (herring, mackerel)	38/43
Groundfish (cod, turbot, halibut)	41/43
Capelin	13/43
Lumpfish	9/43
Scallop	5/43
Crab permits (toad crab or snow crab)	4/43
No other licenses	2/43

Only three out of 43 demographic harvesters reported that they had sold any licenses. This exemplifies the fact that the fishery is often a diversified occupation and the need for multiple licenses. All harvesters seem to have the attitude that every little bit of any species helps. If there were no lobsters they would definitely not be able to make enough money to qualify for the employment insurance (EI) benefits that sustain them when they cannot fish. There is also a feeling of hope that "if any of the other species came back at least we would still have our license and be able to fish them again in the future." There is no doubt, however, that lobster is the most important species to most of these harvesters. Without lobsters these harvesters would be in trouble.

Sixteen out of 43 demographic harvesters did not participate in other fisheries during the lobster season. The remaining 27 harvesters did participate in other fisheries including herring, cod, crab, scallop, and the lumpfish roe fishery. Harvesters reported they used to give up lobster before the season's end to fish cod, but this has not been the case since the mid 1980s. Herring and lumpfish roe fisheries do not affect the effort put on lobster. Scallop and crab fisheries do; many of these harvesters either do not check as many lines or take up their gear earlier in the season. Price and abundance of lobsters relative to these other species seem to be the factors that determine the intensity and duration of effort directed towards lobster. Herring and lumpfish roe are the only species fished on or near the lobster grounds, and no gear conflicts were reported between these and the lobster fishery. The gear conflicts reported (5/43) were between draggers, cod nets and lobster lines.

Section 2e centered on fishing activities and associated strategies. Wind limits varied between harvesters. Wind limits ranged from 15 knots (nautical miles per hour) to >30 knots, with an average of approximately 24 knots. A majority of harvesters (26/43) approached setting lines at the beginning of the season by spreading out the lines across their fishing areas. The other harvesters said that there were special places they would set their lines. Most harvesters used GPS and sounders to find the locations of their lines (26/43 used GPS, sounder, or both). The remaining harvesters reported that they knew where the lines were from using landmarks and compasses; a few (8/43) used these technologies with traditional knowledge, landmarks, compasses or charts. Although a majority of harvesters said that their strategies had changed over the years to include more technology, 12/43 harvesters reported no differences in the way they found the location of their traps over time. These harvesters tended to be the people who entered into the fishery after the mid 1980s and had typically always relied on GPS systems to find the location of their traps. Since previous catches are obviously a very important factor in the harvesters' decision making processes, I wanted to see if there was a difference in how far back they referred to catch when making decisions as to where to set lines at the beginning of the season. When setting traps at the beginning of the season, demographic harvesters tended to refer back to information they have retained regarding catches in particular areas at particular times over several years or even over their careers. These results were also supported by reports from expert harvesters and those who participated during the onboard observation. However, once the traps were set and they began checking them, most reported they would primarily rely on the past week's catch to decide when and where to move lines. When asked how they decided when and where to move lines within each of their general areas, 35/43 replied that a low catch would be the reason they would move a line to another place. Harvesters reported moving lines into areas where catch is better, into shallower water as the season goes on, and following other people. In addition, a few reported going to a place to avoid the crowds. Three participants did not want to answer this question because they felt it would give away their personal strategies.

Interview data indicated that catch thresholds, i.e. the minimum catches needed before they would move their lines, varied between individuals. They ranged from zero lobsters per line per day to five lobsters per line per day. The average catch threshold for all harvesters interviewed was one lobster per line per day soak period. Harvesters also reported they usually compare how all their lines are doing but have thresholds according to which any lower catch per line will mean they will move the line. Catch thresholds have gone down in the past 15-17 years along with declines in individual landings in this area. Individual landings were reported by both expert and demographic harvesters to be between 6,000 and 10,000 lbs in the 1970s, presently the average catch is approximately 2,500 lbs. The decline in landings reportedly became more drastic around the early 1990s. Catch thresholds also go down as the season gets closer to the end. Catch thresholds generally decline by about 2 lobsters per line after the first four or five weeks in the season. For example if a harvester has a catch threshold of 3 lobsters per line at the beginning of the season he is likely to reduce this catch threshold to 1 lobster per line by the fourth or fifth week of the season. Some harvesters reported moving lines due to crowding and related declining individual landings. The harvesters' main reason for abandoning an area was low catches (40/43). Three harvesters did not respond to this question. In some cases low catch was coupled with the crowding situation as the reason for moving a line.

Both expert and demographic harvesters also reported that they would move a line if the catch was too low (below their individual catch threshold). Harvesters decide to move their lines depending on how well all their lines are doing. If one or several lines are doing well (catch above catch threshold) they will likely move more traps to that area. If few or no lines are doing well they will generally move into shallower water or move based on information from others (either within the area or to another area). Harvesters tolerate lower catch thresholds as the season goes on and the landings decrease. Catch thresholds typically start to decline drastically around half way through the season when individual catches start dropping off.

The numbers of lines the harvesters check every day varies according to the number of licenses fished from each boat. Harvesters fishing one license tend to be able to check all their lines everyday for the first part of the season. Those harvesters who are buddied up tend to check ¾ of their lines everyday or as many as time allows. Both demographic and expert harvesters reported that they do not check all their lines every day after the first four or five weeks of the season. Later in the season both groups check half or less than half of their lines per day.

A majority (37/43) of harvesters wait until the last week of the season and gradually take their lines in, usually taking the lines that are not 'fishing well' first. The rest of the harvesters (6/43) take their lines in after 4 to 6 weeks in the season, when catches are usually down and/or they go offshore fishing other species.

Expert and demographic harvesters as well as the harvesters who participated in the onboard observation reported that the sequence of areas (SOA's) visited and the routes taken (straight line circle, etc) always depended on the wind speed and direction although they also depend on the areas they checked the day before. When wind speeds were high (wind limit above 30 miles per hour but varied between harvesters), harvesters would not go fishing. If the forecast was for high winds (but still below the wind limit), harvesters would start their day farther offshore and work their way in depending on what direction the wind was blowing. If the forecast was reporting that the wind would become stronger later in the day harvesters would start hauling their lines farthest from home and work their way into shore, so they would be close to land if the wind started increasing. The specific wind directions and related SOA's and routes were very complicated and differed between communities because of their geographic positioning in the Bay. Certain wind directions would affect certain communities in different ways. For example, in the communities in the northern sections of the Bay such as Bartletts Harbour north and northeast wind does not prevent them from fishing because they are in a sheltered area with respect to the wind direction. In southern communities like Port aux Choix strong north and northeast winds affect their decisions to go fishing. Also the harvesters who were buddied up tended to check outside gear one day and the inside (closer to shore) gear the next day.

Subsection 2f related to the competition for lobsters resulting from the influx of licenses in the mid-1980s. In the demographic interviews, harvesters were asked how they decided to fish when they started fishing for lobsters. Two out of 43 reported there were community territories, seven reported there were individual territories, six followed others, two used trial and error, and 24 out of 43 said it was on a first come first served basis. It was reported that berths to fishing areas were passed on in the past, but when the influx of licenses into this area happened, the system changed to one of first come first served and no rights to any individual or community territories were upheld. Community territories are not recognized by DFO.

As shown in Table 4.7, harvesters reported that the number of boats within each respective fishing area around the communities has increased in most places. Harvesters reported an increase in the number of boats in all communities except for Bartletts Harbour, Castors River South, and Castors River North where there were only a few new licenses after the mid 1980s. In the past four to five years, however, these community areas have also experienced an increase in the number of boats from other communities. Several harvesters from Castors River South fish out of Josephine's Cove, which did report an increase. Long Point and New Ferolle were not covered during these interviews but were covered during the expert/retired interviews and the follow-up phone interviews, and no significant increase was reported.

When asked if there would ever be a situation where it would be too crowded to set traps, 20 out of 43 harvesters said it would never be too crowded and that they would squeeze a line into the area. Fifteen responded that they would move inside or outside the area, two harvesters did not have an answer.

Table 4.7. The relative number of boats per community fishing area prior to and after the mid-1980s**.

Community Area	**Number of boats pre-1985**	**Number of boats after mid 1980s**	**Comments**
Port aux Choix	5-10	30-35	Increased after 1985 but then approximately 7 took buy back
Gull Rock (between Port aux Choix and Eddies Cove West	7-12	40	Increased after 1985
Eddies Cove West	5	15	Increased after 1985
St. John Island	No data	8-10	Increased but decreased a little because buyback
Tilt Cove	1-2	25-30	Increased
Doctors brook	No data	20	Increased
Barr'd Harbour	5	20 (30 including adjacent overlap areas)	Increased from 4 –5 boats to over 20 boats fishing from Barr'd Harbour
Hummocky	No data	30	Increased
Hare	No data	30-40	Increased
The Wolf (back of St. John Island)	No data	20	Increased but recent decrease due to people moving out to the bottom of Bay
Whale Islands	No data	20-30	Increased
Josephine's Cove	6-10	20	Increased
Castor River North and South	8-10	16	Stayed the same until past 4-5 years
Bottom of the Bay	8-10	40-50	Increased dramatically
Bartletts Harbour	12	12	Stayed the same until past 4-5 years increased past 12

Long Point and New Ferolle	16	16	Stayed the same

Note: Not all boats can occupy all their areas at the one time. So this figure indicates the number of boats that tend to fish that area during the season. The numbers presented for before the 1980s were inferred from conversations with harvesters; some data could not be inferred with a high degree of accuracy

When asked if they would describe their lobster grounds as having more, less or about the same degree of crowding now as when they started fishing, 25 out of 43 said more crowded, 18 out of 43 said less crowded, and seven said about the same. Those who said less crowded were generally harvesters who started after 1985 and those who indicated decreases were referring to the effects of the license buy back program. There were also reports that crowding on The Wolf and around Hare Island has declined over the past four or five years because the lobsters are understood to be fished out. These areas are still being fished but not to the extent they were in the late 1980s and into the 1990s. Reports suggest many harvesters who fished these areas have since moved their lobster lines from these areas to the bottom of St. John Bay (see Fig. 4.3).

The harvesters reported that the crowding had negatively impacted their individual landings: 30/43 said they had seen a decrease in their landings after the mid 1980s; 13/43 reported that their landings had stayed pretty much the same, but these were primarily people who started fishing in the area after 1985.

Subsection 2h dealt with lobster conservation. When asked about trends in their lobster landings, 29/43 harvesters reported a decrease in landings over the course of their careers (which ranged from careers that started in the 1950s to careers that started in the 1990s). Eleven reported that their landings had remained constant; mostly people who entered the fishery after 1985, and 1 reported an increase. With a majority of harvesters reporting declining landings, I asked them how optimistic they were about the future of the lobster fishery in St. John Bay. Table 4.8 summarizes their responses to this question.

Approximately 50% of harvesters reported being at least somewhat optimistic and the other 50% were not optimistic about the future of the lobster fishery. All said they supported v-notching, returning berried and small lobsters, and handling lobsters with care. Twenty-eight said they would report poachers, although a few said only if they did

Table 4.8. Harvesters' assessments of the future of the St. John Bay lobster fishery.

Attitude	Number of harvesters
Very Optimistic	2
Optimistic	10
Somewhat Optimistic	10
Not very Optimistic	13
Pessimistic	8

not have to give their name. V-notching was most often selected (13/43) as the most important conservation effort, and the space between the laths in a trap was most often listed as the least important conservation measure (15/43). As with the expert interviews, poaching was not considered to be a large problem in St. John Bay; only a few reports of poaching were provided. People had mixed feelings about DFO's role in conservation: 22/43 said they do not see the fisheries officers enough. Only 9/43 harvesters thought DFO officers were doing their job.

4.4 Onboard Observation

The onboard observation consisted of joining ten harvesters for a day of lobster fishing. During the onboard observation, I noticed slight differences in the way each harvester fishes for lobsters. Observations generally confirmed information derived from the expert and demographic interviews. For example, as indicated in the expert and demographic interviews, the harvesters who fished by themselves seemed to use fewer traps per line (6-7) than harvesters who fished with another person on the boat who used 7-8 traps per line.

The crew composition on the boats where I did onboard observation was as follows: four fished alone at least part of the year, one fished with a shareman, five fished with their wives (a few of these were buddied up). Eighty percent of the harvesters had relatives fishing with them. This is comparable to the findings from the demographic interviews in which 77% of participants fished with relatives. Participants reported that most of the boats fishing from Eddies Cove West; five of the boats fishing from Barr'd Harbour, and several from Port aux Choix had husbands and wives onboard. In other communities within the Bay this phenomenon is less prominent, but no specific numbers were obtained. In this sample, women's experience in the lobster fishery ranged from thirteen years to just one year.

Results from this sample confirm other reports that buddying up increased after the downturn in the cod fishery. In addition to economic reasons for buddying up, one harvester also said he liked working with a buddy because he found it boring fishing by himself.

During onboard observation, harvesters were asked their opinions on the best types of bait. Individual opinions differed, although the main species used are herring and mackerel. Harvesters in this area seemed to have access to larger quantities of herring than mackerel. In the past, harvesters caught herring to use as bait, but due to the reported decline in the species in their area and the low price they receive for it, many harvesters now buy bait from the local fish buyers for approximately 38 ¢/lb. This is an added expense and a change from earlier years of the fishery.

The color and patterns painted on the buoys are different among harvesters. These help them distinguish their traps from those of others. I found it interesting that harvesters can recognize which buoys belong to other harvesters from their community as well as some from other communities. Six out of ten harvesters would watch when and where others were moving their lines. This is important in terms of fishing strategies. They associate certain buoys with successful harvesters or harvesters who have been reportedly doing well in the past week, and pay close attention to the movement of their buoys. This sometimes affects the harvesters' decisions regarding when and where to move their own lines.

All harvesters reported changes in the way they fish for lobsters as a result of changing technologies. The introduction of the chute has made fishing for lobsters safer and easier than in the past. The chute is a platform that is attached to the side of the boat and runs the length of the boat (Figure 4.2). The traps are placed on it as they are hauled out of the water. While the traps are on the chute the lobsters are removed and the traps are re-baited. The chute also makes the work less labor intensive because harvesters do not have to lift the traps out of the boats; the chute allows them to push the traps off the side of the boat one by one.

Figure 4.2 Harvester hauling trap onto a chute.

Nine out of ten harvesters had chutes on their boats. Some had reported using them for over ten years but others reported that they had only been using them for a few years. When the harvesters are checking their traps they haul them out of the water with the aid of a hydraulic motor, which requires less effort than hauling the traps by hand. Depth sounders were also used on nine out of ten boats in order for the harvesters to know what depths they were fishing. The degree to which they rely on these sounders differs greatly among harvesters. One harvester had adapted a different strategy in that he mostly followed other fishermen and set his lines alongside them.

Harvesters I fished with had several different strategies for knowing what areas to fish for lobsters and for catching lobster. Half of the harvesters reported they had either traditional berths (passed on from relatives) or traditional community areas but still followed others and used a little trial and error as well. The remaining five harvesters followed others but as they started to gain experience they used more trial and error to find additional areas.

The depths for setting pots recorded in the time period between May 17th and June 12th (time period of onboard observation) were between 11 and 4 fathoms (20.1 and 7.3 m). These depths differed among harvesters depending on the amount of shoal water available in these specific areas, and the time of the season when I joined them onboard. All harvesters reported moving into shallower water later in the season. I did not hear the harvesters talking about specific bottom types associated with lobsters but when asked they all replied that rocky bottom seemed to be the best. However, they had caught lobsters on other bottom types as well.

As indicated in the demographic interviews, catch thresholds varied among harvesters. A few said that their catch thresholds had declined dramatically over the past 15 years. Where once they would have moved a line if it had less than ten to fourteen lobsters they now have catch thresholds of between zero and five lobsters per line per day soak period before they will consider moving them. All harvesters reported their catch threshold would decline later in the season as the majority of the lobsters are caught during the first three to four weeks of the season. The average catch per line described by the ten harvesters for the end of their season was 1.6 lobsters (some harvesters have higher numbers of traps per line). Another factor in deciding to move their lines seemed to be crowding of lines in a small area, which is believed to be related to declining catches.

Four out of ten harvesters had their lines tangled with other harvesters while I was fishing with them. Each individual has a maximum number of lines fishing in a certain area he will tolerate before he will move. These values are different depending on the individual's strategy.

Communication among harvesters was investigated during onboard observation as well as during demographic interviews and informal conversation on wharfs and fishing cabins. In a few instances during onboard observation other harvesters would pull up alongside the boat and ask the participants how many lobsters they had. The importance of communication really became evident after the harvesters would stop fishing for the day and go back to their community wharf where there would always be interesting conversations between harvesters.

All harvesters who participated in the onboard observation reported that they were guarded about the information they would share with others. The amount and degree of their information sharing depended on their relationship to the other harvester. In general, information on their total catch for the day, their highest catching lines and the general area where it lobster was being caught were the types of information shared with other harvesters. However, harvesters would leave out information on specific locations or depths where they were catching lobsters. Reports from these and other harvesters suggest the influx of harvesters with whom traditional harvesters did not have close relationships definitely heightened their sense of the need for secrecy. Harvesters fishing from the same communities seemed to share more information within their community group than with people from other communities within the Bay. This made sense since they are generally fishing the same areas, and they would have closer relationships with these people. Harvesters fishing from the islands, and the smaller communities seemed to share more information among each other than those from larger communities. The harvesters who were related seemed to share more detailed information with each other than they would with those who were not related. The accuracy and probability of harvesters sharing information was higher between family members. The sharing of information decreased in a hierarchical fashion from family members to other harvesters fishing from different communities. Such nonverbal communication as watching when and where other boats move lines is an important part of some harvesters' decision making processes. However, they usually only pay attention to this when their own catch is very low. They did not seem to may much attention to gossip if their catches were average or high.

The number of boats in most fishing areas increased after the mid-1980s. During the period of onboard observation, the most crowded areas seemed to be areas where two communities' fishing areas overlap, such as those areas between Port aux Choix and Eddies Cove West, and those areas such as the ones around Doctors Brook and Hare

Island, and the large shoal area offshore of Bartletts Harbour and Castors River North and South (locally called Big Shoal or bottom of the Bay) where boats from several communities share some of the same areas. At any given time in these overlap areas it was easy to see at least eight to ten boats. Since the harvesters usually have several different areas to check lines, they would not all be fishing the same area at the same time but it was clear from the number of different buoys that many more than ten harvesters fish some of these areas.

4.5 Discussion

Overall, findings from the expert interviews and demographic and strategic interviews were generally consistent with those from the onboard observation. The combination of information from the different research instruments has allowed me to reconstruct trends in landings and effort changes in the St. John Bay lobster fishery and harvester communities for the past thirty years. It has also produced a rich understanding of the demographics of contemporary harvesters, the current spatial and temporal dynamics of the fishery, the structure of fish harvester communities, crew structure, contemporary fishing strategies, alternatives to the lobster fishery, and harvester views on conservation. The following section concentrates on some of the key findings from the field research related to long term trends in the St. John Bay lobster fishery and issues related to fishing practices

<u>Changing spatial dynamics</u>

Information in this section is a compilation of information from demographic and expert interviews mapping sections. Between the mid 1980s and the late 1990s dramatic changes occurred in the fishing areas of St. John Bay. As many more harvesters entered the fishery and fishing pressure and competition intensified, the spatial dynamics of the fishery changed from a pattern of localized fishing in "community territories" located on grounds adjacent to individual communities to one in which fishing tends to be much less localized and the system of community territories has broken down. Throughout St. John Bay, access to particular grounds and areas now appears to be determined on a first come, first served basis. In addition, the area around Port aux Choix from Point Riche to Barbace Point (see Fig.4.3) quickly became fished out and the harvesters utilizing this ground started to expand eastward towards Eddies Cove West. Reports suggest that in the 1970s there were only a handful of harvesters utilizing these grounds. After the mid 1980s the area became crowded and the landings in this area declined.

The area around Gull Rock (west of Hunters Point) has become an overlap area between harvesters in Port aux Choix and Eddies Cove West. The areas around Hummocky Island and the north west side of St. John Island (The Wolf) have also experienced intensification of fishing effort as people fishing from St. John Island and Hummocky Island were joined by harvesters from Eddies Cove West, Whale Island, Barr'd Harbour, Doctors Brook and Tilt Cove. There have also been some reports of harvesters moving their lines from The Wolf down to Big Shoal.

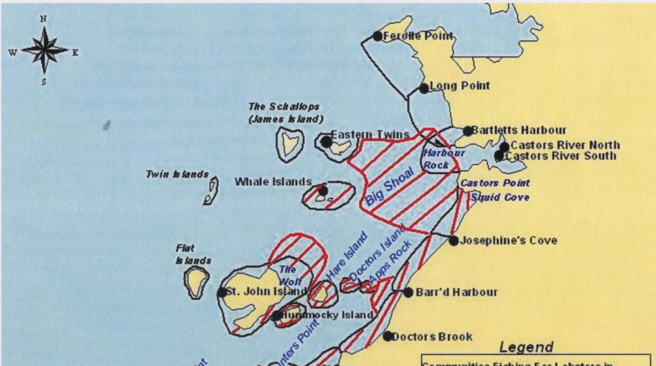


Figure 4.3. Changing spatial dynamics of St. John Bay Lobster Fishery.

The Hare Island grounds have also experienced a substantial increase in fishing effort. In the past, only a handful of people, mostly from Barr'd Harbour and a few of the Islands, fished around this Island. In contrast, at the time of the study, Hare Island was in the middle of an overlap area where harvesters from Eddies Cove West, Barr'd Harbour, Doctors Brook, Tilt Cove, Whale Island and Josephine's Cove came to fish.

The fishing area around Whale Island also saw intensification in that local harvesters now share these grounds with harvesters from Barr'd Harbour. Doctors Islands and Apps Rock used to be individual fishing areas for a few of the traditional lobster harvesters from Barr'd Harbour but are now shared among harvesters from Barr'd Harbour, Whale Islands, and some from Josephine's Cove and Doctors Brook.

The entire coastline from Barbace Point to Squid Cove is now fished much more intensively than in the past. Since the mid to late 1980s harvesters from communities in the south of the Bay have expanded up the coastline causing a chain reaction all the way to Squid Cove. Large areas of overlap along St. John Bay's coastline have replaced the once fairly obvious community territories.

The offshore Islands including Flat Island and Twin Islands in the south and the Schallops (James Island) and the Eastern Twins (Fox Islands) in the northern part of the Bay do not seem to have been affected to the same degree as other parts of the Bay. Not many harvesters fish this far offshore.

The communities toward the north of the Bay (Bartletts Harbour, Castors River North, Castors River South, New Ferolle and Long Point) were affected in a different manner from those in the centre and south of the Bay. Fewer licenses were transferred into these areas in the 1980s and 1990s, and the local community fishing areas remained basically unchanged until approximately 1997. However, in the 4 or 5 years prior to my fieldwork in 2002 harvesters from communities to the south such as Whale Island and Barr'd Harbour responded to declining landings in their own areas by starting to shift towards Big Shoal. They had heard from other harvesters that people were catching more lobsters down there and moved their gear from places like Hare Island and The Wolf down to the Big Shoal area. Some participants suggested these other areas (Hare Island

and The Wolf) had been fished out. The numbers of boats utilizing the Big Shoal area has increased dramatically, and there is now intensive fishing pressure in this area. Harvesters from Bartletts Harbour, Castor River North, Castor River South, and Josephine's Cove who traditionally fished this area are feeling trapped with nowhere left to go.

Change in the structure of harvester communities

The structure of harvester communities has changed substantially since the influx of harvesters into the lobster fishery in St. John Bay in the mid 1980s. In some communities such as Port aux Choix many of the new lobster harvesters were from Port aux Choix but had never fished lobster before the mid 1980s. Some of these new harvesters obtained licenses from traditional lobster harvesters who retired, while others obtained licenses from outside areas such as Bonne Bay. Since many of these new harvesters were friends or relatives of existing harvesters reported conflict between the two groups was minimal. However, harvesters have become even more guarded with their information since the arrival of new harvesters and increased competition for lobsters. The relationships between lobster harvesters from a larger fishing community such as Port aux Choix may not have been as strong as in a smaller community or an Island community but this influx definitely tended to diminish the closeness of the lobster harvesters within communities. In addition, Port aux Choix harvesters now share more of their grounds with harvesters from other communities such as Eddies Cove West due to the crowding and expanding on lobster fishing areas. This would mean they are in more frequent contact with harvesters from adjacent communities, which may also be weakening community structure.

Barr'd Harbour underwent a drastic change in the structure of the harvester community. This was once a small lobster fishing community occupied by one family. All five of the men made their living fishing lobsters as the main species. This family lived all year in the community which even had a one-room schoolhouse. The community structure in Barr'd Harbour was once very tight knit, comprised solely of family members. The Barr'd Harbour harvesters would share their landings from the lobster among themselves.

Over the years the members of this family slowly started to move out of Barr'd Harbour into larger communities to the north but always returned to Barr'd Harbour when they fished for lobsters in the spring and summer. This close-knit community structure endured a major change in the years following 1984. Traditional cod harvesters who had generally obtained licenses from the Bonne Bay area began moving in and building cabins in Barr'd Harbour. At the time of the study, over 30 licenses were being fished from Barr'd Harbour. Overall, a six fold increase has taken place in the numbers of lobster harvesters fishing from this community. The following pictures were taken in Barr'd Harbour in the spring of 2002. Figure 4.4 shows just a few of the Barr'd Harbour harvesters on the small wharf getting ready to set their truck loads of traps.

Figure 4.4. Harvesters in Barr'd Harbour 2002 getting ready to set traps.

In this community, although some harvesters had buddied up with brothers and other relatives, few had close relationships with others who had moved to Barr'd Harbour. They came from many different communities such as Green Island Cove, Flower's Cove, Greens Island Brook, Sandy Cove, to the north of St. John Bay. Perhaps the fact that nobody lived here year round made this a good destination for new harvesters because they could build fishing cabins without any conflict. In any case, the community structure in Barr'd Harbour changed from one of a close-knit, family-oriented fishing community where each family member had specific fishing areas with little overlap and they all shared in the profits, to a situation where many harvesters from different communities were competing with members of this family and with each other.

Figure 4.5. Barr'd Harbour cabins in 2002, northeast orientation.

The change in community structure can be seen in Figures 4.5 and 4.6. A majority of the cabins in these pictures were built after the mid 1980s. The phenomenon of building fishing cabins only used for the lobster fishery is also seen on most of the Islands (St. John Island, Hummocky Island, Eastern Twin Islands, and Whale Island), and the communities of Tilt Cove, Doctors Brook, and Josephine's Cove. In Josephine's Cove some of the harvesters are actually from Castor River South and from communities north of St. John Bay. Harvesters from both Josephine's Cove and Castors River South had traditionally fished in the same areas.

Figure 4.6. Barr'd Harbour cabins 2002, taken from a boat oriented southeast.

The decline of the cod fishery in the small boat fishery on Newfoundland's west coast in the mid 1980s, its closure in 1993 and reclosure again in 2003 has had major impacts on the economic lives of lobster harvesters and their families in St. John Bay. These changes have been at the root of all the major changes to this lobster fishery. The cod fishery in this area used to begin around the middle of the lobster season and, at that time, many harvesters would stop fishing lobster to fish cod. This meant that less effort was being directed on the lobsters in the early years of the fishery. Now with few other viable fisheries, the harvesters fish the entire lobster season, and more harvesters use their lobster licenses. Harvesters started shifting to lobster fishing in the mid 1980s even before the cod fishery closed. Lobster changed from being a fishery that allowed them to economically prepare for the cod fishery to being their main and most important fishery. This was an important change in the history of the lobster fishery in St. John Bay.

The majority (65%) of harvesters who participated in the demographic and fishing strategies interviews who are now actively fishing in St. John Bay, started doing so in the mid 1980s. Of these, 41% transferred licenses from the Bonne Bay area, 26% obtained licenses from communities within the Bay, 22% obtained licenses from communities north of the Bay that were not being used, and 11% obtained licenses from Port Saunders.

This means that the number of licenses fished from St. John Bay more than doubled after the mid 1980s. This influx and its related effects have substantially affected the spatial dynamics of the St. John Bay fishery at the level of inter-community interactions and at the level of interactions among households within communities. Prior to this period, a series of informal community territories tended to govern interactions between harvesters from different communities and the spatial dynamics of the fishery. These territories have largely broken down. In addition, the effects on landings of the intensification of effort have been associated with a spatial shift in fishing effort from the Port au Choix end of the Bay towards the Bartlett Harbour end and from coastal areas towards more offshore areas. The perception among some harvesters is that these spatial shifts are partly a response to the fishing out of some areas.

The high degree of mixing on fishing areas within St. John Bay differs not only from the past but also from the spatial dynamics of lobster fisheries in some other areas. Around the Eastport Peninsula, for example, despite the downturn in the cod fishery and increased effort within the lobster fishery community fishing areas appear to have remained largely intact. Each community has a defined area and overlap is usually limited to small areas between two adjacent communities (Davis *et al.*, 2002).

All results suggest that harvesters caught more lobsters in fewer numbers of lines and with less technology in the past. With fewer boats fishing for lobster and fewer lines being utilized by these boats the fishing effort in the 1950s 1960s and 1970s was much lower than it is at present. The traps were larger, the number traps per line was greater, they hauled their traps by hand and they did not have GPS systems or chutes. As a result, the fishery was more physically demanding than it is today. Smaller engines and less navigation equipment probably also means that the lobster fishery was more constrained in terms of the size of the areas that could be efficiently fished by a particular crew and by wind and weather conditions.

The fishery was less expensive to maintain since they could catch their own bait, build their own boats and traps and they didn't have the same costs for boats, engines, fuel and licenses. As observed during the study, the introduction of sounders and GPS systems has meant that some harvesters rely less on landmarks and traditional knowledge for navigation and selecting fishing areas. The harvesters who reported no changes in the way they decided where to set their traps either had always used a sounder and GPS or always used traditional knowledge (landmarks, areas etc). Some harvesters had adopted both strategies, in that they had always used landmarks and other traditional knowledge but had started using GPS systems because they found it more efficient and because these gave them access to more information. Sounders and GPS technologies have made it easier to monitor fishing areas, fishing gear and to identify lobster habitat. They also mean that harvesters can now strategically place every line in a very specific location increasing their chances of catching a lobster if it is in the immediate area. Finally, the introduction of GPS systems allows harvesters to pinpoint lobster locations and in some cases return to these locations year after year.

In St. John Bay crowding, overlap and spatial shifts appear to be linked to the high numbers of harvesters, to the fact that many of the harvesters do not live in these communities (they only fish there), to the effects of overfishing and to the lack of strong historical or family ties to the St. John Bay communities. These change reflect changes in the structure of fish harvester communities. A fishery where licenses were mainly obtained from close relatives changed to one where licenses were transferred between people from other communities who might or might not even know each other. This has implications for communications among harvesters and the overall dynamics and health of the fishery. These changes are affecting future management options for the St. John Bay lobster fishery. Most notably, this change in community structure means that it will be harder to get all harvesters to agree on any one management initiative since they come from differing backgrounds, education levels, age groups, communities, and points of view. That said, no conflicts were reported as a result of this influx of new fishermen in the mid 1980s. To some degree, harvesters seemed to empathize with the new entrants and figured they could not blame people for trying to make a living and support their families.

In Maine, lobster gangs would protect their areas and prevent other harvesters from mixing in these areas (Acheson, 1981 and 1987). Within some of the more successful lobster gangs there was a strong sense of community, family and tradition that tied these harvesters to their areas. This is not to say that harvesters from St. John Bay do not have a strong sense of community because some of them have been fishing from communities in St. John Bay for over 30 years. However, the majority of harvesters started fishing after 1985 and many of them do not even live in the Bay except for the fishing season.

The lobster fishery, like many other fisheries in Newfoundland, is grounded in family tradition going back several generations, with licenses being transferred from grandfathers to sons, to grandsons and harvesters learning how to fish from fathers, brothers or uncles (other male kin). In the earlier years of the fishery (1960s-1970s) many of the expert harvesters reported fishing by themselves; some supported sharemen, i.e. adult male crew members from other households, usually male kin. Crew composition has changed over time in that, at the time of the study, most harvesters had enlisted the help of their children and wives rather than men from other households. This is a sign of economic stress in that it reflects pressure to keep all the economic benefits (income and E.I. eligibility) from the enterprise in the one household.

No major adjustments in fishing strategy or behavior were reported as a result of the increased presence of harvesters' wives in the fishery. However, as indicated by Grzetic (2004), gaps in women's training related to operating the vessel and navigation could result in tense situations on the water should something happen to the women's husbands while fishing. Most women did not seem worried about this because there are so many boats around that could provide assistance if something like that should occur.

The harvesters who were buddied up reported doing this after the mid 1980s; most cited economic reasons. It is cheaper to maintain one boat rather than two. By buddying up, they cut down on the bait expense, gas expense, expenses associated with motors, and expenses associated with damage to traps. Expenses can be split between the two partners instead of being one person's responsibility. The community of Barr'd Harbour had far more buddy pairs (10) than any other community in the Bay. Many of these were harvesters who moved to Barr'd Harbour and who had never fished for lobster until forced to do so after the cod collapse. These people moved to Barr'd Harbour because it was not inhabited by anyone year round, thus making it easier to establish their operations and likely reducing the amount of local resistance to their moving in. A form of chain migration seems to have occurred in this area with these in-migrants being followed by brothers, uncles, and cousins who obtained additional licenses. Within the first few years of moving to Barr'd Harbour many of these harvesters had buddied up. In times of uncertainty it seems there can be strength, security and comfort in numbers.

Overall, harvesters now generally fish the maximum number of traps permitted and the majority of those with a lobster license permitting them to fish in the area are fishing their licenses. In contrast, in the 1970s, some harvesters had lobster licenses but weren't fishing them and the number of pots fished could vary substantially between harvesters.

Over time, harvesters have tended to reduce the number of traps per line when faced with a reduction in their trap limit, thus keeping the number of lines the same. Although today's lines are shorter than those fished in the past , individual lines presently being fished in the Bay could still be as long as 100 fathoms (182. m) with a buoy line strung along at the end of each line. Wide spacing reduces competition between traps on the same line but with the large number of licenses and a trap limit of 425 traps per license in the Bay, the result is a lot of crowding.

All harvesters fished in a range of depths and, to a lesser extent, across different bottom types when they were setting their lines. This highlights the fact that some harvesters tend to fish in deeper water than others. The preferred depth in which a harvester will set his lines at beginning of the season is an important individual characteristic. Although not all harvesters said bottom types were part of their strategy most would set on rocky bottom as opposed to muddy bottom.

The use of test lines was also identified as an important strategy. Harvesters use these to test out the waters and see what depths they are catching the most lobsters in. They often put these lines in differing depths from most of their regular lines in order to make sure they are not missing any lobsters. The harvesters also tended to spread out lines within fishing areas in order to improve their chances of finding the lobsters. Some harvesters have special places where they have had very good catches in previous years and take some of their lines and set them in these places year after year.

The reports from the expert and demographic interviews indicate a substantial reduction in overall catch rates in St. John Bay in recent years. The catch per trap was much higher in the 1970s than it is today despite efficiency increases. All expert harvesters also reported declines in the lobster population over the course of their careers. Today's harvesters are spreading their pots over much larger areas in order to catch fewer lobsters. The reports of fewer small and spawny lobsters than in earlier years indicates that the lobster population is becoming very unstable with fewer year classes comprising the population. The combination of natural fluctuations in lobster recruitment and increased effort suggest that overall, within St. John Bay, lobster populations may be very fragile and, in some areas, populations have crashed.

Increased prices for lobsters over the past 30 years appear to have partially offset the effects of increased costs and declining catch rates. Thus, while individual landings have been declining, lobster prices have tripled since the early years. However, the combination of reduced landings and increased costs also appears to have reduced the number of households that can be supported from a particular enterprise. Concentrating earnings from enterprises in a single household through changes in crew composition and reducing expenses through buddying up have helped some enterprises survive, but harvesters are having a difficult time. The demographic harvesters reported that if the price were lower they would face even more serious economic trouble.

It is not surprising that 20 out of 43 harvesters reported the importance of lobster to their incomes had remained the same. Lobster is the most important species to the majority of harvesters, especially given the lack of other available species and closure of the cod fishery in the early 1990s. Although the cod fishery is not as important to their incomes as it was because of small quotas, it still helped them top up their Employment Insurance benefits.

Ability to diversify into other species like crab and shrimp has helped lobster harvesters in other areas like Eastport survive. St. John Bay harvesters generally do not have access to these species and are thus particularly reliant on lobster. A few have scallop licenses and very few have access to crab. Many have capelin licenses but the capelin fishery has not been financially viable in this area in recent years. The lumpfish roe fishery is a supplementary fishery for some but overall, dependence on lobster for most is extreme.

Information on the history of changes in management initiatives and harvesters' responses to these changes was also collected during the interviews. It is possible that shortening of the season did not have any positive effects on lobster abundance because harvesters report they just fished harder during the shorter season. In the past, many lobster harvesters also fished cod during the latter part of the season which meant a lot of them did not fish for lobster for the entire 12 weeks that was available to them before this change. So this management initiative appears to have had little effect on effort and landings. The increase in the minimum carapace size that was introduced in 1998 and v-notching (to the extent that it is carried out) have probably been more effective. In 1996 a trap limit of 425 pots per license was introduced in St. John Bay. As mentioned earlier, harvesters have developed strategies for reducing the number of traps per line in order to help compensate for the effects on landings of this management initiative. Related to this, harvesters haul their lines more often and have more equipment like sounders to help them look for lobster habitat. Most felt the reduced trap limit probably had no effect on the number of lobsters they would catch. The lower number of traps did, however, make the fishery somewhat less intensive. It may also have reduced costs as fewer traps need to be built or purchased. However, the current trap limit is still very high by Newfoundland standards.

Within both expert and demographic interviews, attitudes towards DFO were split. Approximately half of participants reported that DFO was doing an adequate job and the other half said they were an inadequate job. The harvesters provided some important suggestions for ways to help DFO with the management of the fishery. Many harvesters thought it would be a good idea to have harvesters' provide more input into the stock assessments and scientific decisions about where to sample for lobsters. They were concerned that DFO scientists were not sampling the right areas and that this was providing false approximations of lobster stocks. They thought overall communication needed to be better between themselves and DFO and that harvesters should have more input into DFO's decisions.

The most prominent suggestions for ways to deal with the substantial pressure on the lobster stocks included additional buyback programs designed to reduce the number of licenses fished from the Bay, and another cut in the trap limit. Few suggested that the fishery should be closed for a few seasons to give the lobsters a chance to recover and those who did were retired and therefore no longer dependent on lobster for their livelihoods.

Attitudes towards the future of the lobster fishery in St. John Bay were mixed. Approximately half of the harvesters had an optimistic view of the future; the remaining half had a pessimistic view of the future. All harvesters agreed that if nothing is done the fishery will be in trouble. Harvesters generally reported that the lobsters they were catching looked healthy but some reported a decrease in the number of small lobsters they were seeing. Most harvesters reported that v-notching was an important practice. All harvesters seemed to be genuinely concerned about conserving the stocks because they know that conservation of the lobster stocks will directly affect their future in the fishery.

4.6 Conclusion

The results of the fieldwork confirm that St. John Bay has undergone several important changes over the past 30 years, the majority as a result of the cod closure.

Increased pressure from the influx of harvesters has produced a very different pattern of fishing areas than was present in the 1970s, and crowding on many of these areas. There have been changes in the way harvesters fish for lobsters and in the effort they put on the stocks. Additional changes have taken place in community structure, communication, and in management initiatives. It is obvious that all communities have been affected either directly or indirectly because of the cod collapse and subsequent influx of new licenses into St. John Bay.

Overall, fieldwork results highlight the dynamism of harvester – lobster and harvester - harvester interactions in St. John Bay over the past thirty years and provide some important insights into factors underlying that dynamism. Many different fishing strategies were identified as well as differences between harvesters in terms of the strategies that they used. Characteristics such as the number of traps per line, technologies used, decisions related to where to fish (area and depth), catch thresholds, the degree of crowding tolerated, buddying up, and wind limits were individual characteristics that could be modeled.

The next two chapters describe the incorporation of the results from this fieldwork into an IBM of the St. John Bay lobster fishery and the results of five experiments with this model. The modeling component is presented first by introducing modeling in general, then providing some examples of other models in use with a focus on where this model fits into existing research. The model developed for this research is then presented in detail with explanations of all the model components and how they work together and are related to fieldwork findings. The calibration of the model is presented at the end of the next chapter. Chapter six presents the results of the modeling experiments.

Chapter 5: Modeling Methods

5.1 Introduction

This thesis draws on two different fields—sociological studies of fishers and fisheries one the one hand and computer based simulation models on the other—that are not normally combined. The fisheries aspects have already been explained in detail in previous sections. The focus of this chapter is on the modeling aspect of the research and how it relates to and influences the information collected in the field.

A simulation model takes a real life situation, in this case a lobster fishery, and translates it into a computer environment. The model structure reflects the structure of the lobster fishery in general. The model is relatively generic; it is made specific to a particular case by means of the input data and parameters that characterize the application, in this instance the lobster fishery of St. John Bay, Newfoundland. The input data include digital maps of St. John Bay, length of season data, management data, lobster population data, characteristics of harvesters, and calibrated parameters. The harvesters are the basic units of the simulation and boat agents represent each of the harvesters involved in the lobster fishery. Information collected from the scientific literature and information collected during fieldwork are used to ground the simulation agents in the empirical data patterns that characterize the St. John Bay lobster fishery. The simulation runs through every day of the lobster season, the boats setting lines and returning each day to check and possibly move their lines. The boats move their fishing lines from one area to another as they look for and follow the lobsters.

The model can be used to gain a deeper understanding of the observed dynamics of the lobster fishery in the bay. Beyond that, it can be used to perform what-if experiments to explore the effects of possible changes in environmental conditions, social structure, or management policy. In this part of the study, five experiments are run. The first experiment tests the importance of communication among boat agents to see if communication can improve catch values. The second experiment includes a scenario whereby the seasonal variation in the spatial distribution of the lobster population is set to increase over the timeline of the simulation to see how the boats would react to changing environmental circumstances. The importance of communication under these circumstances is also investigated. The third experiment tests what would happen if a new management initiative involving the creation of community territories was introduced and compares this scenario to the present situation where access is based on the principle of first come first served over the entire bay. The fourth experiment explores how harvesters would respond to the implementation of a new trap limit in 2004 and 2005. This experiment is then expanded to include an additional stipulation of a minimum number of traps per line to see how this would affect behavior of the boats and catches. The final experiment introduces closed areas and examines their influence on catches and strategies.

5.2 Why modeling as opposed to traditional statistical methods?

In the past statistics have been the primary tools for studying fisheries. Fisheries biology uses statistical techniques to estimate vital rates (recruitment and mortality) in order to project short term changes. Spatial movements are often not used. This is because fisheries biology has made a deliberate choice to model demographics at the scale of the stock, in order to deliver advice in a timely fashion. Statistical techniques are used in fisheries biology to quantify uncertainty not 'uncover interactions'. The same is true of sociological studies of harvesters: statistical techniques are employed to arrive at reliable characteristics of the data and the patterns and relationships within it. While such research is very useful, even essential, it does not generally uncover the processes generating the situation described by the statistics, though it may provide indications as to where to look for those processes. Statistical methods cannot usually uncover the interactions of individuals within the systems, or changes in the behavior of individuals over time as a result of changing environmental, social, and economic conditions.

In the context of this project, statistical techniques are useful for estimating the average age of harvesters and other demographic information on who fishes for lobsters in St. John Bay. They can also be used to find out if there are significant differences between catches under varying model simulations. However, statistical methods alone will not allow us to understand the cumulative effects of strategies and underlying behavioral processes that could be used to predict future reactions to changes in the fishery. The use of an IBM allows the user to uncover patterns of behavior at the level of the community or the entire Bay that emerge from the behavior of individuals. The relationships and communication among individuals are represented within the IBM.

5.3 Modeling Literature review

Simulation modeling has been in existence for many years and many different types of models are available. Two of the newer modeling approaches being used presently are cellular automata (CA) and individual based models (IBM's).

5.3.1 Cellular Automata Modeling

The CA approach to modeling has a rule-based dynamic that allows high spatial detail to be retained in the final product. CA models are generally defined as a grid of cells, each cell having a discrete state that can be changed as a function of cell states within a neighborhood using various rules within the model, and all cells are updated simultaneously in each iteration of the model. Tobler (1979) was the first to highlight the fact that because CA models are computationally simple and retain high spatial detail, they are a good choice for modeling land use dynamics.

In later research by geographers Couclelis (1985, 1988, and 1989) and Phipps (1989), CA's were further developed to investigate the general characteristics of spatial processes. In the 1990s CA models were applied to detailed land use modeling, to simulate changing land use within urban landscapes (e.g. White and Engelen, 1993a, 1993b, 1994; Batty and Xie, 1994;; White *et al.*, 1997; White, 1997; Wu, 1998a, 1998b; and Portugali, 2000). The high spatial resolution of these models allows them to produce relatively accurate representations of city dynamics. Batty and Xie (1994) developed CA models for the purposes of spatial analysis and planning. They present two applications of a CA model—the first to Savannah, Georgia, and the second to a suburban area on the periphery of a mid sized North American city, Buffalo, New York. They focus on how these models can be used to show urban growth and structure from local rules within the model.

Standard CA models have two characteristics that are not desirable in the land use dynamics context: they are defined on a homogenous cell space and they are unconstrained, so that all cell states at time t+1 depend only on local cell states at time t. White and Engelen (1997) have modified the traditional CA by implementing three linked components. The first component is a GIS which stores the data on particular land uses at all localities and also the suitability of each cell for these land uses. The next component is the CA itself, representing the local spatial dynamics in the system whereby cell states represent land uses or land cover. The land use states are categorized as either function or feature. Function cell states such as forestry, housing, industry and commercial use can change (as a result of transition rules) to any other state, although some are likelier than others. Features are states that do not change as a result of the CA, such as water bodies and parks. The changing of a cell state depends on the additive effect of the states of its neighborhood cells, the intrinsic suitability of the cell, calculated by the GIS, a stochastic perturbation, and the global demand for cells of each state. The last component of the integrated model is a macro scale model, consisting of three linked models representing the non-local dynamics of the population, an input-output model of the economy and a model of the natural environment. The macro model determines the demand for land for various activities, and these demands constrain the cellular model by determining the number of cells of each state required.

The model was calibrated to the Island of St Lucia in the Caribbean to investigate the effects that climate change could possibly have on the economy and society of that locality. The authors caution that one run of the model should not be used to predict the state of St. Lucia 40 years in the future. However, in some cases, such as when the rate of population growth is known, the model may be able to provide a useful prediction of land use patterns 10-15 years in the future. These cautions would apply equally to most simulation models including the one in this project. It is still very hard to make long-term predictions because so many factors can change unexpectedly. The models can implement "what if scenarios" allowing the user to explore several different possible futures and so develop insights that could be used in strategic planning. In addition they provide a way of introducing the spatially localized effects of environmental factors, through the integration with GIS, into the operation of standard economic and demographic models, such that the effect of this integrated behavior can be examined.

The model of the lobster fishery developed in this project runs on a cellular automata based model of the lobster population. The harvesters are modeled in an IBM, and that model runs on top of the CA model of the lobster population. The CA is used to model the distribution and migration of the lobsters, and thus the changing distribution of lobsters over time. One of the traditional weaknesses of the CA approach has been the discrete cell state, which would not be of any particular use for the model of lobsters being proposed here. For many years biological oceanographers have used grid models based on concentrations within cells—for example models of phytoplankton in which the concentration in each cell depends on both divergence terms (movement) and insitu terms (production and loss). Wu and Martin (2002) developed a CA that explores the possibility of having continuous cell states. They proposed cells that have densities instead of discrete states. This is more appropriate for the lobster model because it can represent the number of lobsters in each cell and how that changes. In this project we also recognize the importance of non-homogeneity in the cell space. We use bottom depth and bottom type to define the suitability of cells, which in turn affects the number of lobsters (population density) within each cell.

5.3.2 Individual Based Modeling

Individual Based Modeling uses the individual (in this case a boat) as the basic unit in the model, with each individual having as many characteristics as needed. Each individual then reacts to changing local circumstances during the simulation according to a list of rules. In this project we are interested in the individuals' behaviors and strategies under different scenarios, and what collectively they are doing. A variety of characteristics and strategies govern their behavior. The mechanisms controlling the harvester's decision-making and strategies operate on the level of the individual. By using the IBM approach we can study the individuals as individuals, but also as groups or as a collectivity, showing their reactions to new management initiatives, the effects of their interactions with each other or the effects of changing social structure.

Schelhorn *et al.,* (1999) and O'Sullivan and Haklay (2000) report that agent based models (ABM) are becoming powerful tools with potential for applications in geography, policy development, and decision support and urban planning. Although the terms ABM and IBM are often used interchangeably a distinction needs to be made. In ABM's the agents are a computing technique defined as autonomous software agents (Doran, 1997, Gilbert and Troitzsh, 1999) using artificial intelligence to solve problems, and are therefore do not necessarily model real world agents (Lomuscio, 1999). Agents in an IBM represent real world entities such as boats or people. Other studies of agent-based models do refer to the agents as real world individuals. O'Sullivan and Haklay provide an example in the STREETS model of pedestrian behavior in a complex spatial environment. The model integrates a social and economic database in a GIS with an individual based model of pedestrian movement. The model has two distinct components, the street network and the location of attractions such as stores and office buildings along this network. Although the authors concede further work needs to be completed on the STREETS model they conclude that the Agent Based Modeling approach is highly applicable to this field.

Individual based modeling approaches have also been incorporated into studies of natural pollution and the environment (McCauley *et al.*, 1992, Carter *et al.*, 1998, Grimm, 1999, Clarke *et al.*, 2001, Railsback and Harvey, 2002, Sendova-Franks and Van Lent, 2002, Yamanaka *et al.*, 2003). Carter *et al.*, (1998) modeled the population dynamics of grasshoppers in Colorado using this approach. This approach was chosen to capture the phases of the development of grasshopper eggs. Each egg was modeled separately, given characteristics upon its arrival in the simulation, and then aged. An integrated model was developed that added the nymphs (young adults) and adults to the egg stage component.

Carter *et al.* reported that the model produced consistent results in terms of the timing of egg hatching, and introduction of nymphs and grasshoppers into the population. They added an environmental factor of precipitation and concluded that this modification greatly improved the accuracy of results, as they were compared to annual survey data. In the future these models may be able to help provide comprehension of grasshopper population fluctuations by identifying the most significant factors affecting mortality of the species.

Some bio-economic models of lobster fisheries have been developed (e.g. Sutinen and Gates, 1995, Milon *et al.*, 1999). SIMLOB is a bio-economic model that is used by scientists in Maine for making conservation recommendations (Sutinen and Gates, 1995). These models focus on the bio-economics of the fishery but do not encompass the decision-making processes of individuals. Therefore these models do not predict what effects the management recommendations will have on harvester decision-making and thus the final outcomes of these recommendations.

Some work has been done using agent-based models to discover strategies such as the model developed by Thébaud and Locatelli (2001). This model is based on Sugden's (1989) driftwood model to study emerging processes of resource sharing and associated strategies.

Little work has been done applying IBM's to fisheries. One of the few examples is the work of Bousquet *et al.* (1994) on simulating fishing 'households' (individuals in this model) of the central delta of Niger. The simulations were used to study the transition from individual behavior to general behavior (groups of households) to see if variability at the individual level and variability in the environment could be linked to variability that is characteristic of society. Households of fishermen are different according to their ethnic groups, number of people occupying them, origin etc.

For the Bousquet *et al.* study ecologists and biologists gathered information on the interaction between people and the resource at the individual level. Information included catch in a given place at a given time, and where fishing activities took place. Anthropologists and economists gathered information on the social structures in the study area and their histories. They reported that a crisis resulted from both conflicts between fishermen who claimed different rights to the resources and a drought that has shrunk the resource.

Building the simulator consisted of knowledge representation using an object-oriented approach, whereby the fish and fishermen were represented as objects. The knowledge was described in the form of rules and was organized in the form of a "blackboard system"(a kind of system diagram) allowing points of view from aforementioned disciplines to interact with each other. For example they used ecological rules in order to simulate fish growth.

The first component of the model simulates the environment (river, channels, flooded plains, and ponds) where the fish and fishermen interact. These areas are where the fish grow, reproduce, migrate, enter into competition, and die, and where the fishermen occupy space. This component is a basis for the simulation of fishermen's decision making. The environmental component allows researchers to investigate how an individual's behavior affects the characteristics of the fish populations.

The model of the fishermen's decision-making process is achieved by adding objects (agents) representing households to the environmental simulation. The household agents are given characteristics such as ethnic group and number of individuals within the household. The agents are entered into the simulation and then go through four phases in the decision-making model similar to classical decision-making models. The first phase, called the building phase, records all possible fishing and agricultural activities under the environmental conditions. Each fisher object defines objects called agendas for each possible activity and stores information on these agendas in the course of the perception phase. The perception phase allows the agents to retrieve information on all these potential activities. Each individual's agenda stores quantitative and qualitative data. The agent has quantitative knowledge such as the experience of past catches and he can choose to use this in a risky way or in a cautious manner. This allows varying attitudes towards uncertainty to be discovered when agents interact with the resource. The qualitative knowledge characterizes each possible action into favorable, unfavorable, impossible or compulsory categories.

The next phase, the selection phase, allows the individual to make a choice between the different possible activities. Activities are classified as combinations of biotype and environment (e.g. pond-cast net, river-cast net, river-gill net). Several possibilities are available including selection of the most profitable activity, selection of the activity that receives the most favorable opinions, or selection of the activity that receives the least favorable opinions.

The third phase is the decision making phase. The decision making in the fishing households not only involves the ecological environment but the social environment as well. This social situation is considered using two approaches. The agents can take a top-down approach or a bottom up approach. The top down approach associates a set of constraints with fishing households. The structure of the fishing society and the distribution of fishing activities are supplied via knowledge gathered in the field and are represented as rules. For example, "If household 'x' and Ethic group 'y' = 'z' Then 'A' compulsory activity." The bottom up approach associates the fishermen with other households with which they can interact and it specifies the principles that govern these interactions. For example, each agent may have 4 neighbors. He can copy the activity of the best neighbour, the activity most common to the group, or the activity least common to the group. The bottom up approach is closer to the lobster fishery model developed in this thesis since it allows neighbors to interact.

The last phase is the action phase, which is implemented after the activity is chosen and the households go fishing. Depending on the activity selected the agent chooses equipment and occupies a specific area such as a channel or a flood plain. Then the agent catches fish depending on equipment used and the areas chosen and records this experience in memory for future decision-making. The fish population also changes as a result of the fish being caught.

The model was used to perform various experiments involving different decision-making criteria. It does not address variability in fishing success. The researchers first tested a scenario in which households acted as rational agents by always attempting to maximize profit. In this scenario, the households change their occupation of space according to the area where the fish resource is in the highest abundance. Results showed that all agents simultaneously made the same decision, except when water was low and the agents occupied both rivers and ponds. They concluded that this simulation was too simple to be useful.

Next Bousquet *et al.* modeled economically rational agents in relation to human and environmental variability. Again the agents tended to occupy the same areas at the same time. Then the simulations were run with households having different levels of risk attitude. One third of the agents selected their activities with reference to the average experience; one third selected their activities with reference to their best achievement during the two previous weeks; and, one third selected activity with reference to their worst achievement in the previous two weeks. Results showed more diversity in the occupation of the areas. The agents tended to select different activities, and changes in the areas they occupied were more spread out over time. This shows that different attitudes towards risk may change the occupation of space.

Third, they modeled the effect of social interactions. In this experiment, perception and decision-making were not only individual but also collective. Social relations among different groups are captured using two possible approaches - the bottom up approach and the top down approach - and the consequences investigated. They highlight the importance of communication with others in a fishing society and the fact that fishermen do not always base decisions solely on their own experience (as was the assumption for the other simulations).

In the bottom up simulations, households share information either with one other household or with four other households. Comparison of the results of the two bottom up approaches with the results from the economically rational agents simulations showed that communication networks may change the occupation of space.

Bousquet *et al.* also examined the effect of spatial interaction among households by having part of the agent population act as rational agents and the rest copying or not copying their neighbors. In these simulations there are ten groups of five household agents. Each group has one rational agent and four other agents that either consistently copy or not. Results showed that the group consisting of one rational agent, one non-copier and three copiers yielded the highest benefits. The conclusion was that within a heterogeneous environment diversifying the occupation of space would be a good strategy.

The top down approach explained above uses anthropological observations to specify the organization of fishermen's society. Before the 1940s, the Bozo ethnic group of fishermen occupied the ponds and flood plains and the Somono group occupied the river. Rules were implemented to constrain the household's use of space according to these patterns. Changes since the 1940s such as the licensing of fishermen (and therefore limits on the free access for all fishermen to all areas), technological advancements in equipment, drought and fish population growth meant that appropriate constraints would no longer operate at the level of the ethnic group but at the individual level instead. Both ethnic groups now occupy any of the areas. Since much of the data needed is not available in this area, and the resulting changes and consequences are poorly understood, the authors suggest that the model be applied in other areas where the appropriate data are available to examine how accurately the model predicts the occupation of space.

The research of Bousquet *et al.* highlights the potential of individual based simulation models, and in relation to the conduct of science it illustrates the importance of interaction between social and ecological scientists. The study does not, however, examine the sharing of partial information or the effects of the different levels of communication that a harvester would use in decision-making. For example a harvester would share more information and more accurate information with a close relative than with someone he doesn't know, perhaps from another community. In the model developed for this project we run simulations with various levels of communication (depending on relationships among agents), and we introduce parameters that allow us to control the accuracy of the information being shared.

5.4 Individual based model of the St. John Bay lobster fishery

5.4.1 Overview

The information obtained from the fieldwork component of the project was used to develop an individual based simulation model calibrated to the St. John Bay lobster fishery. On the basis of pseudocode developed in this research project, the model was programmed in visual C++ for a Windows platform at the Research Institute for Knowledge Systems (RIKS), Maastricht, The Netherlands, and makes use of modules previously developed at that Institute for other dynamic spatial simulation models. An executable version of the model, together with a user's manual and an overview of the project, can be downloaded at no cost from the RIKS website: **http://www.riks.nl** .

In this model the bay is represented as a raster of cells 200m x 200m; this cell size was chosen so that the dimension of the cell was larger than the length of a line. Each cell has a specific depth, bottom type, number of lines, and number of lobsters trapped and not trapped. Every boat in the lobster fishery is modeled as an individual. Each boat is assigned characteristics that will help it make decisions. These boats are the core component of the model. Additional boat agents are added to the model at appropriate times during the simulation. Rules based on information from the fieldwork guide boat behavior and strategies. At the start of every season the boats set their lines in the cells of their individual areas. As each day passes, each boat checks its lines and decides to move them or to leave them where they are. Catch values are recorded for each of the boat's fishing areas. If the catch is very low, the agent can decide to move lines to his own best cells, into shallower water, or move lines elsewhere on the basis of information from other boats. As the boats move around catching the lobsters the lobsters slowly move towards shallower water.

In this model, the year-to-year variation in the number of lobsters in any particular area doesn't depend on the number of lobsters caught the previous year. The lobster population for every year was based on landings data. At the beginning of every season, the lobsters are distributed in the cells on the basis of the total number of lobsters for that year, depth, bottom type and a stochastic factor. The lobsters that are not caught by the boats move from cell to cell on a daily basis. Thus the boat and lobster interaction is at the cell level on a daily basis.

Information from interviews informed the data set that was produced to represent the St. John Bay lobster harvesters as accurately as possible. I developed a database in which each individual boat is assigned characteristics. These characteristics include a begin date for when they start fishing, as well as an end date, dates when they started and stopped buddying up (if this is applicable), depth at which they set their lines, numbers of traps they use, the number of traps per line, etc. Each boat agent was given an identification number so that it could be represented as an individual within the model. Each boat moves around the map setting and checking its lines for lobsters. They move their lines if the catch is too low.

Since the focus of the Coasts Under Stress project required a model of the St. John Bay lobster fishery, I generated a boat population representing as closely as possible the actual history of the boat population of the bay, in so far as I could determine it from the interviews and other data. However, if the model was being used to address more general theoretical questions, a boat population would be generated randomly with characteristics determined by variable parameters.

The focus of the model is on lobster-harvester interactions, and on the effects of fishing behavior on catch. While there was no time to develop a detailed model of lobster movement within the scope of this master's thesis we do have a simple model of lobster distribution and migration. This simple model is consistent with key elements of lobster behavior (see Lobster component below).

The structure and logic of the model were developed to be as generic as possible so that the model could be applied to other lobster fisheries that have similar underlying strategies. For example, with some minor changes to underlying maps, changes in the lobster population and a different set of boats to approximate another area, this model could be applied to the Eastport lobster fishery. If the underlying strategies were different in terms of the way harvesters fished for lobster (e.g. if the lobster harvesters did not use strings of traps on a line) then the model would not be generic enough to apply to another area. If the underlying strategies are similar then we could use this model in similar lobster fisheries. The ability of the model to be applied to other lobster fisheries makes the model more flexible as a possible management tool.

The model is a first attempt at modeling a complex fishery. Consequently it does not yet include several important aspects, which should certainly be covered in future versions. For example, it would be desirable to include the opening, closing and relative success of other fisheries (cod, etc), as well as prices of all fished species, since these are known to impact fishing effort. More generally, economic and community structure modules could usefully be incorporated into the model.

5.4.2 St. John Bay IBM and its components

The model consists of several components. The boats component is the major one. Other components include a season component, a management component, a sea floor component, a catch component, and a lobster component. Data from interviews and other sources were used to supply the information needed to develop and parameterize these various components. Information on harvester characteristics, behavior and strategies is the basis for the rules that drive the model during the simulation.

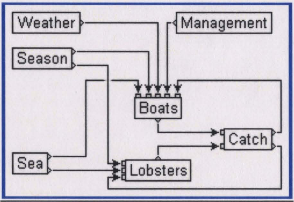


Figure 5.1. Interface of Lobster fishery model and its components.

Weather Component

This portion of the model was not implemented in this first version of the model due to time constraints and the inconsistencies in wind speed and direction figures in the literature. The wind speed factor prevents boats from fishing on days when it is too windy to safely go fishing. The wind speed that will deter a boat agent from fishing is called the wind limit and is stored as input data for each boat so that it can be used in future versions of the model. It also means that if the wind is fairly strong the boats will often only fish their inshore areas as opposed to other areas farther offshore. If the wind speed is too high the harvesters report that they stay in closer to shore (inshore areas) and do not go to the areas farther offshore. This rule is already in the code so that it can be implemented easily in the future. Wind direction affects the particular sequence of areas a boat visits on a particular day. This would also have required sets of these sequences of areas for each boat for every possible wind direction. This would take a significant amount of time to develop and it was not possible for this project.

Season Component

The model runs through each day of the season for the 40-year (1972-2012) study period. The length of each season was estimated based on data from lobster management plans. In general the season went from 12 weeks (84 days) at the beginning of the study period, to about 10 weeks (70 days) at around 1984, to 8 weeks (54 days) in 1997. These values can be changed within the model.

Sea floor component

Using British Admiralty nautical chart no. 4680 of the area, a digital raster representation of the sea floor of St. John Bay was produced (Fig. 5.2). The bathymetry was represented in fathoms since these were the units present on the chart being used and also because this is usually how the harvesters refer to depth values. Since the attraction of lobsters to a particular area is highly dependent on the bottom type, a representation of the ocean floor bottom type is also present in this component (Figure 5.3). Our only source for bottom type data was the nautical chart that had point data descriptions from soundings. The bottom type data is therefore approximate and appears as polygons because a polygon was formed around each point and interpolated as such. The bottom type in each cell is assigned a suitability value from 0 to 1, where bottom types with values closer to 0 are less attractive to lobsters and bottom types with values closer to 1 are more attractive. For example, bottom types that are rock or gravel get suitability values of 0.9 and 0.99 respectively and bottom types of mud and sand are assigned values of 0.45.

The region modeled is divided into 54 areas (Fig. 5.4). These are used in the initialization of the model to specify the areas initially fished by each boat. Areas were associated with communities on the basis of the composite of all interview maps from fieldwork. They are also used to define community territories. The imposition of community territories, with boats from a community restricted to fishing within the territory assigned to that community, is one possible management option. Community territories defined in interviews frequently overlap, thus, in Figure 5.5 below a community territory is a collection of defined areas from Figure 5.4. Note that for some communities the territory consists of more than one region on the map in Fig. 5.4, when some fishing areas are shared with other communities. The community fishing areas defined for this project are listed in Table 1 Appendix F.

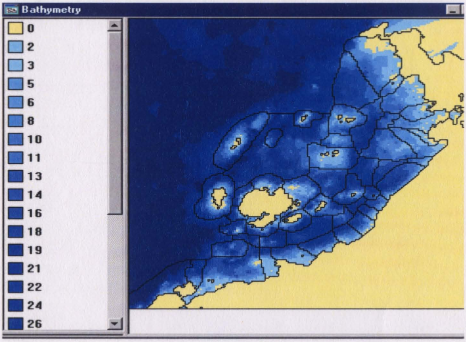


Figure 5.2. Digital bathymetric representation of St. John Bay.

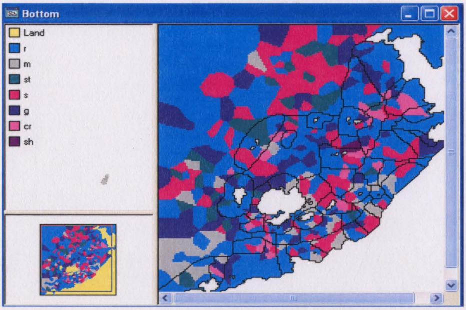


Figure 5.3. Bottom type as represented in the Lobster fishery Model.

r = rocky bottom, m = muddy bottom, st = stones, s = sandy bottom,

g = gravel, cr = coral, and sh = shells.

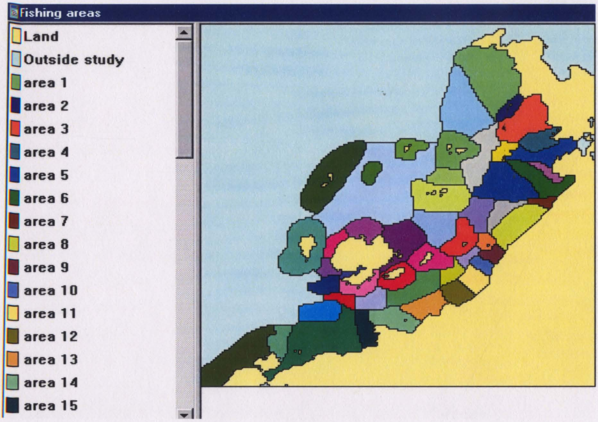


Figure 5.4. Fishing areas defined in the model.

Figure 5.5. Community territories of the St. John Bay lobster fishery as represented in the model.

Management component

The management component was developed in part with information from the Canadian Department of Fisheries and Oceans (DFO); for example trap limits for each year of the simulation are handled within this component. The primary function of the management component is to permit the model user to perform what-if experiments on the effects of management options for the fishery. For example, experiments can be performed on the effects of mandating trap limits for user defined years or a minimum number of traps per line; implementing community fishing territories at a specified time; and defining areas to be closed.

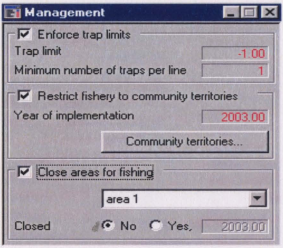


Figure 5.6. Management dialogue box within the model.

Lobster Component

The lobster module must first provide a total population of lobsters available for catching at the beginning of each season. Data on lobster landings obtained from DFO were used as a basis to supply the lobster model with relatively accurate numbers of legal sized lobsters for each year. The Fisheries Resource Conservation Council of Canada (FRCC, 1995) report on lobster states that although landings in Newfoundland did not show a sustained increase from the 1970s like other areas in Canada, there was a peak in the early 1990s. In St. John Bay the peak year was in 1989 but landings were also very high in 1985, the year after the influx of new harvesters into the Bay. The landings data fluctuate but tend to decline fairly steadily after 1990.

The numbers of lobsters in the model were calculated from landings data. Since at the time of my request to DFO, landings data for just St. John Bay (Statistical Section 48) were difficult to extract from existing data, and since for most years data for LFA 14B and 14C were not available separately from DFO, it was decided that combined LFA 14B and 14C data would be used throughout the study period. (For location of these areas see Figure 1.2.) As can be seen in Fig. 5.7 the combined landings data for 14B and 14C are similar to the data for 14B alone. For details, see Appendix G.

Since the model runs on a representation of the lobster population, I had to transform the landings data from tons into the equivalent number of lobsters. The landings data was converted into pounds and the pounds for each year had to be transformed into the numbers of lobsters for each year. There was an increase in the minimum legal size of lobsters in 1998, making the lobsters that were being caught larger and heavier. From reports of the number of lobsters needed to fill a crate (100lbs) before and after the minimum size increase I was able to determine the average weight of a lobster from the period before 1998 to be 1.1 lbs, and after 1998 to be 1.4 lbs. Using this estimate I then transformed all landings data from tons to number of lobsters and took a 5-year running average. The 5-year running average (Fig. 5.8) shows the same trends as the landings data. The running average rounds out the huge spike in 1989 but still possesses all the important characteristics of the real lobster population. The lobster population trend in the model was then calibrated so that catches generated by the model replicated as closely as possible the five year running average of actual landings. A comparison of the model numbers caught and the five-year running average is presented in the calibration section of this chapter (Fig. 5.15).

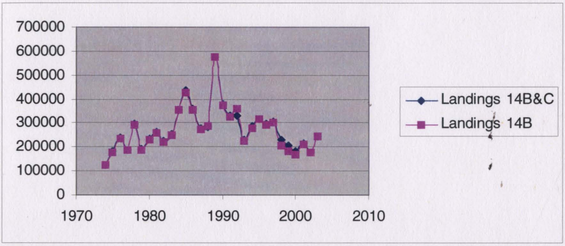


Figure 5.7. Comparison of landings data from 14B and 14BC (1974- 2003) combined.

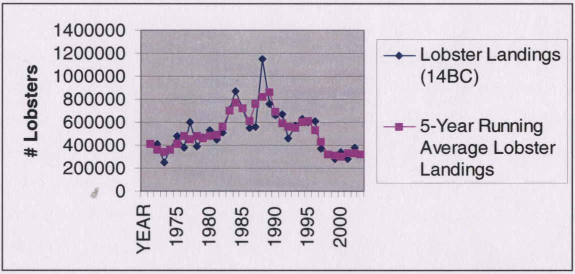


Figure 5.8. Comparison of actual lobster population and running average.

This population of legal sized lobsters is then distributed in cells across the bay, and a migration routine generates daily lobster movements during the season. A simple cellular model of the spatial dynamics of the lobster population captures what is known empirically of the changing daily and seasonal distribution of lobsters. Specifically the lobster population is attracted more to certain bottom types than to others; prefers certain depths depending on the date; is patchy; and varies from year to year.

Horne and Schneider (1995) reported spatial variance of measures such as densities in biological species have been used to quantify the degree to which organisms are aggregated. Indices of the variance to mean ratios were used as a measure of aggregation, whereby a ratio greater than 1 would represent a patchy spatial distribution of species. Wahle and Steneck (1991) have reported that the patchiness of lobster distributions off the coast of Maine is related to habitat type. Within most coastal areas, large stretches of soft, muddy bottom would be practically void of lobsters but all stretches of rocky bottom would most likely have some lobsters of some sizes. Smaller animals would predominate on gravel-cobble bottom (providing shelter) but would also be found on large cobble-boulder bottom where larger lobsters reside. (Wahle, 1988 and 1990, and Wahle & Steneck, 1991).

Within the model there are two types of patchiness associated with lobster distributions: patchiness due to attraction to certain depths and bottom types, and patchiness due to random concentrations. The degree of attraction of the lobsters to a specified preferred depth can, if it is low, produce patterns of lobster distribution that are spread out over the entire Bay or, at the other extreme, it can produce a pattern where lobsters stick to specific depth bands, resulting in a linear pattern of lobsters over the entire Bay. The parameter controlling this doesn't change from year to year. The second type of patchiness does not depend on depth; instead it is random, with the patches changing location from year to year. In the model this is called seasonal variation.

Lobsters move into shallower water as the water gets warmer and the season progresses (the daily movement routine in the model). As temperature increases during springtime, lobsters become more active and probably detect the temperature gradient as they move around more or less randomly and gradually end up in shallower water through random movements as the fishing season progresses. However, even during the latter part of the season, the population still occupies a fair depth range, i.e. they are not all in the very shallowest depths (Ennis, 1984a, Ennis *et al.*, 1989). Over most of St. John Bay the bottom slopes very gently and lobsters have to move greater distances to achieve a significant shift in depth and temperature.

In this model lobsters are distributed over the Bay at the beginning of each season, and then migrate from cell to cell during the course of the season. Both the initial distribution and the daily movements depend on the preferred depth on that day in the season and the bottom type.

First, the preferred depth at day t of the season is calculated as

$$dt = ds + t * (ds - df) / tt$$

where dt is the preferred depth on day t of the season
ds is the preferred depth at the start of the season,
df is the preferred depth at the end of the season,
t is the day in the season,
tt is the number of days in the season;

The attractiveness of a cell, m_j, for lobsters is given by

$$m_j = q_j (1 + 1/(1+\exp(-c * |d_j - dt|))),$$

where q_j is the attractiveness of the bottom type in cell j ($0 \leq c \leq 1$),
c scales the degree of attraction to the preferred depth,
d_j is the actual depth of cell j.

The higher the value of c the more lobsters move to the preferred depth, creating a sinuous linear distribution; the lower the value of c the more the lobsters remain dispersed around the preferred depth.

To generate the initial seasonal lobster distribution, the map of St. John Bay is divided into four quadrants. These quadrants are then subdivided into four quadrants and so on to a total of four levels, such that the smallest quadrant is $1/256^{th}$ of the entire map. At each level, the proportion of lobsters that will be placed in each quadrant is established as a product of (1) the square of the proportion of lobsters that went into the quadrant the previous year (this introduces some temporal autocorrelation into the regional lobster populations, (2) the total attractiveness of the 200 meter cells that lie in this quadrant relative to the total for the four quadrants in this super quadrant, and (3) a random number. The random number is drawn from a distribution with fixed mean and standard deviation s, where s ($0 \leq s \leq 1$) is a parameter specified by the user; this parameter determines the patchiness of the distribution (seasonal variation in distribution). The subroutine to allocate lobsters follows the formula:

$$N_j = (m_j / \Sigma_{j\varepsilon(g,i)} m_j) * lob(g,i).$$

where N_j is the number of lobsters in cell j

lob(g,i) is the number of lobsters in quadrant (g, i).

This equation means the lobsters in quadrant g are initially distributed among the individual cells i in proportion to the m_i values of the cell.

The parameters controlling patchiness determine the degree of variation in the lobster distribution from year to year. If $s = 0$ the lobsters will be in the same places at the beginning of each season, with no seasonal variation. For larger values of s there is a larger variability in where the lobsters are at the start of each new season. As s approaches 1 the population becomes very patchy, with the population almost entirely concentrated in a few sections of the bay, and this changes dramatically from season to season. Lower values of s represent the situation during the earlier period of the fishery when the harvesters would have been fishing several year classes of lobsters, and lobster patches would have been more plentiful and therefore the population more dispersed. A higher value of s characterizes the situation with a lobster fishery that largely fishes one-year class and that is therefore characterized by greater patchiness, with more year-to-year variation.

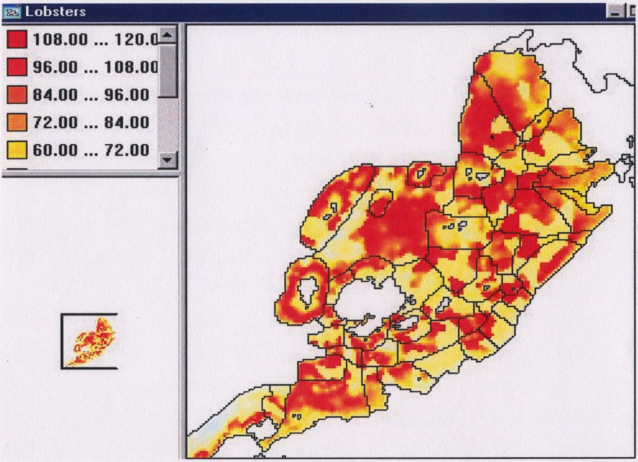


Figure 5.9. Map of lobster distribution used in baseline scenario (day 2, 1976).

Once the lobsters are placed in their initial cells the lobster daily movement routine is run for a specified number of iterations to establish the distribution to be used in day one of the season. This is done in order to eliminate the boundary effects due to the quadrant procedure. The daily movement routine then migrates the lobsters from cell to cell during the season. The daily movement is calculated as follows:

For all cells j, the updated lobster population, N_j , is

$$N_j = (\Sigma_{nj} N_k P_{kj}) - (\Sigma_{nj} N_j P_{jk}) - K(j)$$

where $P_{jk} = m_k / \Sigma_{nj} m_j$ (where N_j indexes the 4 cells of the von Neumann neighborhood of cell j plus the cell itself).

K(j) is the number of lobsters caught in cell j; at t=1, K(j) = 0

Thus the lobster population decreases over the season as a result of the boats catching the lobsters. The lobster catch routine within the model is implemented after the daily movement subroutine and before the harvesters check their lines. For one lobster in a cell, if there is one trap, q = the probability of not catching it; q is an input parameter. For T traps in a cell, q^T = the probability of not catching it at all, in any of the traps, and $p = 1 - q^T$ is the probability of catching the lobster. Then for N lobsters in a cell, the probability of catching k (0<=k<=N) lobsters is given by the binomial distribution:

$$p(k) = (n!\, p^k q^{N-k}) / (k!\, (N-k)!)$$

A uniform random generator chooses a value of k—call it K(j) —from the p(k) distribution. K(j) is the number of lobsters caught in all traps in the cell j. It is not necessary that K(j) be integer. The catch is distributed equally among all traps in the cell. Thus if more than one boat has lines in the cell, the catch is distributed among all the boats in proportion to the number of traps each has in the cell. While the probability of catching a lobster when there is only one lobster and one trap is very low, the probability of catching a lobster when there are n lobsters and t traps is much higher. Also, when the lobster is not caught today it may be caught tomorrow. The lobster module allows the user to see maps of lobsters and lobster movement as they change through the season and through the entire simulation.

As mentioned earlier, one major limitation of this lobster model is that it is simply a lobster distribution model, not a full lobster population model; the lobster population is simply read from a file at the beginning of each season. More specifically, the model does not have a carry over from fishing effort in one season to the growth of the lobster population in subsequent seasons, nor does it represent age cohorts or larval drift. It is important to mention that these limitations prevent any predictions of total catch trends into the future. They also mean that we cannot predict the degree to which a policy implementation will affect catch over the long run. However, when a realistic lobster population model becomes available, it could be substituted for the existing component and long-term trends in lobster populations, as well as the cumulative impacts of management initiatives, could then be modeled. Since the focus of this research is on understanding the behavior of the harvesters rather than the dynamics of the lobster population, these limitations will not significantly affect the findings of this research.

Boats Component:

This is the major component of the model. Each boat is represented as an agent. These boats constitute an artificial data set that is meant to mimic the actual boats in the fishery. Each boat agent has a set of individual characteristics stored in a Boat Characteristics Array (Table 1, Appendix H). This array stores information on starting dates and ending dates of its career, buddy up information, the number of traps, and the number of traps per line, the depth at which he starts the season, information on his relations, etc. The data set was constructed to replicate data collected from harvesters during interviews. Information required to construct this array was based largely on the interviews with harvesters and experts; this was especially the case when reconstructing the situation for the early years of the study period. Information on number of licenses was obtained from DFO. The simulation code iterates through the agents in random order to avoid boats first in the list having an advantage.

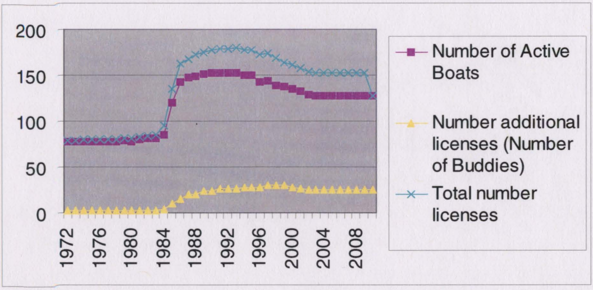


Figure 5.10. Estimated number of licenses and number of boats in St. John Bay; numbers are assumed to remain constant after 2003 season.

After the boat population is established, the agents go through a series of rules in order to catch lobsters. On the first day of every season the agents decide the number of lines they will use; decide what areas to fish and the portion of lines they will set in each area; decide the number of test lines they will set; and select cells within the areas to set lines in. After the first day, the agents check their lines and, based on their individual catch thresholds, decide what lines need to be moved. The agents can move lines into cells that have yielded higher catches, into shallower water cells, or into cells based on information from other agents. Agents record their catch values at the end of every day and then return home.

Agents decide how many lines they will use

Each agent reads in the value for trap limit (the legal limit on the number of traps that may be set per license) to see how many traps they will set. If there is no trap limit for that year they will take the value from their initializing data (see Appendix H). If there is a trap limit imposed for that year the agent will only fish the allowable number of traps. The agent also reads in the number of traps they will use on each line. These two values allow the agent to calculate the number of lines they will use. Harvesters report that they will change their number of traps per line over the years thus maintaining roughly the same number of lines. This strategy allows them to cover the same amount of ground as they did with a larger number of traps. This strategy was implemented in the model. The number of traps will double if a boat decides to buddy up (i.e. two licenses are used on one boat); the timing of such events is encoded in the input data.

Agents decide which areas to fish and proportion of lines they will set in each area

Each agent decides which areas they will be fishing. For the first year this information is found in the input data; in subsequent years it is possible that there will be new areas, since all areas fished in past seasons are considered at the start of the season. During the course of a season, an agent may enter new areas, not previously fished, either through local movements around a cell that take him over the boundary into a new area, or through information received from other agents. Each new agent entering into the fishery after the first year is assigned areas already used by agents from the same community. This simulates the new harvesters following others, a strategy that was reported by harvesters during interviews. The follow-others strategy means that the new harvesters will follow harvesters with more experience and set their lines in the same areas.

The lines the agent sets are divided up equally among all their areas for the first year of the simulation. After the first year the proportion of lines the agent sets in each area depends on last year's catch in that area. The agent adds weight to areas with little or no catch in memory so that areas with small catches can still possibly have lines set in them, and areas with no catch in previous years will likely be abandoned.

Agents decide the number of test lines and regular lines they will set

Test lines represent lines that are used to find the lobsters; they are set in shallower or deeper water than the regular lines. Regular lines are those that are set in cells of the appropriate depth for that day in the season. An agent reads in the number of test lines from the input data; the rest will be regular lines to be set in each area. If the number of lines the agent is going to set in a particular area is not greater than the number of test lines, all lines in that area will be set as test lines. Each boat has a number of test lines between 1 and 3 for each area. The higher the number of test lines the more area can be checked for lobsters. In turn the agent has a higher probability of finding new areas to fish because he is using more trail and error, by setting and moving into more cells.

Agents select cells within each area fished in which to set regular and test lines

The begin depths for each harvester were identified as an important characteristic and information about this characteristic was obtained during demographic and strategy interviews. A begin preferred depth value for the beginning of the season is recorded in the input data. A preferred depth range is defined around the begin depth using a begin depth differential parameter. Use of a range is important because of error in the digital representation of the Bay and because it increases the number of suitable cells. The preferred depth range changes as the season progresses as described above in the Lobster Component. The agent randomly selects cells in the area that fall within the depth range. The agent continues until all lines are set in each area. The test lines are set in the same manner, except that lines must be set in cells that fall outside the preferred depth range. There are two test depths: one shallower and one deeper than the beginning preferred depth. In the input data each agent is assigned a number of test lines he will set in each area this number ranges from one test line per area to three test lines per area.

Generally, the model runs through the code for each boat until all boats have their lines (both test lines and regular lines) set on the first day of each season. Each cell the agent chooses to set lines in must also satisfy a no-overcrowding criterion. Each individual decides whether or not the cell is "too crowded", by comparing the number of lines in the cell to a number found in the input data for each boat. The 'too crowded' characteristic is the number of lines in one cell that agent can tolerate before it becomes too crowded and they decide to move. Agents either have a too crowded value of 200 (meaning the agent is less tolerant of crowding and would likely move away from the crowd a little bit to set or move his lines) or a value of 250 meaning he is more tolerant and would try to squeeze his lines into a more crowded area. In addition, the agent may not set all his lines directly in the cell he has chosen; alternatively there is a parameter controlling the number of lines that get set in this cell and the number of lines that get set in the surrounding cells. This allows the agents to spread out their lines and use more trial and error.

Catch Threshold and Soak Period

Catch thresholds for all participants were identified as important individual characteristics and were recorded during the demographic and strategy interviews. To determine meaningful catch thresholds it is necessary to take into account the number of days traps soak in the water before harvesters check them (soak time). The effective catch threshold thus is specified in terms of the number of lobsters per line per day of soak period. Within the model, each agent has a threshold catch per line below which he will not leave lines in the cell; this is specified in the input data for each boat. Since interview data suggest that thresholds decline as the season goes on and also decline over the study period, two parameters, δ8 and δ7, have been included to allow the user to determine how much the threshold will decline. Catch threshold is calculated as catch per day of soak period, the soak period being the number of days since the line was last checked. An agent will normally check all lines each day but if there are too many lines, this is not possible, and so some will be checked on the next day.

Agents check their lines

On every day of the season after the first day, agents check their lines and record their catch values. Each agent calculates the average catch per line in each cell. If the agent's catch per line per day of soak period is lower than the threshold value for that day he will move all lines from the cell. If it is equal to or higher than the threshold, he will keep some or all lines in that cell. Depending on how good the catch is in the cell compared to the best catch that day, he moves a number of lines in proportion to this. The parameter δ1 determines the proportion of lines that will move. The larger δ1 the greater the proportion of lines that will move; for $\delta 1 = 0$ all lines will stay.

Choosing a cell to move lines into

When lines are moved a cell is chosen as a target cell for an area to which they will be moved. The various ways in which the target cell is chosen are discussed in the following paragraphs. However, the lines that are moved are not all moved into the target cell. Rather, a probability distribution is used to put varying numbers of lines into cells in the vicinity of the target cell, including that cell itself. Beginning with cells immediately adjacent to the target cell, and extending out to a maximum radius of 8 cells, lines are set in cells that satisfy certain criteria: the cell must be within the proper depth zone, otherwise it is rejected, and it must satisfy the no overcrowding criterion mentioned above. Each agent can only set 10 lines in each cell, preventing them from setting all their lines in one cell, which would not represent observed behavior. After a line has been set in the cell, the agent sets the soak period = 1, records the cell type as test or regular, and keeps a record of the number of lines in the cell.

Agents move their lines into "good cells"

When an agent wants to move lines he searches the list of cells he has checked that day for the cells with the highest catches exceeding the catch threshold. These are the target cells and a parameter δ2 controls the proportion of lines that will be moved into the vicinity of these cells, as opposed to the proportion that will be moved into shallower water, or moved on the basis of information from other agents. The smaller the parameter value the larger the number of lines that will move into the vicinity of the target cells. A second parameter, δ3, controls the way the lines are distributed among these "good cells". The larger the parameter value the higher the probability that the distribution of lines will be skewed in favor of the best "good cells". If the parameter = 0 all lines will be divided equally among "good cells".

Agents move lines to shallower water

The lines that are not moved to the vicinity of "good cells" either go to shallow water cells that had good catches in the previous year, or they move to cells on the basis of information obtained from others. A parameter δ12 controls the split between these two options. For higher values of the parameter, more lines will go to shallow cells; for δ12 = 1 no lines are moved on the basis of information from other agents. During the first week of the season any lines not moving to the vicinity of good cells will move to shallow water, since no information is available during this period. In the first year agents move shallow water lines into cells in the right depth band in the initial fishing areas, with a maximum of five lines per cell.

To locate shallow target cells, the agent looks at all cells in the appropriate (shallower) depth band that had average daily catches above the current threshold during the previous year. The parameter δ4 controls the distribution of lines among these cells.

The larger the parameter value the higher the proportion of lines that will go into the vicinity of the best of these cells. If the δ4 = 0 the lines will be divided equally among the cells. If there are not enough sufficient shallow cells meeting the catch criterion to hold all the lines to be placed in shallow cells, the remaining lines are added to the lines to be located in cells based on information shared by other agents.

Agents move lines on the basis of information from other agents

The results from fieldwork suggest that a hierarchy of communication was in place. Boats would most often use information from relatives. The hierarchy starts with the closest relatives and ends with boats from other communities. A representation of the hierarchy can be seen in Table 2, Appendix H. Specific information on exact location of catches and depths are perturbed before the information is shared; information from the lower levels of the communication hierarchy would be subject to higher levels of perturbation, and therefore constitute less reliable information).

After the first week boats can seek information from other boats in the simulation. Boats seek information from the most reliable sources first, and failing to get useful information, move on to less reliable sources. The information sought is data on the location of the cell currently yielding the best catch, as well as that catch. The input data for each boat includes a list of other boats operated by relatives and friends. These sources are listed in order of reliability--for example a father is more reliable than a cousin. Other sources, less reliable, are other boats operating out of the same community and, least reliable, boats operating out of other communities (Table 2, Appendix H).

In the information sharing routine catch is expressed as the sum of the catch per soak day for the last 5 days. Unreliability of the information is represented by a random perturbation of the catch data, not the cell location. In the gossip routine we draw random numbers from a normal (gaussian) distribution with mean M and standard deviation δ9 * rf(ii) * M. The rf(ii) value is the reliability of the source the boat is gossiping with. The value of M differs for relatives, community members and others. For δ9 = 0 all information is completely accurate.

If this perturbed catch is greater than 5 times the agent's best catch per day from cells checked the current day, the agent moves lines to the vicinity of that best cell. When the agent receives information from another (unrelated) agent in the community, the best catch among agents in that community is perturbed, and if this perturbed catch is large enough, he moves lines to the informant agent's best cell. Note that this is not necessarily the cell with the community's best catch (the one that was perturbed). When someone from another community informs the agent, the best average-catch-over-an-area gets perturbed and if this perturbed catch is good enough, the agent goes to the best cell in the areas fished by that community. Note that this cell does not have to lie within the best area (the one that was perturbed).

Agents go home

The agents return home and record catch information at the end of each day.

5.4.3 Features of the Lobster Fishery Model

The lobster fishery model has a number of useful features. The lobster component allows the user to view maps of the lobster population through the duration of the simulation. It shows the user how the population changes from day to day and year to year and allows the user to change parameter values and see the effects on the distribution of lobsters as well as the lobster landings.

The boats component allows the user to see maps of the distribution of all lines in the bay each day of the season (Fig. 5.11); the sequence of these maps thus shows the shifting location of lines as harvesters attempt to follow the lobsters. These maps can also display the distribution of traps. It is also possible to display lines (but not traps) by community (Fig.5.12), with lines belonging to agents based in each community shown in a different color. Finally, the user has the option of viewing the lines (or traps) belonging to just one boat, in order to follow the detailed behavior of any agent. For every day in the simulation, for any selected agent, the number of traps and the number of lines being fished, as well as the total number of lines possessed are shown in the boats dialogue box.

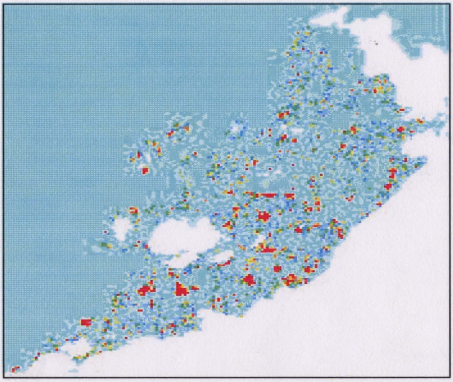


Figure 5.11. Number of lines (for all agents) per cell on day 4, 1972.

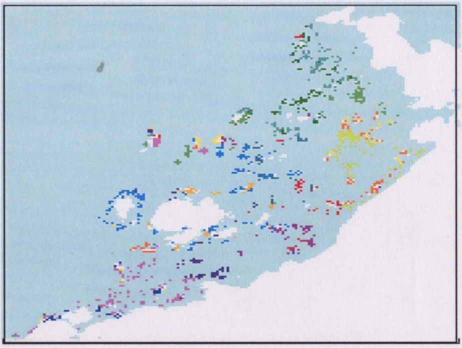


Figure 5.12. Number of lines in each cell, by community, on day 4, 1972.

In the catch dialogue box a running sum of the total season's catch (for all agents) and the total daily catch is shown. The catch in the first 4 weeks of the season is also shown in this dialogue box. The user can also pick any one individual boat and view its daily catch as well as its seasonal catch. The daily catch for all agents is also mapped as shown in Figure 5.13. As is the case with the lines map, the user can also view an individual's catch on a map as well. These maps show the total catch (number of lobsters) per cell.

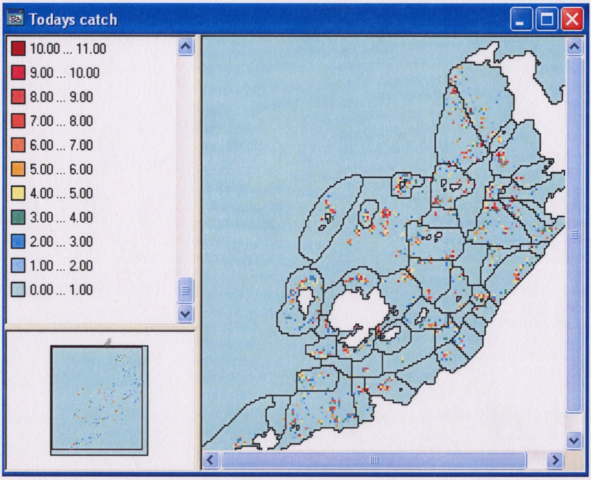


Figure 5.13. Total daily catch for all agents on day 4, 1972.

The management dialogue box allows the user to implement trap limits in any year of the simulation. It can also be used to run simulations whereby the agents are restricted to community territories (one proposed management initiative) beginning in a specified year. The management dialogue box also allows the closing of any of the fishing areas. Maps of the fishing areas and the community territories can be viewed by clicking on the sea dialogue box.

Output Files

At the end of each simulation pertinent information is written to an excel file and is saved for analysis during experiments. The information includes total yearly catches; yearly average catches per boat and per license, yearly community catches and the catch in the first 4 weeks of every season (for all boats, for each community and for each individual). In addition, information on each individual is recorded including the number of licenses, lines, traps, and the catch in each of the individuals' areas.

5.4.4 Calibration of the model

Numerical calibration

The model was calibrated manually, in two stages. In the first, parameters in both the lobster module and the boat behaviour model were calibrated to give a good replication of actual seasonal catches over the 30 year simulation period. In the second stage, parameters were adjusted so that the distribution of catch within the season matched reported values. These two criteria were used because the only consistent data sets available that were useful for calibration were seasonal landings data for the years 1972 to 2003, and logbook data collected in 2000 and 2001. In addition, harvesters reports provided additional, non numerical, information that was useful in constraining the calibration.

In the first stage the model was calibrated to reproduce as closely as possible the actual landings in St. John Bay over the past 30 years. The landings data was highly variable from year to year, so it was smoothed using a five year running average. Two sets of parameters were involved in this stage: those controlling lobster behaviour and those determining fishing behaviour. Lobster movements day to day during the season are primarily determined by four parameters (final calibrated values are shown): those for the preferred depth for the beginning of the season (d_f) and the end of the season (d_s); the parameter that controls the scatter of lobsters around the preferred depth (c); and the set of parameters controlling attraction to various bottom types. A further parameter (s), determining year to year variability of the beginning of season lobster distribution is also important, since greater year to year variability in lobster locations makes the lobster more difficult to locate. A final lobster parameter (q), representing the probability of a single lobster *not* being caught in a single trap in a cell, is the most important one in determining overall catch levels. The beginning and end of season depth parameters were largely constrained by harvesters' reports, although these parameters were adjusted somewhat during the calibration. Initial bottom type parameter values were suggested by previous lobster habitat research (Wahle, 1990) and harvester reports. The other parameters were adjusted freely since no relevant data was available to constrain them.

In addition to the lobster behavior parameters, the parameters representing boat strategies for moving lines and thus finding lobsters were adjusted. These parameters control the proportion of lines that stay in the cell ($\delta 1$ & $\delta 10$), move to vicinity of good cells ($\delta 2$ & $\delta 3$), move into shallow water ($\delta 4$ & $\delta 6$), and move based on communication between boat agents ($\delta 9$ & $\delta 12$).

Once these parameters were calibrated the baseline model closely resembled the landings data (purple line and blue lines match up in figure 5. 14 below). I used A mean error calculation (Appendix G) was used to compare model catch results to the 5-year running average, and parameters were adjusted to reduce this mean error. The final calibration resulted in a mean error value of 0.0040 or 0.4%, which was judged to be acceptable.

As a check on the calibration, the average catch per boat and the average catch per license reported by harvesters during interviews were found to be comparable to the average catches generated in the baseline scenario (Figure 5.15). From reports of harvesters the average catch per license in the 1970s and early 1980s was on average 6600 lobsters per boat.

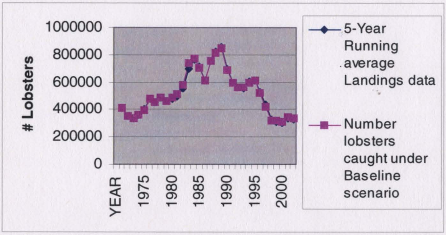


Figure 5.14. Comparison of lobster landings and lobsters caught in the baseline scenario.

Results vary among individual catches since fishing a higher number of traps out of a boat would allow for higher catches. In addition reports suggest that some years are better in certain fishing areas than others. In the mid to late 1980s individual landings generated under the baseline scenario were around 5000 lobsters per license. Again this value falls in the range reported by harvesters (5000 to 8800 lobsters).

By the 1990s reports suggest the average catches were between 2750 and 4400 lobsters. Since the year 2000 the average catches are approximately 3500 lobsters. Baseline scenario results from the early 1990s onward are slightly higher than reports given by harvesters. This in fact should be the case, since we used a slightly larger area when obtaining the number of lobsters that would be used in the model. From reports some harvesters began moving out of St. John Bay in the late 1990s (but not necessarily out of 14B, on which landings data was calculated). These harvesters' landings would have been included in the landings data that we used for St. John Bay. This could mean that the number of lobsters in the model is slightly higher in St. John Bay than was the case in reality for this time period. Since these estimates of average catches for these time periods are based on information from the 7 expert/retiree interviews and additional follow-up interviews, it is also possible that the estimates from the harvesters are by chance a little lower than the actual average.

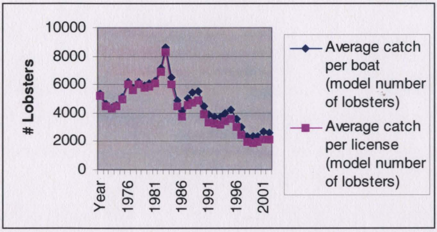


Figure 5.15. Model results baseline scenario: number of lobsters per boat and per license.

In the second stage of calibration, parameters were adjusted so that the simulation replicated the distribution of catch within a season. In order to do this the proportion of lobsters caught in the first 4 weeks was compared to the 2000 and 2001 logbook data, which are the only available data on daily individual catches. These data were obtained from the DFO fisheries observer. They consisted of daily catch records of 8 harvesters who fished in St. John Bay during the 2000 and 2001 fishing seasons. All delta parameters controlling boat agent strategies for moving lines and thus finding lobsters were adjusted. Specifically, these parameters control the proportion of lines that stay in a cell (δ1 & δ10), move to vicinity of good cells (δ2 & δ3), move into shallow water (δ4 & δ6), and move based on communication between boat agents (δ9 & δ12). It was also necessary to re-calibrate the parameter (s) that controls the seasonal variability in the lobster population. When the value of s was too large the lobster population was so unpredictable from season to season that the boat agents could not find the lobsters. Lastly, it was necessary to re-calibrate the parameter q controlling the probability of a lobster not being caught in a trap.

This final calibration of the model, after both stages, is taken as the baseline to which calibrations representing other scenarios can be compared. Data on landings, baseline model output, and calibrated baseline parameter values are shown in Appendix G.

Table 5.1 compares the calibrated simulation results with the average catch per boat and the percentage of catch caught in the first 4 weeks of the season. There is a reasonable match between actual catch and simulated catch. We do not expect an extremely close match because we used a 5-year running average. If the underlying harvester behavior, lobster behavior and their interactions are correct then the simulated catch values will also be correct. The results show that the model reasonably replicates the mean catch per license and early catch (catch in first 4 weeks) in the actual data.

Table 5.1. Comparison of model results and empirical data: mean catch per license and early season catch (percentage of total season catch).

Year	Empirical data, mean	Model results, mean	Empirical data, early season catch	Model results, early season catch	Difference empirical and model data
2000	1401	1886	64%	67%	+3%
2001	2220	1948	67.5%	66%	- 1.5%

I then ran the baseline simulation with different random seeds to investigate the variability between the simulations. All scenarios ran for 10 years from 2003-2012.

Table 5.2. Mean catch per boat: Four runs of the baseline scenario (4 different random seeds).

Year	Baseline scenario run1	Baseline scenario run 2	Baseline scenario run 3	Baseline scenario run 4
2003	2434	2409	2360	2369
2004	2530	2559	2508	2551
2005	2609	2577	2529	2530
2006	2575	2620	2596	2550
2007	2632	2574	2579	2519
2008	2613	2560	2602	2572
2009	2672	2564	2566	2571
2010	2630	2594	2620	2622
2011	2641	2582	2602	2607

2012	2646	2604	2631	2626
Mean	2598	2564	2559	2551

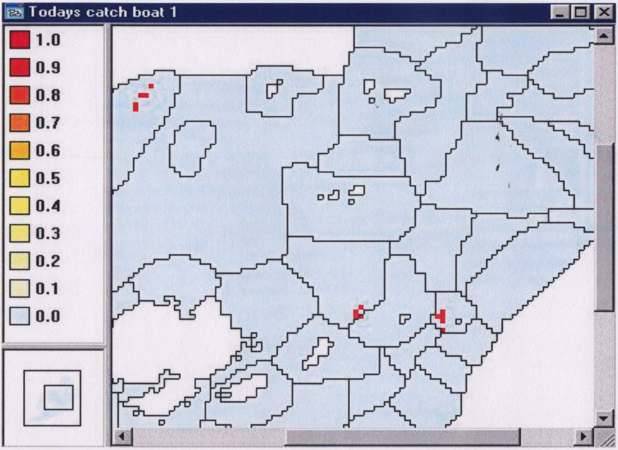
The mean value for all four baseline scenario runs was equal to 2568 with a standard deviation of 71 lobsters. There is little variation between runs of the baseline scenario.

Non-numerical comparison: A look at several days in the same run.

In general the boat agents move their lines when the catch on a line is below their individual catch threshold. Looking at individual boats within simulations, it can be seen that when a boat agent's catch is low they will move their lines around, but when the catch is high they will leave their lines where they are. This is in accordance with what is found in reality. The boat agents also move their lines into new areas. One way in which they do this is by randomly selecting cells in the vicinity of a target cell, which allows the agents to use trial and error to find lobsters. They can also move to new areas by using gossip information from other boats. As seen in Fig. 5.16 the individual boat does appear to move lines into cells that have the highest catch (red cells) which is in accordance with what is reported in reality.

Do boats tend to move lines into shallow water as the season progresses?

The lines are set in a reasonable pattern consistent with information gathered during fieldwork in the area. Visual examination of the total number of lines on the first day of the season shows that lines are spread out according to the individual preferred depths in their fishing areas. A map of the total number of lines shows that the majority of lines are being moved to shallower water (many of which are close to the coastline) by the end of the season. This is the pattern that harvesters described during fieldwork.



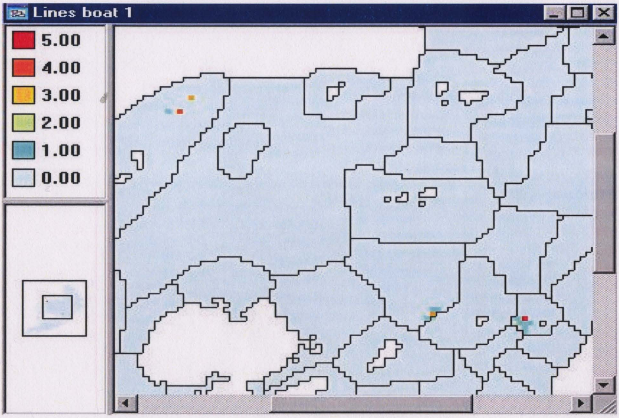


Figure 5.16. Boat id 1, catch day 4, 1976 (top); Boat id 1 lines day 5, 1976 (bottom), after moving lines.

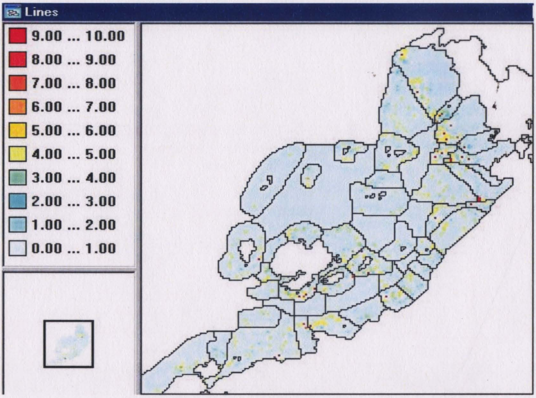


Figure 5.17. Map of total number of lines in St. John Bay for day 2, 1976.

As can be seen from Figures 5.17 and 5.18 and by referring back to Figure 5.2 (bathymetric map) the agents tend to move their lines into shallower water later in the season. More lines are closer to the shoreline and closer to the islands than at the beginning of the season. A comparison with the bathymetry map shows that the majority of agent's lines are in the shallower areas in the latter part of the season.

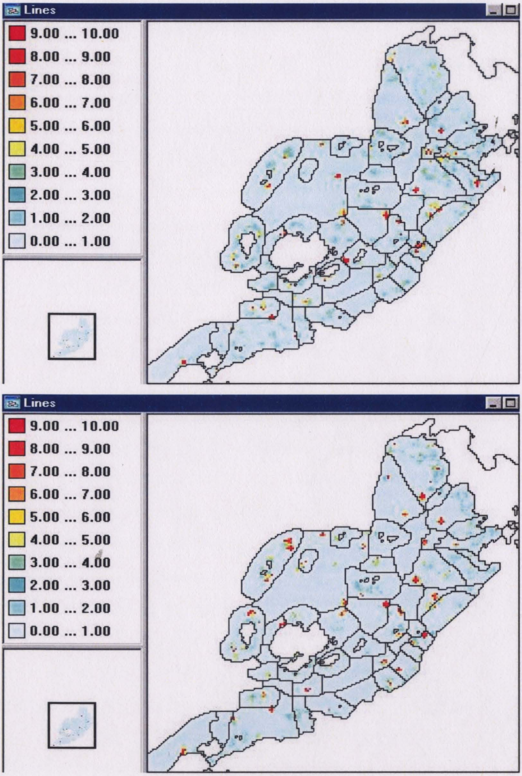


Figure 5.18. Maps of total number of lines in St. John Bay for days 42 (top), and 84 (bottom), 1976. Lines are moved into shallow water later in season.

5.4.5 The baseline scenario: can the model reproduce actual historical spatial changes?

I ran the baseline scenario to ensure the model would produce essentially the same changing spatial dynamics as was reported during fieldwork. After the mid 1980s and continuing into the late 1990s the increase in the number of new licenses and the increase in buddying up brought about patterns of intensification and expansion on lobster fishing areas. A comparison of figures composed from fieldwork data and maps produced by the baseline scenario in the model (Figures 5.19 and Figure 5.20) displays the models' ability to reproduce these spatial patterns.

The baseline map from 1976 (Figure 5.19 top) shows a representation of of the fishing areas in St. John Bay at this time. Figure 5.19 (bottom) shows the areas utilized by boat agents in the model in 2002. In Figure 5.19 (bottom) the areas outlined in red extending along the entire coastline of the Bay, and areas around the Islands were those areas reportedly fished by harvesters in 2002. The baseline scenario at this time predicts that the agents were fishing in most of the areas indicated by the harvesters interviewed (Figure 5.19 (bottom) red highlight). In the baseline scenario (Figure 5.19 (bottom)) there were very few areas where lines were especially concentrated (red and orange cells); a more scattered pattern of lines was present. The red cells indicate where there are 9 or more lines in a cell. Where there are red cells they are scattered and usually only one or two red cells are present; there are no areas of high concentration (red cells) of lines present.

After the influx of licenses and the increase in buddying up there were remarkable changes in where harvesters fish for lobster (see areas indicated in red on Figure 5.19). Harvesters reported fishing more areas and their areas became larger. Areas that had the highest increases in number of lines were Barbace Point, Gull rock, most areas of St. John Island, areas offshore of the coastline from Tilt Cove to Bartletts Harbour, Hummocky Island, Hare Island, Whale Island, Doctor's Islands, Apps Rock, and Big Shoal (also called Bottom of the Bay).

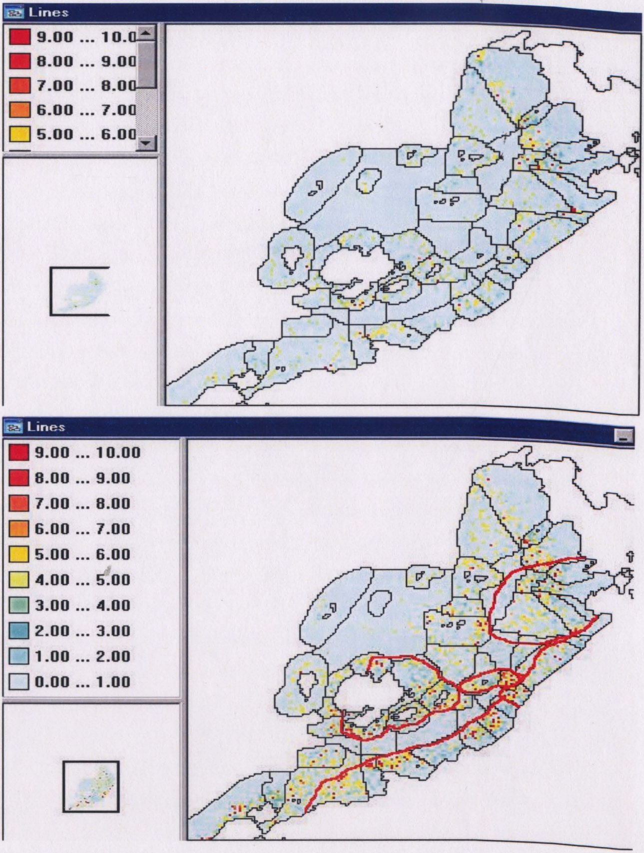


Figure 5.19. Total number of lines before and after the influx of harvesters into St. John Bay: days 2, 1976 (top) and 2002 (bottom), baseline scenario. High influx areas indicated during interviews are outlined in red (from composite map of interviews).

Barbace Point has been reportedly fished out and harvesters have shifted gear eastward. Around St. John Island, especially on the northeast side, many harvesters reported taking lines away from this area to shift to Big Shoal or the bottom of the Bay. The crowding and higher concentration of lines in the Port aux Choix area forced an eastward shift that has had a domino effect (because most communities have seen an increase in the number of harvesters) down the coastline towards Bartletts Harbour. One of the highest increases in harvesters was in Barr'd Harbour and as a result Hare Island, Whale Island, Doctors Island, and Apps Rock have also seen an increase in the number of lines present.

Comparing these reported spatial changes with the output of the baseline model, the distribution of lines shown in Figure 5.19 shows that there was a large increase in the number of lines (note the red cells) in essentially the same areas as those reported by the harvesters as having a large influx of activity (reported areas outlined in red). I chose 2002 because it was the year I collected the spatial information, and the composite map shows the spatial dynamic up until that year. Also by 2002 the consequences of the influx of fishers that started in the mid 1980s and the intensification in fishing effort that continued until the mid to late 1990s had largely worked themselves out. The shift to the Bottom of the Bay was reportedly towards the latter part of the 1990s and it is starting to develop in the simulation map of 2002 (Fig. 5.19). However, the shift towards the bottom of the Bay did not develop in the baseline scenario to the same degree as it did in reality. This is not surprising since the underlying strategies involved in this process were too complicated to add to the model at this time. In order to produce this pattern—the fishing out of the areas agents moved from and an increase in the number of lobsters on big shoal—the model would have to include a lobster component in which the lobster population reflects catches in previous seasons. In addition, we do not have different age cohorts in the lobster population so the model does not capture the processes of larval drift, and growth of lobsters into legal sizes. However, it is possible that the larvae could be well enough distributed in the Bay that larval drift will not be a source of major patchiness. Alternatively, the movement of lobsters in the years prior to reaching recruit size could possibly eliminate any patchiness in the larval distribution. In addition, agents from these communities may not actually get a chance to gossip (they are from different parts of the Bay) with each other. This means the agents would not know that Big Shoal has higher catches and therefore the move would not occur.

The concentration around the islands farther offshore (Twin Islands, Flat Islands, The Schallops, and the Eastern Twins) does not resemble what was reported in reality. Since these islands are a fair distance from shore they are not as crowded as many other areas in the Bay. The majority of boats that fish around the Eastern Islands are owned by people who live on them and in communities like Ferolle Point and Bartletts Harbour which are not far away. Since this time-distance factor has not been implemented in the model the boats do not take this factor into their decision-making process and therefore end up in these places since the lobsters are present.

The patterns of community lines largely resemble those that were reported by informants. Model results showed community lines in the 1970s were highly distinct and not a lot of overlap can be seen in most of the community lines. Boats from communities tended to stay within their own areas as defined in the input data. Areas defined in the input data were those reported by informants as being those fished by members of the various communities in the 1970s. The overlap that was seen in these maps was between communities that traditionally shared a lobster ground. For example, Castors River South and Josephine's Cove share common ground, and Port aux Choix, Old Port aux Choix, and St. John Island share common ground as well. Reviewing a map of community lines in the 1970s there are very few black cells, i.e. cells with agents' lines from more than one community. After the influx of new harvesters this picture changed drastically. This can be seen in the baseline scenario as well by comparing community lines from Day 21, 1976 and 2002 (Fig. 5.20).

In general the model described in this chapter is able to give a reasonable representation of the changing spatial dynamics of the St. John Bay lobster fishery. An understanding of how the different model components work together to determine boat behaviors sets the stage for experiments using the model. These are described in the next chapter.

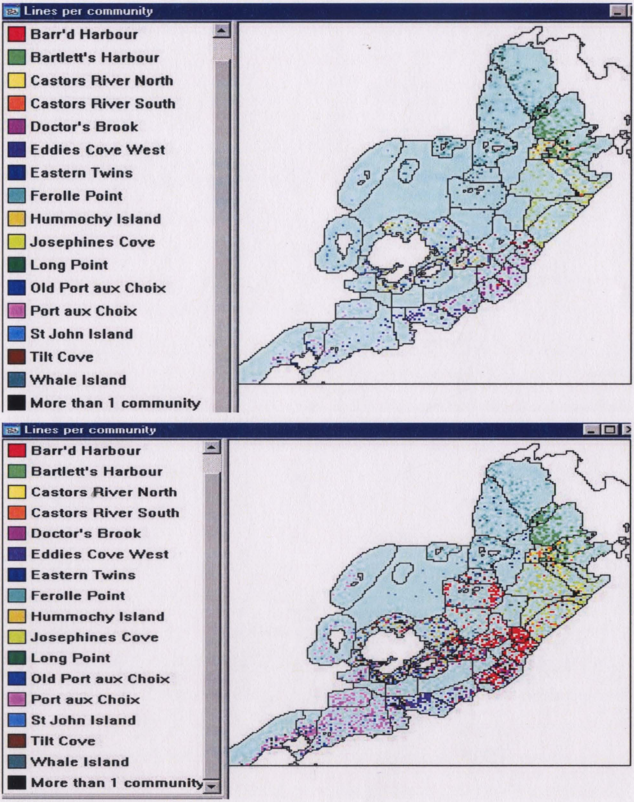


Figure 5.20. Spatial distribution of community lines, Baseline scenario: day 2, 1976 (top) and 2002 (bottom).

Chapter 6: Model Results

6.1 Introduction

This chapter reports the results of the model experiments conducted as part of my research. An explanation of how each experiment was developed is followed by the results of that experiment and a brief discussion of these results.

The first experiment explores the importance of communication among harvesters and how this influences the numbers of lobsters caught. The second experiment tests the effects of an increase in seasonal variation in the distribution of the lobsters on catch and the importance of communication among harvesters. The third experiment concerns community territories as possible management initiatives. It explores the effects on total catch values and average catch per boat for all harvesters as well as the catch variability under high and low seasonal variation. The fourth experiment tests two different trap limit initiatives in order to study their effects on catch. The first trap limit initiative introduces a new trap limit in 2004 and another in 2005. In addition to these new trap limits, the second simulation also has a stipulation of a minimum allowable number of traps per line. The fifth experiment introduces a new management initiative by closing certain areas to commercial fishing, and explores the effect this new management initiative has on over-all catches, and the catch values of the communities most affected by the closed areas.

It is important to reiterate the limits of what the model can predict before the results of the experiments are presented. While the model includes a realistic lobster distribution and small-scale movement of lobsters, it lacks some important capabilities. Nor does the model have different age cohorts of lobsters. In addition, the total population and distribution of lobsters in one year is not related to the fishing of lobsters in previous years. This means that at the end of the experiments we cannot draw conclusions on how much the catch will increase or decrease (either overall or in a particular area) in the future. However, it was suggested by one biologist that given the fishery consists almost entirely of new recruits, and that these are almost entirely removed each year. Therefore it is reasonable to assume that there is in fact no relationship between catch one year and initial stock size the next year. We can only say that the model predicts the immediate increase or decrease in catch as a result of certain changes of parameter values or management initiatives; and while changes in catch would in reality be expected to affect future population levels, this impact is not modeled.

6.2 Experiment 1: the importance of communication among harvesters

This experiment was designed to test the importance of harvesters' communication with each other. By changing the value of parameter δ12 we can force the agents to communicate a lot or a little, and therefore determine how often they move their lines based on "gossip". In the section below, the word gossip is used synonymously with communication between agents; in the context of the fieldwork the word gossip is the same as the sharing of information among agents in the model. It is not meant to have any negative connotations.

By setting δ12 = 1 the agents do not move any of their lines based on information from others. When an agent wants gossip he goes through a hierarchy of other agents, starting with his closest relatives, from whom he retrieves catch information related to that relative's best catch cell. By changing the δ9 parameter we can control the amount of perturbation in the reliability of the information on the catch in the cell being shared between the agents. The reliability of information was discussed in Chapter 5. When δ9 = 10 the information is highly inaccurate; when δ9 = 0 the information is not perturbed and is therefore accurate. If δ9 is large the catch will frequently be communicated as being higher than it actually is and the agent will then decide to move lines to the relevant cell when that is not actually an appropriate action. Conversely, when the catch is reported as being smaller than it is, the agent may decide not to move lines to the cell when in fact he should.

I ran several simulations with everything except the parameters related to communication held constant. The first simulation represented a situation in which there was no communication (no lines were moved on the basis of information from others). The second simulation represented a situation in which the agents shared information and the perturbation of the information was high (inaccurate information). The third simulation represented a situation in which the agents communicated with each other and the information they shared was reliable (accurate information). The results of all these simulations are shown in Table 1, Appendix I and the statistical values are shown in Table 6.1 below. The statistics are based on catch values for 40 years for each simulation.

Table 6.1. Mean, variance, and standard deviation of catch under no gossip and gossip scenarios.

Statistic	C1=No gossip (δ12= 1)	C2= Gossip (δ12 =0.1) and inaccurate information (δ9=10)	C2-C1	C3= Gossip and accurate information (δ9=0)	C3-C1	C3-C2
Mean	494830	473666	-22164	470263	-24567	3403
Variance	26381742147	26278760994		25356597939		
Standard deviation	162425	162107		159238		

The results (Table 6.1) show that sharing information with other harvesters has the effect of lowering the overall yearly landings but the difference is not statistically significant at the 0.05 level (two-tailed t, t=0.58, p=0.56, df =78). Furthermore, communicating with accurate information does not increase catch values consistently: eight years out of forty showed an increase in catch while using more accurate information as compared to using inaccurate information (Table 1, Appendix I), but again the difference was not significant at the 0.05 level (two tailed t, t=0.68, p= 0.49, df=78). As well, there was no significant difference at the 0.05 level between the mean catch of the no gossip scenario and the mean catch of the accurate gossip scenario (t=0.095, p= 0.92, df=78).

A one tailed F test showed no significant difference between the variances of catch values in the no gossip scenario and the inaccurate gossip scenario at the 0.05 level (F=1.00, p= 0.495, df =39,39). Next, a one tailed F test showed no significant difference at the 0.05 level between the variance in catch values between the no gossip scenario and the accurate gossip scenario (F= 1.04, p= 0.44, df= 39,39). As well, there was no significant difference at the 0.05 level between the variance of catch values between the accurate gossip scenario and the inaccurate scenario (one tailed F, F= 1.03, p= 0.456, df= 39,39). During interviews I never explicitly asked the question, do you think gossip helps increase your catch? However from informal conversations with harvesters onboard their boats and on wharfs, it seems that they gossip only when their catch is extremely low. Since harvesters only seem to listen to gossip when catches are low this suggests that they don't really think it helps, otherwise they would gossip when catches are average. When catches are extremely low harvesters start believing gossip that they would not normally believe.

In order to determine if these were specific results due to the particular random seed used or whether they represent the general behavior of the model I re-ran the simulation with several different random seeds. All of these results confirmed prior results suggesting that communication among harvesters has the effect of lowering catch values within the model.

One possible explanation as to why these results seem counterintuitive is that many of the relatives and community members who the boats are communicating with are fishing the same areas. The agents gossip with relatives most often. Relatives are most often from the same community, and therefore keep lines in the same general areas. This would mean that gossiping would not send them to any different areas and would likely have little or no effect in terms of increasing catches. In such a case the agents would be better served by moving into shallower water than listening to gossip.

In the community maps below I compare simulations with and without gossip. I chose 1995 because it was a typical case. I needed to examine the behaviors of the boats in order to figure out why catches are decreasing with the introduction of gossip.

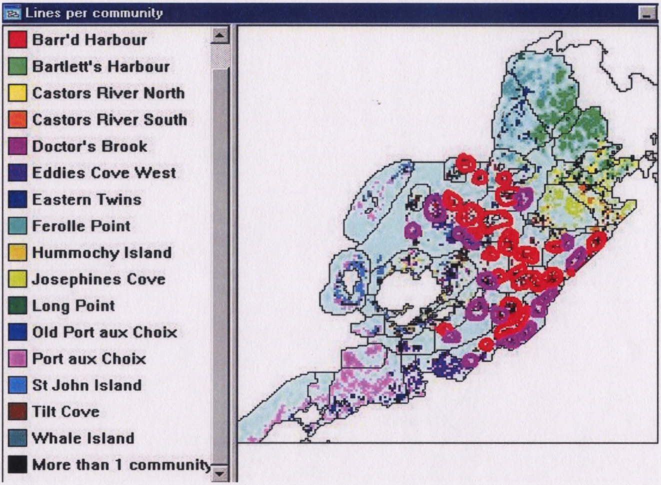


Figure 6.1. Distribution of community lines under **no gossip scenario** day 27, 1995. Dark pink outlines cells occupied by Doctors Brook lines, red indicates cells occupied by Barr'd Harbour lines.

By comparing Figures 6.1 and 6.2 it is evident that the introduction of gossip does not drive the agents to move into new areas. Instead, the agents fish fewer areas under the gossip scenario. This gives weight to the hypothesis that the gossiping keeps the agents within a smaller number of areas fished by their community members since those are the most likely candidates for gossiping. The ability to sample more areas and areas that are more spread out allows boats under the no gossip scenario to achieve higher catch values.

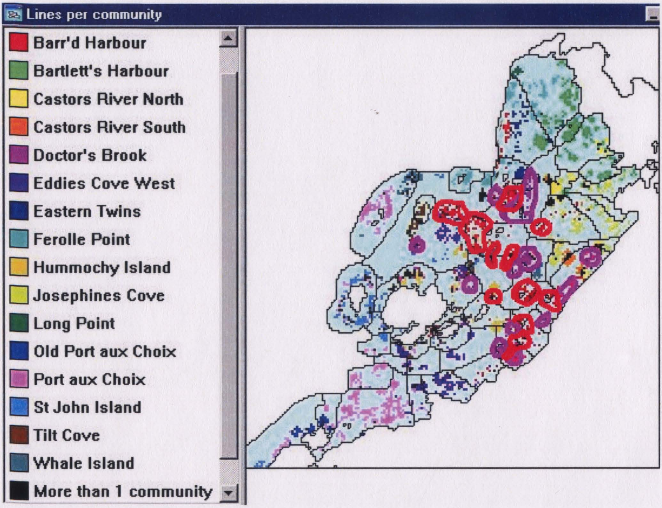


Figure 6.2. Distribution of community lines under **gossip scenario** day 27, 1995. Dark pink outlines cells occupied by Doctors Brook lines, red outlines cells occupied by Barr'd Harbour lines.

Next I examined whether non-gossiping agents move more often into shallower water (Figure 6.3). To test this I examined two maps of each scenario, one from the middle of the season and one from the end of the season. I examined two communities, Barr'd Harbour and Doctors Brook, both of which had lower catches in 1995 under the gossip scenario.

As can be seen from Figures 6.3 the boats do indeed move to shallower water under the no gossip scenario. The lines from Barr'd Harbour move towards the islands into shallower water. The majority of lines from Doctors brook are all in close to shore (shallower water) by the end of the season. In both cases the catch was higher under the no gossip scenario.

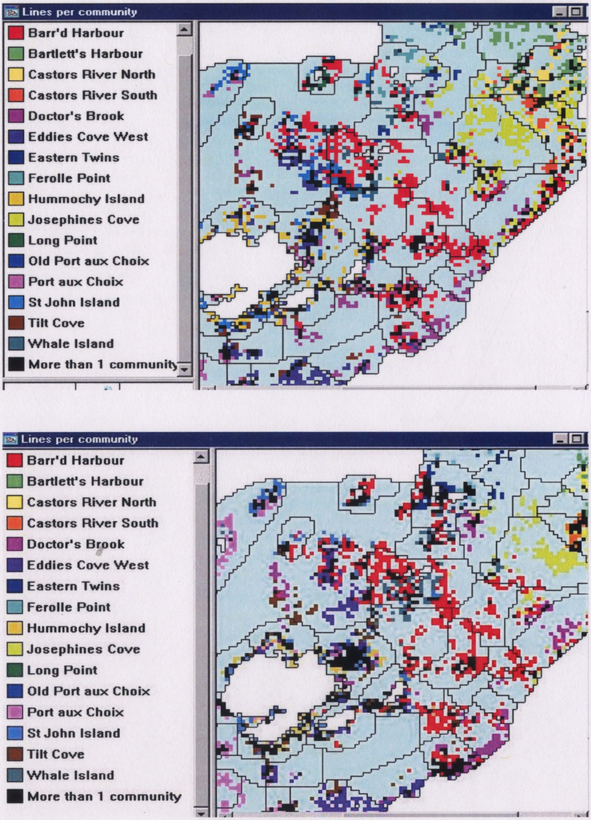


Figure 6.3. No gossip scenario: community lines set from Barr'd Harbour (red cells) and Doctors Brook (pink cells), day 27 (top), and 54 (bottom), 1995.

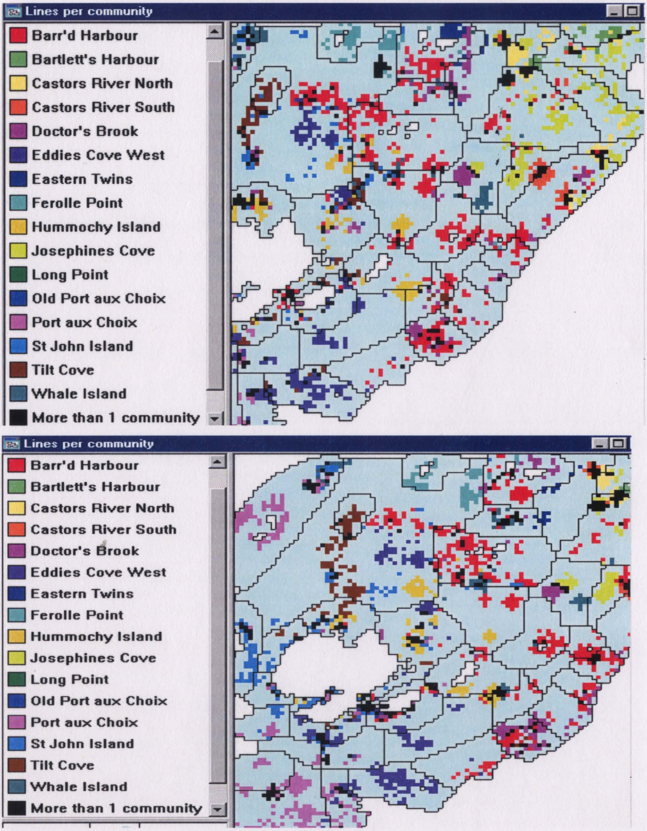


Figure 6.4. Gossip scenario: community lines set from Barr'd Harbour (red cells) and Doctors Brook (dark pink cells), days 27(top) and 54(bottom), 1995.

The pattern of moving to shallower water (Fig. 6.4) does not seem to be as evident in the gossip scenario. This could provide some additional explanation as to why the catch values are lower under the gossip scenario.

6.3 Experiment 2A: the effects of increased seasonal variation in the distribution of lobsters

The trend in the lobster landings shown in Figure 5.8 in the previous chapter suggests that the lobster stocks of St. John Bay could be crashing. There is an evident downward trend after 1989. Lobsters are under extreme fishing pressure since the influx of new harvesters to St. John Bay. As explained in the previous chapter, lobster fisheries under increased pressure from heavy fishing may depend heavily on small lobsters that have just matured into legal size—i.e. first year recruits. This could produce a more patchy lobster distribution pattern because the composite distribution of multiple age cohorts must be more even than the distribution of any one cohort. Concentrations of legal sized lobsters could therefore be at the north end of the bay in one year and the south end of the bay the next year.

This experiment was designed to explore situations in which the lobster population is spread out over the sea floor according to depth and preferred bottom type, phasing into a situation where the lobster distribution becomes patchier over time. The assumption is that seasonal variability increased more quickly after the increase in fishing pressure due to the introduction of new boats during the mid to late 1980s, because with increased harvester pressure the population of legal size lobsters is likely to be increasingly dominated by one age cohort, which would mean that the distribution of lobster would likely be patchier. Figure 6.5 shows the trend in the parameter value that controls the degree of variability in the distribution of lobsters from one year to the next. In the first period the seasonal variability is increasing more slowly than in the second period.

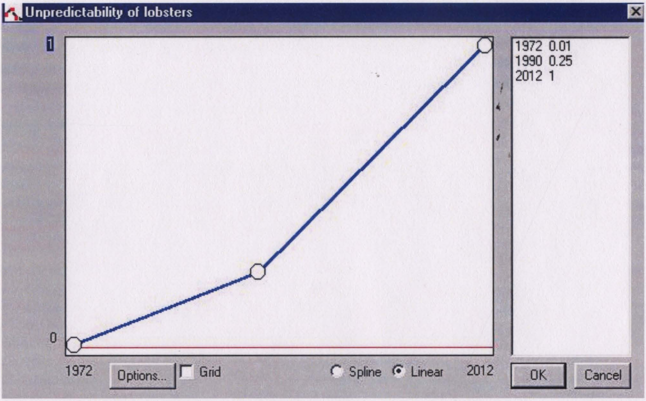


Figure 6.5. Seasonal variability of lobster distribution from 1972- 2012.

In the four maps presented below (Figures 6.6 and 6.7) the change in seasonal variability is exemplified in the distribution of lobsters. These figures are followed by the results of total yearly catch values, average catch values, early catch values, and community catches under this scenario (Tables 6.2 – 6.4).

In terms of both total yearly catch values and average catch values the introduction of higher seasonal variability increased catch values. A two-tailed t test confirmed that there was a significant difference between the mean catch values of the baseline scenario and the high seasonal variability (in lobster population) scenario at the 0.05 level (t= 3.35, p= 0.001, df=78). Although the mean catch values between the scenarios were different, the year-to-year variances of catch in these two scenarios were not significantly different at the 0.05 level (one tailed F, F=1.28, p= 0.216, df=39, 39). Given that the two simulations had the same number of lobsters, in a patchy distribution situation lobsters would be more concentrated. If this is the case, the boats are locating the lobsters faster, moving their lines less often and catching the lobsters faster. This interpretation is supported by the results presented in Table 6.3 that show the catch in the first 4 weeks (early season catch) as a percentage of total catch. The early season catch is much higher with higher seasonal variability in the distribution of lobsters. Since this is the case the high catches should be concentrated in only some of the communities, depending on their location and the location of the lobsters for any given year.

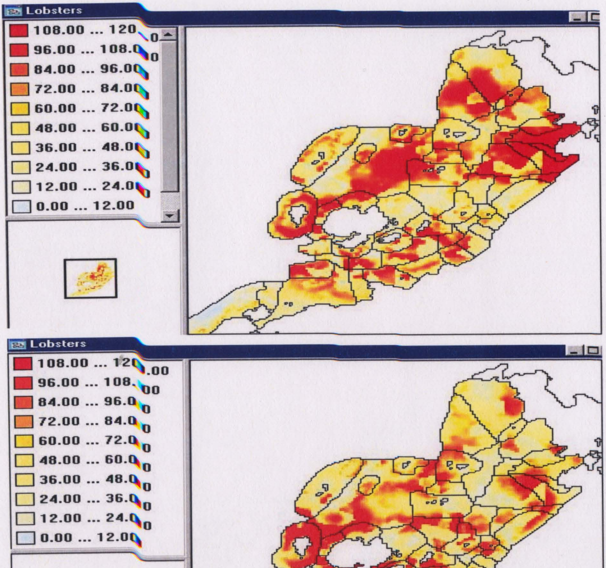


Figure 6.6. Low seasonal variability: lobster distribution day 2, 1975 (top) and 1976 (bottom).

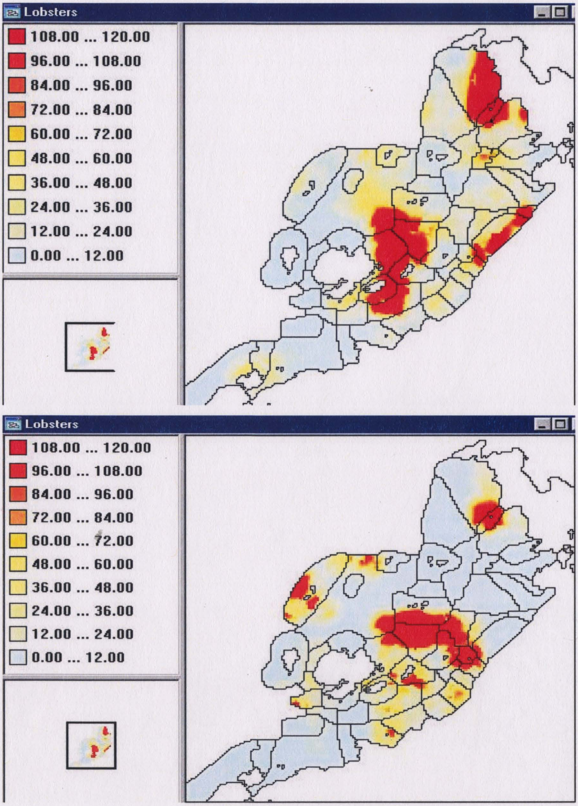


Figure 6.7. High seasonal variability: lobster distribution day 2, 2002 (top) and 2003 (bottom).

Table 6.2. Total annual catch and mean catch per boat under baseline and increased seasonal variability scenarios.

Year	Total annual catch			Average catch per boat		
	Baseline scenario	High seasonal variability	Difference	Baseline scenario	High seasonal variability	Difference
1972	414076	414076	0	5378	5378	0
1973	354610	349167	-5443	4605	4535	-70
1974	337862	350076	12214	4388	4546	158
1975	358059	385827	27768	4591	4946	355
1976	397835	405350	7515	5100	5197	97
1977	480001	660194	180193	6154	8464	2310
1978	450251	531536	81285	5772	6815	1043
1979	489941	642499	152558	6202	8133	1931
1980	463931	489800	25869	5948	6279	331
1981	485420	577025	91605	6068	7213	1145
1982	508891	685935	177044	6283	8468	2185
1983	579306	806422	227116	7152	9956	2804
1984	735958	1040294	304336	8658	12239	3581
1985	776354	970193	193839	6470	8085	1615
1986	702792	829757	126965	4915	5802	887
1987	615408	709681	94273	4158	4795	637
1988	755373	930142	174769	5070	6243	1173
1989	817725	964008	146283	5415	6384	969
1990	845370	954031	108661	5562	6277	715
1991	687978	780755	92777	4497	5103	606
1992	594474	675979	81505	3885	4418	533
1993	564711	647521	82810	3715	4260	545
1994	563743	642938	79195	3752	4286	534
1995	596982	716330	119348	3980	4776	796
1996	609762	758019	148257	4264	5301	1037
1997	519909	561380	41471	3610	3898	288
1998	423713	597549	173836	3048	4299	1251
1999	323104	480664	157560	2358	3508	1150
2000	316800	487019	170219	2347	3608	1261
2001	313695	426823	113128	2359	3209	850
2002	341252	536122	194870	2645	4156	1511
2003	333721	473381	139660	2607	3698	1091
2004	346582	537949	191367	2708	4203	1495
2005	334623	558966	224343	2614	4367	1753
2006	333549	536028	202479	2606	4188	1582
2007	333870	435837	101967	2608	3405	797
2008	335998	501470	165472	2625	3918	1293
2009	333340	528331	194991	2604	4128	1524
2010	338749	481484	142735	2646	3762	1116
2011	335133	545792	210659	2618	4264	1646
Mean	486246	615159	-128913	4300	5413	-1113
Var	25824034902	33279812026	-	2537239	3871607	-
Sd	160699	182428	-	1593	1967	-

Note: In the table above 'Var' represents the variance and 'Sd' represents the standard deviation

Table 6.3. Early season catch: comparison of baseline scenario and high seasonal variability scenarios.

Year	Baseline scenario	High seasonal variability	Difference
2000	67%	94%	27%
2001	66%	74%	8%
2011	65%	96%	31%

As can be seen from Figures 6.8 - 6.11 below the agents find the lobsters quicker and catch a greater number of them by the end of the season under high seasonal variability scenario. It would be expected that certain communities would have higher catches. Is there any difference between community catches? Do communities closer to the concentrations of lobsters have higher mean catches? The results are explored in the section below.

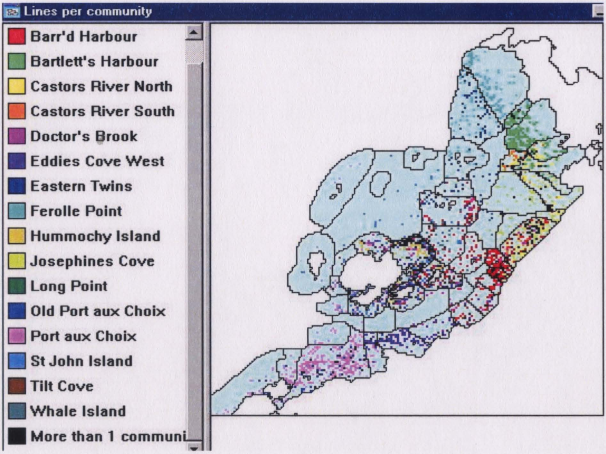


Figure 6.8. Distribution of community lines day 2, 2011, under high seasonal variability.

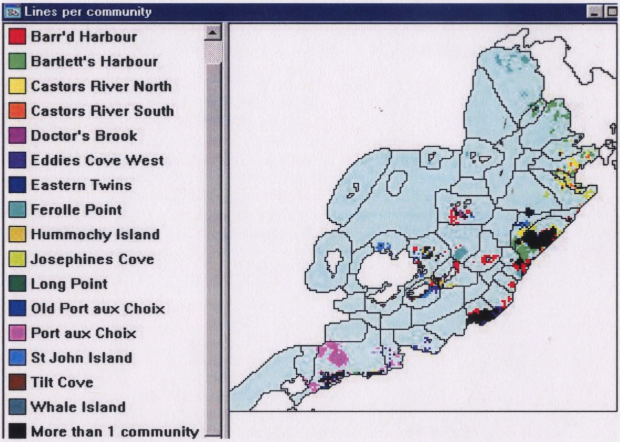


Figure 6.9. Distribution of community lines day 54, 2011, under high seasonal variability.

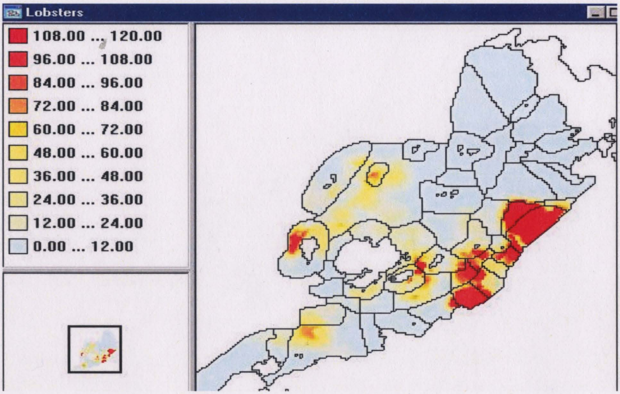


Figure 6.10. Distribution lobsters day 2, 2011, under high seasonal variability.

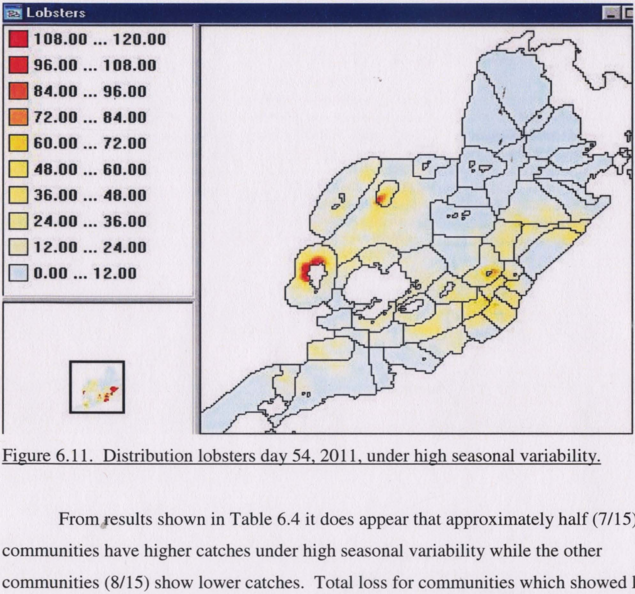


Figure 6.11. Distribution lobsters day 54, 2011, under high seasonal variability.

From results shown in Table 6.4 it does appear that approximately half (7/15) the communities have higher catches under high seasonal variability while the other communities (8/15) show lower catches. Total loss for communities which showed lower catches was 12481 lobsters. Total gain for those communities which showed increases in catches was 39129 lobsters. This could explain why the total catch values for all agents seem much higher when comparing this scenario to the baseline scenario. From the maps above it appears agents from certain communities find the concentrations of the lobsters fairly quickly, most of them concentrating their lines by the first weeks of the season. Communities that had higher catches include Barr'd Harbour, Tilt Cove, Eddies Cove West, Josephine's Cove, Castors River North, and Castors River South. The lobsters are concentrated in areas typically fished by these communities or are adjacent to areas fished.

Table 6.4. Mean catch per community under baseline and high seasonal variability scenarios in 2011.

Community	Mean catch baseline scenario	Mean catch high seasonal variability	Difference C2-C1
Barr'd Harbour	3493	8320	4827
Port aux Choix	2531	446	-2085
Old Port aux Choix	1732	541	-1191
St. John Island	2885	1647	-1238
Hummocky Island	2579	1582	-997
Whale Island	2666	1196	-1470
Tilt Cove	3817	5673	1856
Eddies Cove West	2201	2577	376
Doctors Brook	4023	10203	6180
Josephine's Cove	1748	12524	10776
Bartletts Harbour	2138	603	-1535
Castors River North	1677	5235	3558
Castors River South	1361	12917	11556
Eastern Twins	3747	1962	-1785
Ferolle Point	2496	316	-2180

If agents are setting lines near the boundary of the areas fished by the community, the random perturbation included in the line location module within the model will allow the agents to enter the adjacent, new area, and thus to catch lobsters in areas adjacent to those typically fished by the community.

The communities that showed a decline in catches were Port aux Choix, Old Port aux Choix, St. John Island, Hummocky Island, Whale Island, Bartletts Harbour, Ferolle Point, and Eastern Twins. Although agents from some of these communities seem also to concentrate on patches of lobsters (for example see Port aux Choix lines in pink-purple) the patches have far fewer lobsters than are present in other areas. In some other cases (such as Bartletts Harbour and Ferolle Point, shown in lime green and aqua, respectively) the community lines are not located where any large numbers of lobsters are present. In these cases the areas that hold the concentrations of lobsters are not located close to areas typically fished by agents from these communities. These results seem reasonable since harvesters from Bartletts Harbour or Ferolle Point would still move within their own areas (different depths) or move to adjacent areas in search of lobsters. They would probably keep moving their lines around these areas before they would move down to the middle of the Bay where the lobsters are present. By the end of the season lines from

Bartletts Harbour are present on the concentrations of lobsters, but the move was probably too late to compensate for their earlier lack of success.

6.4 Experiment 2B: the importance of gossip under high seasonal variability

This experiment was designed to test the importance of gossip under a high seasonal variation of the lobster distribution. In a situation where the lobsters are concentrated in one part of the Bay, does gossip increase the agents' catch? –i.e. can agents find lobsters and catch them faster? The total catch values for both scenarios and the differences between the values in each year of the simulation can be seen in Table 2, Appendix I. These results are summarized in Table 6.5 below.

Table 6.5. Comparisons of yearly catch values of two high seasonal variability scenarios: one with gossip, one without.

Year	**No gossip (δ 12= 1)**	**Gossip (δ 12= 0.1)**	**C2 – C1**
Mean	569746	582545	+12799
Variance	36857300416	28668011861	-
Standard Deviation	191982.5524	169316.3071	-

In the previous experiment it was suggested that one reason why catches were higher under the high seasonal variability scenario was that it was easier to find lobsters under the high seasonal variability scenario. If this is true then it may be the case that gossip will help to raise catch values under conditions of high seasonal variability. The catch values in Table 6.5 suggest that this is the case. Furthermore, as can be seen in Table 2, Appendix I, in a majority of years gossip increased the total yearly catch: 24 out of 40 years showed an increase in catch because of gossip while 16 out of 40 showed lower catch values. Since we expect that gossip will raise catch under a high seasonal variability scenario, a one tailed t-test was performed, but it showed that there was no significant difference at the 0.05 level between the mean catch values of the no-gossip and the gossip scenarios ($t=0.316$, $p=0.376$, $df=78$).

A one tailed F test showed no significant difference between the variances of the no gossip and the gossip scenarios at the 0.05 level ($F=1.285$, $p= 0.218$, $df=39,39$).

To see if there was a temporal trend in the differences of catches between the two scenarios I worked with a 5-year running average. The 5-year running averages of catch values were calculated for the no gossip and gossip scenarios. The difference between these values is given in Table 3, Appendix I.

In order to further examine the influence of variability in lobster distribution on the effect of gossip on catch, a pair of simulations (no gossip and gossip) were run in which variability was initially (1974) at a low level, and increased slowly until 1990, while after 1990 variability increased rapidly. The graphs in Figures 6.12 and 6.13 show the trend in the difference in catch between gossip and no gossip scenarios for the periods before and after 1990 respectively. By the year 1993 gossip systematically increases the total catch. This indicates that it takes a certain degree of high seasonal variability in order for gossip to make a difference to the total catch. Regression results indicate that with low but slowly increasing variability, gossip does not affect landings (Fig. 6.12: $R^2 = 0.0027$). Figure 6.13 also suggests a cyclical behavior in catch under the high variability gossip scenario, but this is not investigated further here.

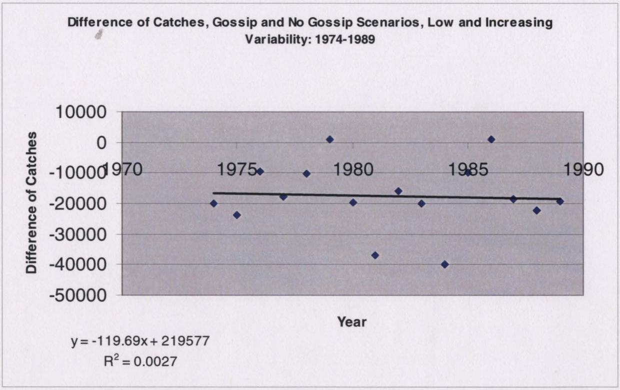


Figure 6.12. Differences of catches, gossip and no gossip scenarios: low and increasing seasonal variability 1974-1989.

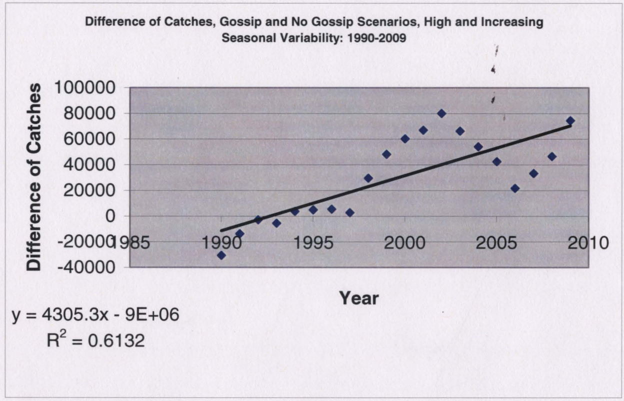


Figure 6.13. Differences of catches, gossip and no gossip scenarios: high and increasing seasonal variability 1990-2009.

6.5 Experiment 3: the implementation of community territories

Information on traditional community territories was collected during the spring and summer of 2002. In St. John Bay, according to informants there were specific areas where harvesters from each community traditionally fished. These areas did not overlap as much as they do today; with the increase in lobster harvesters the situation is now one where harvesters from any community may fish any area on a first come first served basis.

An experiment was performed to see what would have happened if the DFO had formalized and enforced the informal territories that existed prior to the influx of new harvesters in the mid 1980s. If people were only allowed to fish in a defined community territory, how would it affect their landings? Would harvesters from certain communities be more successful in terms of catch than harvesters from other communities? How variable would results from community territories be in comparison to the variability of community catches seen in the baseline scenario, which lacks community territories?

In order to answer such questions two simulations were run. The first is the baseline scenario, with no restrictions on areas fished: each person owning a lobster license has access to all areas within the Bay. The other implements a community territory management strategy beginning in 1972. Community territories are defined on the basis of where most people from each community fished in the early years of the fishery. Community territories are defined as an area or collection of areas (Figure 4.5, and Table 1, Appendix F). Community territories may overlap, so that agents from two or more communities share some areas. All other input data and parameter values were identical in the two simulations.

Do community territories affect catches? If the lines are spread out then agents should have a better chance of finding lobsters. However, if the agents have all their lines concentrated in patches and they happen to find the lobsters early, they may have higher catches. Is there more variability in catch from year to year? We also examine the effects of community territories under two situations, low seasonal variability and high seasonal variability. We then compare these results to results from the baseline scenario under low and high seasonal variability in the lobster population.

Since the number of lobsters and the number of boats within the simulation change from year to yea,r the average catch values vary over the years as well. For a complete table of catches for all the years in the simulations refer to Table 4, Appendix I. Comparison of the total annual catch and the average catch values for the two scenarios shows that catches under the initiative of community territories are lower than in the baseline scenario. This is a reasonable result since the community territories restrict the agents from expanding into new areas and finding more lobsters. From a management perspective it also seems like a good way to reduce effort.

Table 6.6. Mean, Variance and Standard deviation of total yearly catch (for all years) and mean catch per boat (for all years): No community territories and community territories scenarios.

Year	C1= Mean catch no community territories	C2= Mean catch Community territories	Difference C2-C1
Mean	486246	452902	-33344
Variance	25824034902	22789469587	-
Standard Deviation	160698.584	150961.815	-

A one tailed t test showed that although catch decreased as a result of the community territories implementation, there was no significant difference at the 0.05 level between mean catch values under the no community territories scenario and the community territories scenario (t=0.9564, p= 0.1709, df =78). A one tailed F test showed no significant difference between the variances of the no territories scenario and the community territories scenario at the 0.05 level (F=1.13, p=0.349, df= 39, 39).

In addition to examining the total annual catch, the differences between communities were examined for four years selected at intervals across the simulation period.

Table 6.7. Comparison of the differences between average community catch values under the baseline and community territory scenarios for the years 1976, 1986,1996 and 2002, Selected Communities**.

Community	Difference of mean catches: community territories – baseline scenarios				
	1976	1986	1996	2002	Trend
Whale Island	+870	+1701	+1070	+1047	Always +
Ferolle Point	+380	+1649	+1097	+130	Always +
St. John Island	+520	+2856	+2106	+1600	Always +
Bartletts Harbour	-723	-729	-877	-473	Always -

**For full table see Table 4, Appendix I.

The three communities that consistently showed a positive difference (community average catch higher under community territory scenario) were St. John Island, Whale Island and Ferolle Point. The seven communities that consistently showed a negative difference were Bartletts Harbour, Castors River North, Castors River South, Barr'd Harbour, Tilt Cove, Doctors Brook, and Hummocky Island. All the remaining communities showed variations over the years sampled.

The fact that some communities consistently show an increase in community catch as a result of community territories (positive difference) raises several questions. Do these communities typically have high concentrations of lobsters in their community territories? Are there typically fewer boats from other communities in these territories under the community territory scenario? To explain the differences among community catches, examine the maps for the distribution of lobsters (same for both scenarios) and for the distribution of community lines under both scenarios for day 27 in 1976.

Under the community territories scenario in 1976 Ferolle Point boats only share their territories (four fairly large areas) with four to six other boats from Long Point (Fig. 6.15). These areas have high concentrations of lobsters (Fig. 6.14). Whale Island boats have lines fishing on six different areas and all have high concentrations of lobsters.

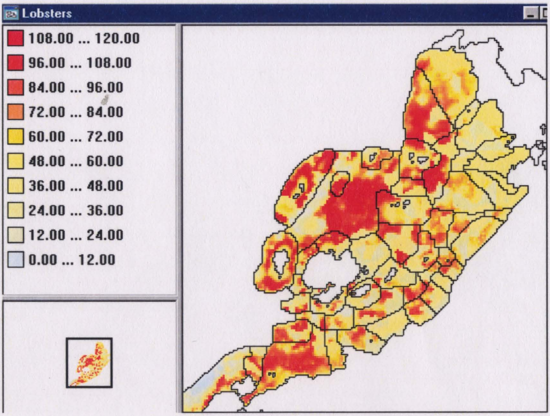


Figure 6.14. Distribution of lobsters, day 27, 1976.

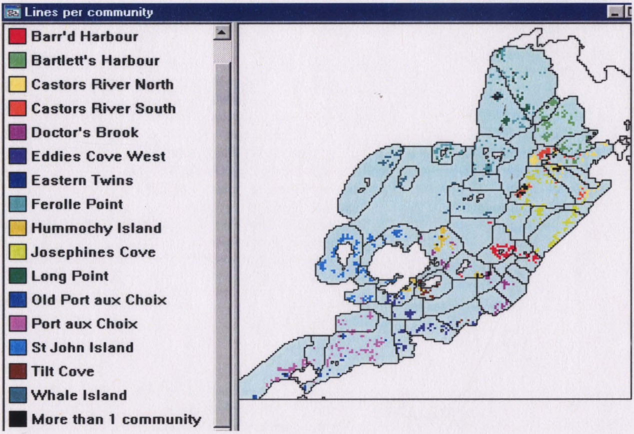


Figure 6.15. Distribution of community lines under community territories scenario, day 27, 1976.

Only two of the areas fished by boats from Whale Island are shared with boats from another community, and those set only a few lines, so competition is minimal. St. John Island boats have lines fishing in nine areas surrounding St. John Island. Although four of their areas are being shared with other boats, from Port aux Choix, Eddies Cove West, Hummocky Island, and Whale Island with a maximum of 20 boats, they concentrate their lines in areas where boats from these other communities are not fishing. The focus is mainly on areas to the north and west of the island where there are high concentrations of lobsters.

Under the baseline scenario (Fig. 6.16), in 1976 Ferolle Point boats share six areas with boats from four other communities (Whale Island, Long Point, Bartletts Harbour, and Castors River North with a maximum of 25 boats).

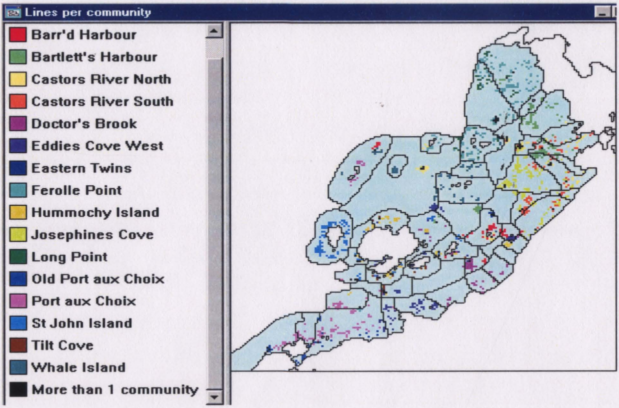


Figure 6.16. Distribution of community lines under baseline scenario, day 27, 1976.

Whale Island is sharing six areas with boats from Port aux Choix, Barr'd Harbour, Castors River North, Eddies Cove West, Ferolle Point, Bartletts Harbour, with a maximum of approximately 30 boats. St. John Island boats are sharing nine areas with boats from Hummocky Island, Eddies Cove West, Port aux Choix, Tilt Cove, Doctors Brook, and Barr'd Harbour.

Under the community territory scenario, the territories that show an increase in catch values always have high concentrations of lobsters in their community areas. But lobsters are in high concentrations in many areas. Therefore the explanation for consistently higher catches for certain communities under the community territories scenario is likely the result of high numbers of lobsters on the community territories in combination with relatively small numbers of other boats sharing the territories.

In the case of Bartletts Harbour where there is always a decrease in catch after the community territory scenario is implemented, the lower catches seem to be related to the lack of concentrations of lobsters. They do not have numerous other boats sharing most of their areas in the community territory scenario. Bartletts Harbour lines are more spread out and cover more area under the baseline scenario. Consequently if the community territories were not in place these harvesters would be able to move around more widely to find lobsters.

From the results of the four years inspected it seems as though the change in community average catches as a result of the implementation of community territories is variable. A community can show an increase in average catch per boat in one year and experience a large decrease in the next. This shows that when agents are confined to specific areas, their catches are highly susceptible to the locations of the lobsters. These scenarios both had low seasonal variability in the lobster distribution but the lobsters still were in slightly different places, at different concentrations, every year.

Looking at overall rather than community catches, what is the effect of the introduction of community territories? It is expected that the introduction of community territories will not make a significant difference under low seasonal variability, but may under conditions of high variability in the distribution of the lobster population. Keeping the number of boats and the number of lobsters constant under both the baseline and the community territories scenarios, I compare the mean catches and variances under the community territories and no community territories scenarios. I then make the same comparisons under conditions of high variability of the lobster distributions. The model was run from 2003 to 2012 with 4 different random seeds, so in total 40 years were recorded. Four of these 40 year runs were made, to cover the four cases of low seasonal and high seasonal variability, under both territory scenarios (Table 5, Appendix I).

The results in Table 6.8 show community territories produce lower mean catch under low seasonal variability of lobster distribution; the difference was significant at the 0.05 level (one tailed t, test t=4.58, p= 0.00, df=78). However, under high seasonal variability the mean catch was not significantly lower under the community territories scenario at the 0.05 level (one tailed t, t=1.06, p= 0.146, df=78).

Table 6.8. Mean catch per boat, variance, and standard deviation for baseline and community territory scenarios under high and low seasonal variability.

Statistic	**Baseline Low seasonal variability**	**Baseline High seasonal variability**	**Community territory Low seasonal variability**	**Community territory High seasonal variability**
Mean	2568	3842	2334	3250
Variance	4982	190255	2476	305481
Standard Deviation	71	436	50	553

A one tailed F test showed that variance in catch is significantly higher at the 0.05 level under the low seasonal variability baseline scenario compared with the corresponding community territories scenario (F=2.012, p= 0.015, df = 39,39). Although community territories reduced variability in catch under low seasonal variability, a one tailed F test showed that there was no significant difference between the variances of catch between the baseline scenario and the community territories scenario under high seasonal variability (F= 1.60, p= 0.07, df = 39, 39). Since in these scenarios the lobsters are patchy and change in location from one year to the next and agents are confined to their community territories, in some years they will catch high numbers of lobsters and in some years they will not, depending on where the large patches are in a particular year.

6.6 Experiment 4: effect of trap limits and a required minimum number of traps per line.

Trap limits are an important management tool. Traditionally, trap limits consist of specifying a maximum allowed number of traps each license holder can use during a season. Trap limits did not exist in the early years of the fishery. In 1991 a trap limit of 600 traps per license was implemented; in 1994 the trap limit was cut to 500, and in 1996 it was cut again to 425 traps per license. Nevertheless, in the province of Newfoundland

and Labrador, St. John Bay currently has the highest allowable number of traps per license.

In the past harvesters have reacted to the lowering of trap limits by decreasing the number of traps they string on a line. They report that this gives them the ability to sample the same area of ocean for lobsters limiting negative impacts on their individual landings. In the simulation model as calibrated, each agent is assigned a number of traps and a number of traps per line at the beginning of the simulation, and then has the number of traps adjusted during the simulation to reflect the trap limits implemented in 1991, 1994, and 1996. Initial traps fished and the numbers of traps per line for each agent, as well as trap limit data, are read from the input file.

In this experiment a baseline simulation (Figure 6.17) without any changes in trap limits after 1996 is used to compare two scenarios in which new trap limits are imposed (Figure 6.18). In the three simulations all parameter values and input data are held constant, except for those relating to trap limits. The first simulation represents a fishery that retains the current trap limits. The second simulation represents a fishery that has new trap limits imposed in 2004 (350 traps) and again in 2005 (300 traps). The third simulation has the same trap limits imposed in 2004 and 2005 but in addition requires a minimum of six traps per line (TPL). Since harvesters reported reducing the number of traps per line as a response to a reduction in the trap limit, presumably to minimize the effect of the trap limit on their catch, it is useful to see whether such a management initiative would be likely to have an effect on their landings. We examine total yearly catch values for the three simulations, the average catch per license and the mean catch of all boats in the simulation.

The introduction of new trap limits in 2004 and had the effect of lowering overall total yearly catch values and mean catch values (Tables 6.9 and 6.10). With the introduction of a minimum traps per line regulation, however, the total yearly catch values are somewhat higher than in the case of new trap limits only. One possible explanation for these unexpected results is that with fewer lines agents keep more of their lines (and more of their traps) in areas with the highest concentrations of lobsters.

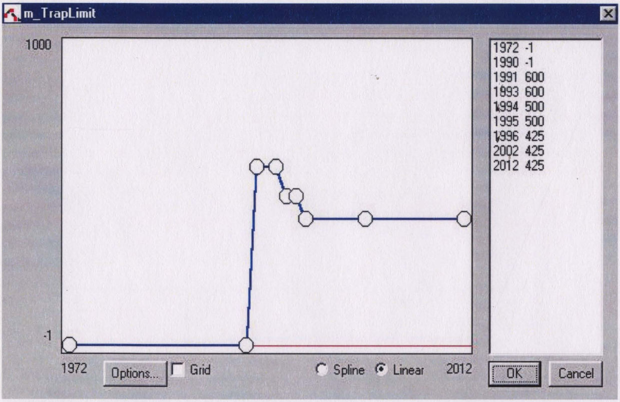


Figure 6.17. Trap limit implementations under the baseline scenario.

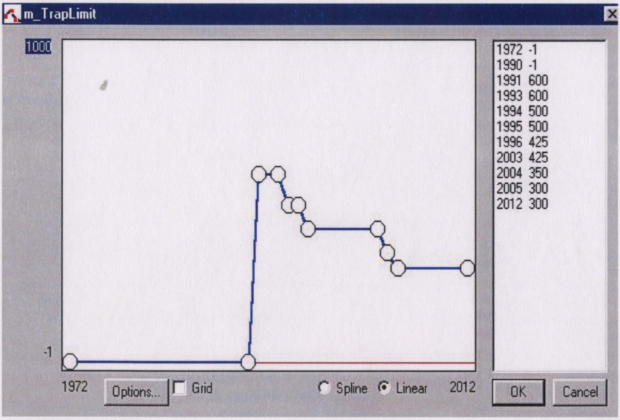


Figure 6.18. Trap limit implementations with additional trap cuts in 2004 and 2005.

Table 6.9. Total yearly catches under three trap limit scenarios.

Year	No new trap limits	New trap limits	Difference C2-C1	New trap limits and minimum TPL	Difference C3-C2
2003	333721	333721	0	333721	0
2004	346582	306207	-40375	311936	+5729
2005	334623	268910	-65713	283579	+14669
2006	333549	269653	-63896	282425	+12772
2007	333870	263827	-70043	277533	+13706
2008	335998	270596	-65402	281109	+10513
2009	333340	264566	-68774	277463	+12897
2010	338749	271778	-66971	279455	+7677
2011	335133	269078	-66055	273204	+4126

Table 6.10. Mean catch per license 2004-2011 under three scenarios.

Year	No new trap limits	New trap limits	New trap limits and minimum TPL
2004	2108	1926	1962
2005	2159	1735	1830
2006	2098	1696	1776
2007	2154	1702	1791
2008	2113	1702	1768
2009	2151	1707	1790
2010	2130	1709	1758
2011	2162	1736	1763

The simulations were run four times over the same 10-year period (2003-2012) (Table 6, Appendix I) to acquire an adequate sample of model output to permit a statistical analysis. The resulting statistical values are presented in Table 6.11.

Trap limits, both by themselves and with minimum traps per line had the effect of lowering catches. In both cases the difference was statistically significant at the 0.05 level (one tailed t test, t=6.21, p= 0.000, df=78; one tailed t, t= 4.18, p= 0.000, df= 78). Limiting the number of traps per line results in higher catches than under the trap limits only scenario; however the difference is not significant at the 0.05 level (two-tailed t, t=0.63, p=0.527, df= 78).

In addition, the variances under both the trap limit and minimum number of traps per line scenarios were significantly higher than in the baseline scenario (one tailed F test, F=2.52, p=0.002, df 39, 39 and F= 1.737, p= 0.044, df= 39, 39 respectively).

Table 6.11. Mean, variance, and standard deviation of catch under Baseline, trap limit and minimum TPL scenarios.

Statistic	Baseline	New trap limit	Difference C2-C1	New trap limit and MinTPL=6	Difference C3- C1	Difference C3-C2
Mean catch, all runs	328744	270874	-57870	278568	-50176	+7694
Variance	81616874	206102055		141771117		
Standard Deviation	9034.206	14356.2549 2		11906.7677		

However, a one tailed F test showed that there was no significant difference at the 0.05 level between the variance under the trap limit and minimum trap per line scenarios ($F= 1.45$, $p= 0.125$, $df=39, 39$).

Table 7, Appendix I shows the changing number of lines, traps per line and subsequent number of lobsters caught, for each boat, before and after the limitations are introduced. Once trap limits are implemented boats most often keep the number of lines approximately the same, but sometimes increase or decrease the number of lines slightly. Once the minimum number of traps per line is implemented, the number of lines an agent is using usually declines more than if trap limits only are imposed, as expected. In the few cases of agents who were not affected, i.e. who were able to keep the same number of lines, under both scenarios the catch under minimum TPL is higher. Since the number of lines in these cases is the same, the change in catch cannot be due to these agents using fewer lines. It has to be related to another factor, like the distributions of lobsters, or the competition for lobsters. Since the lobster population is the same for both scenarios this is unlikely to be the cause. This lends support to the possibility that boats will catch more because the overall numbers of lines have declined and there is less competition for lobsters. In general, boats will have fewer lines and will catch higher numbers of lobsters under the minimum TPL scenario.

Although the implementation of lower trap limits seem to lower the catch (Tables 6.9 and 6.10) and therefore pressure on lobster stocks, there is still an economic consideration. With trap limits, the average catch per license declines to a low level

(Table 6.10). The average catch over all years (2004-2011) under the trap limits only scenario is 1739 lobsters or 2434 lbs of lobsters. Reports suggest that harvesters were already experiencing annual catches approximately equal to these values. In the simulations, however, in some future years, average catches as low as 1696 lobsters occur. At this level, it will be difficult for harvesters to make an economic success of the fishery. One way to offset this reduction in the catches would be to decrease the number of licenses within the Bay. This would increase the average catch per license without significantly affecting the lobster population (the total yearly catches would remain essentially the same from year to year).

6.7 Experiment 5: the implementation of closed areas in 2004.

The management initiative of closed areas has already been implemented in the Eastport lobster fishery. In this region on Newfoundland's east coast the areas around two small islands were closed to commercial fishing. It is the hope that these areas can now act as spawning grounds, and research is continuing in the area to determine if such a measure can have a positive outcome for harvesters' catch rates in the future. In Experiment 5 I closed areas 21-26 around St. John Island in 2004, so that the harvesters can no longer fish in these areas. The closed areas are shown in black in the figure 6.19 shown below.

Figure 6.19. Closed areas (black) around St. John Island.

Table 6.12. Total yearly catch under one run of baseline and closed area scenarios.

Year	Catch, baseline	Catch, closed areas	Difference
2003	305466	305466	0
2004	329800	319868	- 9932
2005	328718	316545	-12172
2006	333234	323089	-10144
2007	333069	324833	-8236
2008	337277	329495	-7781
2009	331129	321143	-9987
2010	337178	322978	-14200
2011	331544	320733	-10810
2012	336081	326598	-9483

The results in Table 6.12 show that the effect of closing areas is to lower total yearly catches. The magnitude of decline in catch values is dependent on where the lobsters are (Figure 6.20). When there are high concentrations of lobsters in the closed areas, the effect on lowering catch values is large. The map of the lobster population densities on day two, 2004 shows there was not a high concentration of lobsters in the closed area. This suggests that the declines in catch values could be considerably larger in a situation where the lobsters were highly concentrated in the closed areas.

Results showing that closing these areas reduced catch values suggest that this management initiative might contribute significantly to the recovery of Bay lobster populations. The more lobsters that are in the closed areas the bigger the effects would be.

However, this management strategy is based on the assumption that an increasing lobster population in the closed areas will largely remain in the closed areas. Although in the model the lobsters move during the course of the season, there is no modeling of larval drift, growth, reproduction, and settlement. There is also nothing that links the lobster population beyond the end of the season to the fishing activity, so we cannot say how much such a policy would impact catches in the long run. Since it takes 7-8 years for lobsters to mature to legal size these results will not show the expected enhancement in catch values until 7 to 8 years after the areas are closed.

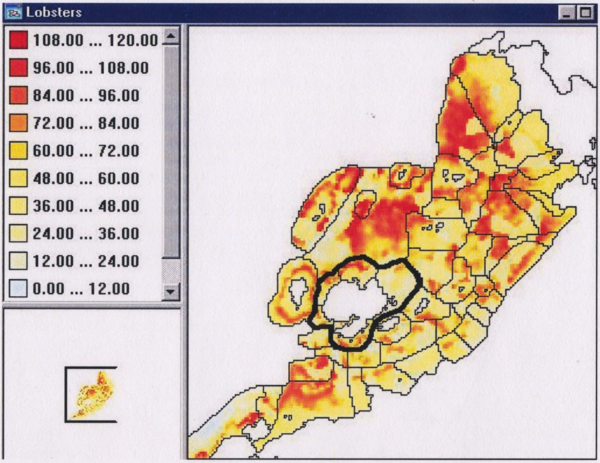


Figure 6.20. Locations of lobsters, day 2, 2004, closed areas outline in black.

Table 6.13. Mean catch, variance and standard deviation, 2003-2012, four runs of the baseline and closed areas scenarios. (For full table see Table 8, Appendix I).

Statistic	Baseline	Closed Areas	Difference (C2 – C1)
Mean catch, all runs for all years	328190.2	319355	-8835
Variance	82108693	53252294	
Standard deviation	9061.385	7297.417	

Results show that closing areas decreases overall landings, the difference between the mean catch values of the baseline and the closed areas scenarios is significant at the 0.05 level (two-tailed t, test t= 4.80, p= 7.4 E-06, df=78). A one tailed F test showed that there was no significant difference at the 0.05 level between variances of the baseline scenario and closed areas scenario (F=0.65, p= 0.90, df=39,39).

In addition to examining the changes in total yearly catches and average catch under the two scenarios, I also wanted to see if closed areas had different effects on different communities. To this end I examined the results of one run. Figures 6.21 and 6.22 below show which communities had lines set in or around the closed areas in the year before the implementation as well as the year after the implementation.

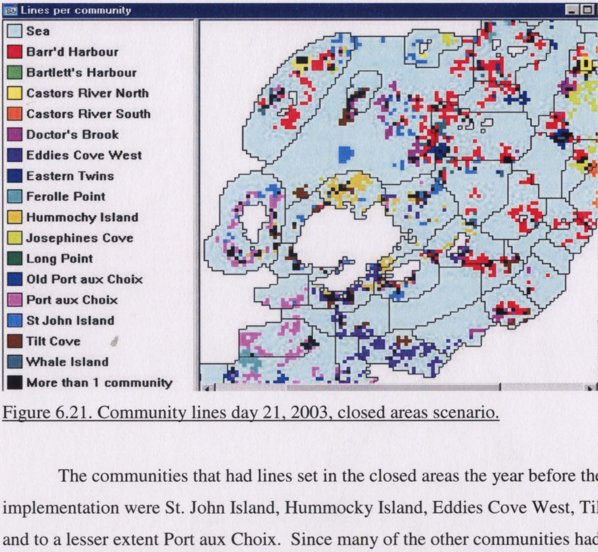


Figure 6.21. Community lines day 21, 2003, closed areas scenario.

The communities that had lines set in the closed areas the year before the implementation were St. John Island, Hummocky Island, Eddies Cove West, Tilt Cove, and to a lesser extent Port aux Choix. Since many of the other communities had lines set in adjacent areas where indirect effects of closing the areas could be experienced, all community averages were recorded and compared to the baseline scenario. The results of the community averages for 2004 are shown in Table 6.14. I also wanted to investigate if any changes occurred in the years following the implementation. Would all communities that experienced a decline in 2004 also experience one in 2011? I have included results from 2011 to represent these changes. Figures 6.23 - 6.24 showing the distribution of community lines in 2011 and the distribution of lobsters in the same year will help explain these changes.

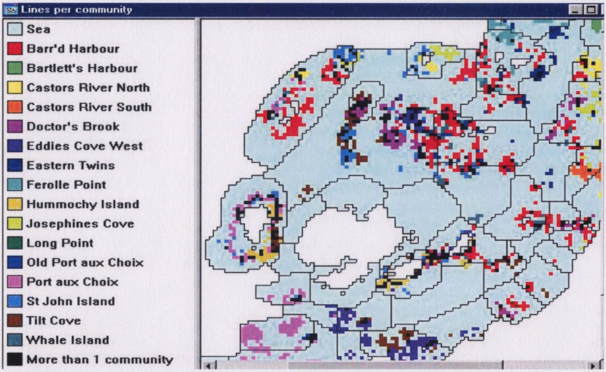


Figure 6.22. Community lines day 21, 2004, closed areas scenario.

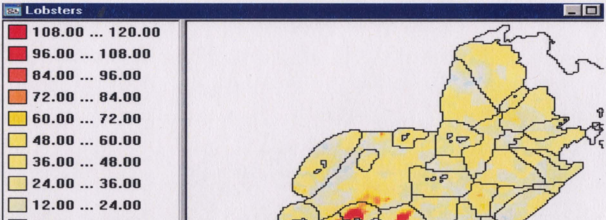


Figure 6.23. Distribution of lobsters, day 21, 2011.

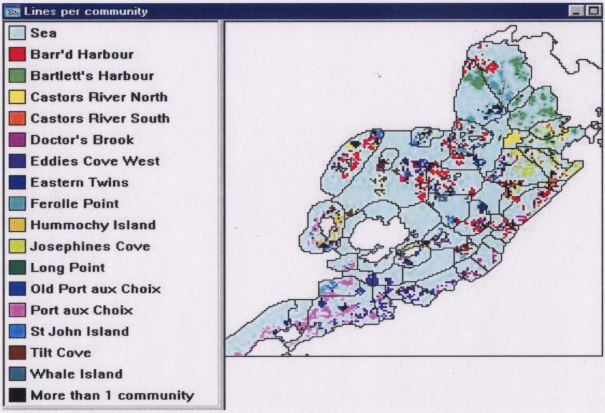


Figure 6.24. Distribution of community lines, day 21, 2011.

Of the communities shown in Table 6.14 below, Port aux Choix showed the smallest decrease (-2), which is explained by the fact that Port aux Choix did not have many lines in the closed areas the year before the implementation was introduced. In 2011, however, Port aux Choix showed a larger decline, exemplifying the fact that harvesters from this community typically did have some lines in the St. John Island areas and would have experienced a decrease in community catch averages at some point in the future. Hummocky Island and Tilt Cove showed the greatest decrease in average community catch as a result of the closed areas (-234, -342 respectively). Both Hummocky Island and Tilt Cove had many lines in the closed areas in 2003 (Figure 6.21). Although Tilt Cove continued to show a decrease in average catches in 2011, Hummocky Island's community catch increased under the closed areas scenario. By examining the distribution of lobsters and where lines from Hummocky Islands are in relation to the lobster population it is clear that their new areas were more productive in 2011.

Table 6.14. Mean catch per boat by community, 2004 and 2011, under baseline and closed areas scenarios.

	2004			2011		
Community	**Mean Baseline**	**Mean Closed Areas**	**Difference**	**Mean Baseline**	**Mean Closed Areas**	**Difference**
St. John Island	3089	3153	+64	2885	2843	-42
Hummocky Island	2268	2034	-234	2579	2682	+103
Tilt Cove	3906	3564	-342	3817	3547	-270
Eddies Cove West	1900	1751	-149	2201	2073	-128
Whale Island	2764	2680	-84	2666	2886	+220
Port aux Choix	2364	2230	-2	2531	2417	-114
Barr'd Harbour	3838	3774	-64	3493	3455	-38
Bartletts Harbour	2331	2371	+40	2138	1910	-228
Castors River North	2013	1988	-25	1677	1739	+62
Castors River South	2406	2359	-47	2076	2287	+211
Doctor's Brook	3940	4047	+107	4023	4101	+78
Eastern Twins	3557	3640	+83	3747	3781	+34
Ferolle Point	2736	2617	-119	2496	2125	-371
Josephine's Cove	2139	2203	+64	1748	1910	+162
Old Port aux Choix	1585	1698	+113	1732	1719	-13

Since the lobster population around St. John Island remains high throughout the season, it is possible, for example, that because lines from Hummocky Island are in areas very close to the closed areas they experience positive effects on their catches due to lobster movements out of the closed areas. Eddies Cove West also experienced a decrease (-149) after the closed areas were implemented because this community also had many lines in the closed areas in 2003. In other communities such as Barr'd Harbour, results showed a decrease in catch values, probably due to the additional communities that had been forced into the same areas, thus increasing competition for the lobsters. This pattern of declines in catches continued in 2011 results. In 2003, St. John Island boats fished in areas adjacent to the areas that were closed in 2004. St. John Island boats showed an increased catch in 2004, which is not surprising, given that most of their lines were already in adjacent areas in 2003.

Bartletts Harbour, Doctors Brook, Eastern Twins, Josephine's Cove and Old Port aux Choix all showed increases in their average community catch in 2004 after the closed areas were implemented. These communities had all or many of their lines in areas away from the closed areas and were not affected the year after the implementation. Bartletts Harbour, Old Port aux Choix, and Eastern Twins continued to show a decrease in 2011. Doctors Brook and Josephine's Cove experienced increases in their average community catch values.

Ferolle Point, Castors River North and Castors River South showed decreases in catch as a result of closed areas in the year following the implementation. In 2011 Castors River North and Castors River South both showed increases in catch values. Ferolle point continued to show reduced catch values. From Figure 6.24 it is clear that there is an influx of lines into the Ferolle Point areas in 2011. There are many lines from Bartletts Harbour as well as Barr'd Harbour. This is probably the end result of a domino effect that ended up at the very bottom of the Bay around Ferolle Point.

In the year 2011, 8 of 15 communities experienced a decline in average community catches, with a total overall decline in community averages of 1204 lobsters. The total increase in average catches was 870 in 7 of 15 communities. From the results it seems definite that closing areas will decrease overall catches, but the effects from year to year in terms of which communities will experience declines or increases in catches seems to be variable.

This concludes the chapter on experiment results. The major issues stemming from these results will be discussed in the concluding chapter. These issues and themes will also be tied into fieldwork results where applicable.

Chapter 7: Conclusion

The lobster fishery in St. John Bay has been a lucrative fishery for over 100 years. Prior to the collapse of the Northern Gulf cod fishery in the 1990s, lobster was not as important to the incomes of small boat harvesters as it is today. In the past, a majority of the harvesters here and elsewhere in Newfoundland fished lobster to receive cash income to start up other fisheries. They would often leave the lobster fishery mid-way through the lobster season when the cod fishery opened. In the mid 1980s the situation in St. John Bay changed drastically. Declining cod landings in the inshore sector and the subsequent closure of the Northern Gulf cod fishery in 1993 triggered major changes to the lobster fishery in St. John Bay. Not only did the number of lobster licenses fished from St. John Bay increase dramatically but harvesters started fishing the entire lobster season and fished over much larger areas than in the past. Since the 1990s, the right to transfer licenses between LFA's has been taken away, leaving a large number of harvesters trapped in an area where landings are in decline and the stocks appear to be in serious trouble.

Despite retirements and license buybacks, the number of licenses in the Bay has more than doubled since the mid 1980s. This change has affected many aspects of the fishery including fishing strategies, crew composition, spatial dynamics, the level of competition for lobsters, individual landings, and economic returns. Declining landings, changes in crew composition such as the incorporation of wives into crews instead of sharemen from other households and the widespread use of buddying up are all indications of intense financial pressure on these harvesters that has been exacerbated by particularly limited access to alternatives species like crab and the re-closing of the Northern Gulf cod fishery in 2003.

In this thesis I have linked two different approaches to studying a lobster fishery. The first involved fieldwork and interviews. This component provided me with detailed information on the history of the fishery since the 1970s as well as on changes in fishing strategies, crew composition and other factors over this thirty year period. The results from this fieldwork component indicate that changing technologies such as the introduction of sounders, GPS systems, hydraulic trap haulers, higher horsepower engines, and the addition of chutes onboard boats have enhanced the efficiency of lobster fishing and produced some interesting changes in the way harvesters fish for lobsters. The new navigation systems used by the majority of harvesters make it easier to pinpoint the location of traps and lobsters and strategically place each line. This increases the harvester's chances of catching any lobster that may be in the immediate vicinity. In addition, as elsewhere, the increased power of boat motors has changed the fishery from a less mobile fishery focused on the interception of lobsters as they move into shallower water to the pursuit of lobsters with the aid of new technologies and faster boats (Gendron et al. 2000). Lobster fishing has also become less labor intensive than in the past, with hydraulics allowing harvesters to retrieve traps from the water and return them more easily using chutes. This is not to say that lobster fishing is no longer labor intensive; all the new technology in the world would not make lobster fishing an 'easy' occupation.

Despite increased efficiency, the pursuit of lobsters and new management initiatives in the 1990s, overall landings are substantially lower than in the past, competition between harvesters is much more intense than it was prior to the mid 1980s, some areas may have been fished out and, in response, effort is now concentrated in the bottom part of the Bay in a shoal area between Whale Island, Bartletts Harbour, and Josephine's Cove (locally known as bottom of the Bay).

Using the fieldwork and interview data as the basis for an IBM model and calibrating the model against the fieldwork findings made it possible to develop "what if" scenarios in order to explore the potential impact of changes in fishing strategies and in management initiatives on landings. During the study, there was a continuous back and forth between the two components in order to develop the IBM of St. John Bay. Five experiments produced very interesting results. However, the modeling to date is somewhat preliminary and much more could be done in the future with improved information on lobster biology, refinement of the model and further experiments. The remainder of this chapter draws together results from the fieldwork and modeling components and identifies areas for future research.

During the period under study, the strategies harvesters used to decide what areas (and where inside these areas) to fish changed from using traditional knowledge and practices (e.g. community areas), compasses and charts, some trial and error, as well as knowledge passed down from their fathers, to following others and going to areas on a first come first served basis. The transfer of licenses into St. John Bay has weakened community structure, which may make it more difficult to introduce new management initiatives in the future. It has also changed communication patterns between harvesters making them, on the one hand, more guarded in their communications but, on the other hand, encouraging information sharing as harvesters grapple with low landings and the need to search more intensively than in the past for the remaining lobsters.

Results from interviews suggest that a hierarchical system of gossip is present in St. John Bay. Harvesters are more likely to share information (relative locations of lobsters and catch in these locations) with family members. There is also a higher probability that harvesters will share more accurate information with family members. The hierarchy starts at the top with close family relations (fathers, brothers) being the most reliable sources of gossip then ends with harvesters from different communities within the Bay where information is less likely and reliable. Gossip between harvesters on islands is not as probable as between family members but it is still more likely than gossip between harvesters from the larger communities.

The first experiment modeled the effect on catches of different levels of communication among harvesters. Although results from this experiment showed that gossiping lowers catch when lobster distributions are relatively stable from year to year, gossiping under the high seasonal variability scenario increases catch (experiment 2B). Fieldwork results suggest that harvesters are only guided by gossip when their catch is low and they are uncertain as to where the lobsters are located. Without gossip it would be difficult for some harvesters to locate and catch lobsters if they are concentrated in only one or two parts of the bay. A 5-year running average of the differences in catch with and without gossip under increasing seasonal variability showed an interesting change around 1990. After 1990 the introduction of gossip increased catches. This suggests that seasonal variability may have to reach a certain threshold in order for gossip to make a difference to the total catch.

Many harvesters reported decreased individual landings over the study period. This is not surprising, since the number of licenses has increased and lobster has become the most important species to their incomes. As a result of declining landings a subsequent decline in individual catch thresholds was also reported. In addition, reports also suggest a decline in catch per unit effort over the study period. A sharper decline in both catch per unit effort and landings occurred after the influx of licenses and in association with increased competition for lobsters. Although the economic effects of lower landings have been somewhat offset by higher prices for lobsters, these results suggest the lobster stocks of St. John Bay could be heading towards a crash and point to the extreme financial vulnerability of these harvesters. A reported decline in small and spawny lobsters is causing concern since the lobster population consists of few age cohorts and the fishery mainly depends on newly matured individuals. It is thought by many biologists that the breeding stock is mainly comprised of small lobsters that have spawned once and will comprise the majority of the population in year + 1 (Ennis and Fogarty, 1997). This may mean a decline in catch the next year. It may also mean reduced amounts of larvae (i.e. reduced reproduction rates) because small lobsters do not produce high numbers of eggs and the eggs produced are more vulnerable than eggs produced by large females. However, it was suggested by one biologist that it is possible that the breeding stock is in deeper water and not subject to commercial catch from coastal traps and therefore fishing effort will have little or no effect on the lobster population. Ennis and Fogarty (1997) do suggest that few large lobsters may explain why populations of lobsters continue to persist at low levels of egg production.

In St. John Bay large lobsters (males and females >126 mm) are protected from the commercial catch. The breeding stock could also be comprised of these individuals as well as smaller immature individuals. There is anecdotal evidence from feedback meetings in St. John Bay (large lobsters being caught in winter flounder (*Pleuronectes americanus*) nets) that this may be the case. With sustained fishing pressure, over time the lobster distribution in a uniform population is more likely to become more patchy than in a situation where no fishing pressure is exerted, with the remaining lobsters concentrated in fewer and fewer sections of the Bay. With no other viable options for diversifying into other fisheries the pressure will remain high on the lobsters and lobster harvesters of St. John Bay.

These changes in lobster landings, catch thresholds, and CPUE provided the rationale for the second experiment (2a). In this experiment, harvesting outcomes associated with an increase in the patchiness of lobster distribution were explored. In the model, the greatest degree of patchiness occurred in the years following 1990 when pressure on lobster stocks peaked. Introducing high seasonal variations in the lobster distribution increased the overall catch. This interesting result was not expected. It suggests that when the lobsters are concentrated in certain areas of the bay, there is no significant difference in the variance of overall catches between high and low seasonal variability (lobster distribution) scenarios. It may be that when the lobsters are in patches it is easier to find them and those harvesters who do locate lobsters experience higher catches in that year. Harvesters from communities located far away from lobster concentrations experience lower catches. I expect higher variance in community catch with high seasonal variability because a few communities (which are fishing in areas where lobsters are concentrated) will have very good catches in the years the lobsters happen to be in their area. However if in the next year the lobsters are at the other end of the Bay their communities will likely have lower than average catch for the year. The result would be higher variance among the community catches under a high seasonal variation in the distributions of lobsters.

The influx of licenses and subsequent crowding of community fishing areas has changed the spatial dynamics of the St. John Bay lobster fishery. The intensification of fishing effort and expansion of fishing areas into almost the entire lobster habitat in the Bay is placing pressure on the lobster stocks. Territories were once smaller and close to the harvesters' home communities but now they have expanded to cover most areas of the bay. Harvesters from more than two communities now fish many areas. Expansion of effort throughout the entire bay may mean that once protected small pockets of lobsters are now heavily exploited increasing the risk of stock collapse and related delays in stock recovery.

This influx of licenses has broken down the traditional community fishing territories in St. John Bay. In other areas such as Eastport, community territories have remained after increased fishing pressure (Davis *et al.*, 2002). In Maine, the traditional territories of communities have also remained after increased fishing pressure (Acheson, 1981, 1987 and 2003). In both these areas catch rates have not suffered declines to the same extent as in St. John Bay.

In experiment 3 I modeled the effect reintroducing traditional community areas might have on catches. Results showed that such an initiative would reduce the overall catches at least in the short term suggesting community territories might help to conserve the remaining lobsters. However, in a few communities, territories led to increased catch. This outcome was due to the operation of fewer numbers of boats from these communities and to higher concentrations of lobsters in these areas. Communities where the introduction of territories appeared to lower catches were communities with low lobster concentrations in their community territories for the period under examination. Since there were few lobsters and the territories prevented them from moving to other areas, the model showed their catches declining. Thus, in a context where lobster distribution is very patchy, management on the basis of community areas or territories will tend to have uneven effects on different groups of harvesters.

The failure of DFO to recognize and enforce community fishing areas probably contributed to the changes that have taken place in the St. John Bay fishery. Within the LFA, under DFO rules, harvesters can fish wherever they choose. In the LFA's, all of the harvesters (including those who took up lobstering in this area in the mid 1980s) select where to fish based on depth and memory of places where catch has been exceptional in the past. They use this information to pinpoint locations to set and move their lines. The majority of harvesters spread their lines out in each of their areas to ensure they can find the lobsters if they are in the vicinity. This highlights contemporary uncertainly among many of the harvesters regarding where the lobsters will be located at the beginning of each season. The setting of test lines in different depths from their other (regular) lines makes it more likely they will find the lobsters if they are not in the preferred depths. Once they start hauling their traps they develop a better idea of where the lobsters are and they start moving their lines based on catch, depth (moving into shallower water as season progresses), and information from other harvesters. Reduced numbers of traps per line allows them to fish the same number of traps in more areas and new technologies have made it easier to strategically position pots and to change the location of lines more frequently.

Many of the harvesters have to buddy up in order to attain better economic security in light of increased competition for lobsters and declining individual catches. The increase in buddying up also means the crew sizes are larger than in the past because many crews now have two license holders onboard. This also means boats will have double the number of traps and this appears to affect fishing strategies.

The strategy of reducing the number of traps per line after a new trap limit is imposed was implemented in the model. It was expected that because the over all number of lines in the areas would be reduced that there would be less competition between lines and thus the number of lobsters on each line would be higher. Although harvesters are split as to whether another reduction in the trap limit should be implemented most of them admit they would utilize this strategy if this were to happen. This implies that a minimum number of traps per line may be needed in addition to a trap limit in order to lower the number of lines and reduce effort.

This possible future management initiative was implemented in the model (experiment 4). Both trap limits and minimum traps per line reduced catches. As expected, the variances under both the trap limit and minimum number of traps per line scenarios were significantly higher than in the baseline scenario. Although the trap limit with minimum traps per line scenario showed increases in catch over the trap limits only scenario there was no statistically significant difference between the mean catch of the two initiatives. Once the minimum number of traps per line is implemented, the number of lines an agent is using usually declines more than if trap limits only are imposed, as expected. This may mean that under the implementation of trap limits and minimum number of traps per line requirements, overall there would be fewer numbers of lines in the bay actually increasing harvesters' catch slightly because there is less competition between lines.

In the few cases of agents who were not affected, i.e. who were able to keep the same number of lines, under both scenarios the catch under minimum TPL is higher. Since the number of lines in these cases is the same, the change in catch cannot be due to these agents using fewer lines. It has to be related to another factor, like the distribution of lobsters, or the competition for lobsters. Since the lobster population is the same for both scenarios this is unlikely to be the cause. This lends support to the possibility that boats will catch more because the overall number of lines has declined and there is less competition for lobsters. In general, boats will have fewer lines and will catch higher numbers of lobsters under the minimum TPL scenario. Due to the nature of the lobster module I cannot say what, if any, effect this would have on lobster population. However, these implementations did reduce catches and they provide some interesting insights into possible implications of harvesters' reactions to a future management initiative such as this one.

The FRCC recommended the introduction of no-take reserves (closed areas) as a lobster conservation initiative. This initiative has been implemented in several Newfoundland communities in recent years including in the Eastport Peninsula area. I decided to run an experiment (experiment 5) to see what effect closing an area in St. John Bay would have on catch. The area around St. John Island was only one possible option from within the Bay. Selection of actual areas to close should be done in consultation with local harvesters. In the model, closure of this area did not result in a statistically significant reduction in catch. This may reflect the limitations of the model. Using this version, we could not say how many lobsters would remain in the closed area or how many additional lobsters would be added each year as a result of this implementation. The main purpose of closed areas is to protect stocks within the areas, particularly egg bearing females, so as to increase egg production in the area. We did not include egg production in the model and would need to know more about larval drift and subsequent settling to the bottom to more effectively model the potential impacts of a closed area on future landings. Accurate predictions of the number of lobsters retained in these closed areas would also be needed.

Results from experiment 5 also suggest that boats from different communities that had traditionally fished lines within these closed areas had different catch results in the years following the implementation. This suggests we would need several small areas in order to spread the short term impact on landings, since closing a large area could initially lead to significantly smaller catches in some communities, even though in the longer term positive impacts on lobster stocks would lead to increased lobster landings.

There were additional data collected during fieldwork that could not be represented in the current version of the model. These data include the introduction of women into the fishery, v-notching, changes in technology, reduction in the number of fishing days, and attitudes towards conservation. An important change is evident in the increased involvement of harvesters' wives and other female relatives in lobster fishing. In earlier years, women's participation in the fishery was considered bad luck. These attitudes have changed over time in the face of economic uncertainty, increased competition for lobsters and declining landings. Harvesters now need to keep the revenues from the boat and income from E.I. in their own family. The introduction of the hydraulic motor and the chute has provided a smoother transition for women fishing for lobsters. Although it is still physically demanding work (for men and women) it is less strenuous than in the early years of the fishery; when traps were larger, they were hauled by hand and were awkwardly hauled up over the side of the boat instead of onto a chute. Although some of these women have had many years of experience (some with as much as 13 years) in the fishery, there is some concern that they will not be able to purchase a license or qualify as a license holder (Grzetic 2004). If this is the case, it could negatively affect the economic futures of families where something happens to the husbands. The economic and other effects of bringing women into the lobster fishery could be implemented in the model in the future. One possibility is that this will affect the intergenerational dynamics of the fishery with children less likely to follow their fathers/parents into the boat.

V-notching is a potentially very important conservation measure in place in St. John Bay. Harvesters reported that v-notching would help conserve the lobster stocks. V-notching could not be modeled in the absence of a fully functioning lobster model. V-notching has become a popular management tool and it would be interesting to model the effects of v-notching on catch and strategies over the long term, in the future.

Changes in technology have included the introduction of faster boats and the chute, navigation equipment, and hydraulic trap haulers. These changes were described at the beginning of the chapter. These aspects of the lobster fishery are not modeled at this time but could be included in the future.

Such management changes as shortening the season and banning Sunday fishing have reduced the number of days harvesters spend on the water. Harvesters suggest these changes have had no major effects on the amount of lobsters they can catch despite the reduction of days spent fishing. It is important to note that the ban on Sunday fishing was received well by most harvesters because they had traditionally taken Sunday off to spend time with their family and for religious reasons. This points to the importance of managers recognizing the motivations behind acceptance of new management initiatives.

The majority of harvesters agreed that the current management initiatives in place were helping conserve the lobster stocks. The attitudes towards DFO enforcement were spilt. The main theme that seems to arise from this portion of the research was the need for better communication between harvesters and DFO. We need better understanding of not only why harvesters agree or disagree with new management initiatives but also the motivations behind their acceptance or rejection. This could help to reduce conflict and help predict harvesters' reactions and strategies in the light of new management initiatives. The focus of management over the past several years has been on reducing exploitation rates, protecting egg bearing females and increasing egg production. In reality the managers are not managing the lobsters but the harvesters who depend on them for a living.

Management issues that were deemed important by participants included v-notching, trap limits, license buyback programs and better communication with DFO. Although attitudes towards DFO were split, most harvesters agreed that for any new management initiative to work it would be necessary to have better communication with DFO and stronger input from harvesters. This has implications for management in the future. Cooperation among harvesters is vital to the success of new management initiatives. The harvesters need to have more control over the research findings in a process where the results are brought back to the community and discussed. In the absence of follow up meetings cooperation of the harvesters will likely cease to exist.

This thesis contributes both to the knowledge of general harvester-lobster interactions through the LEK component and to the modeling literature as well. Developed in as generic a format as possible, the model is a contribution to the limited modeling literature on fishing societies. This application allows harvesters to link their individual experiences with collective outcomes in this context and could be applied in other contexts. Unexpected outcomes allow researchers to formulate possible explanations that would have otherwise not been considered. For example, I expected that the introduction of gossip would increase catches. Since this was not the result I was forced to explore other explanations and return to interview data for additional clues. One possible explanation was that harvesters do not actually put much emphasis on gossip unless their catches are already low, suggesting that gossiping is a last resort strategy.

This research exemplifies the dynamism of the lobster fishery. It is important to study individuals in a lobster fishery where the focus is not on lobsters alone but on the harvester-lobster and harvester-harvester interactions and awareness of the dynamism of the fishery needs to be incorporated into the development of management frameworks. It is not only important to know what harvesters' opinions are on new management initiatives but also how such initiatives might change harvesters' strategies and the motivations behind those strategies.

A future addition to the model would take into account economic considerations. This economic component would model the effects on the lobsters and lobster fishery of harvester access to other fisheries. The opening and closing of other fisheries (such as cod and crab) and their implications for lobster fishery effort could be modeled. Effort would be measured in terms of the number of times harvesters check their lines and the number of weeks they participate in the lobster fishery. The relative price and abundance of lobster and other species might also influence the effort directed towards the lobster fishery.

The federal government buyback programs staring in the 1990s did little to reduce the number of licenses and prevent declining lobster landings in St. John Bay. At present, a majority of harvesters are still many years from retirement (average age = 45 years old) and some have young families. In addition, reports from demographic interviews suggest many of the harvesters have fished since they were young boys and do not have postsecondary education. These demographic features of the lobster harvester population might help explain why the early retirement and buyback programs of the 1990s did not substantially reduce the number of lobster licenses in St. John Bay. Funding from a buyback program would not have been sufficient to sustain a young family for very long and harvesters might find it difficult to find work outside the sector, particularly in the St. John Bay area.

An experiment investigating the effect of license removals on the dynamics of lobster fishing and on landings could also be completed in the future. It would be interesting to investigate how many licenses would have to be removed from St. John Bay in order to keep lobster landings from continued decline and what would be needed to increase lobster landings. In addition, how many harvesters per square kilometer would be optimal in terms of landings? Presently St. John Bay has approximately 0.4 harvesters per square kilometer of the bay. It would be interesting to compare the ratio of harvesters to lobster habitat in different parts of the Island.

The range of management initiatives modeled could also be expanded. Indications from the Eastport study indicate that it was a series of initiatives including not only the implementation of closed areas but the introduction of an exclusive fishing zone for harvesters from the Eastport Peninsula, v-notching, at sea sampling and access to other fisheries that have contributed to lobster recovery and greater stability in the lobster fishery around the Eastport Peninsula (Davis *et al.*, 2002). The model could be run with different clusters of management initiatives of this kind.

The communication experiment could also be developed to take into account more complicated relationships and different strategies within boats and communication rules. In addition, a distance component could be added according to which boats would not be permitted to travel further than a specified distance from their home communities. A weather component with detailed routes and sequence of areas could also be added in future versions of the model. Also in the future better catch memory (in the current model, this only goes back 5 years) should be added since boats refer back to good catches in past years when setting traps.

Lastly, the interview schedules used in this research could be used as the backbone for other historical reconstructions of lobster fisheries. With the expansion of some of the questions and a fine-tuning of the interview schedules in general they could become an important starting point for future research in lobster fisheries in Newfoundland and Labrador and elsewhere.

Bibliography

Acheson, James. M. (1975). The lobster fiefs: economic and ecological effects of territoriality in the Maine lobster industry. Human Ecology, 3(3), 183-207.

Acheson, James. M. (1980). Factors influencing productivity of metal and wooden lobster traps. Maine Sea Grant Technical Report 63. University of Maine Sea Grant Program, Orono, Maine.

Acheson, James. M. (1981). Anthropology of fishing. Annual Review of Anthropology, 10, 275-316.

Acheson, James. M. (1981). Cultural and Technical Factors Influencing Fishing Effectiveness in the Maine Lobster Industry: An Assessment by Fishermen and Biologists. In J. M. Acheson (Ed.), Social and Cultural Aspects of New England Fisheries: Implications for Management (pp. 643-716). Final Report to the National Science Foundation of the University of Rhode Island, University of Maine Study of Social and Cultural Aspects of Fisheries Management in New England Under Extended Jurisdiction.

Acheson, James. M. (1987). The lobster fiefs revisited: Economic and ecological effects of territoriality in Maine lobster fishing. In B. McCay & J. M. Acheson (Eds.), The Question of the Commons: The Culture and Ecology of Communal Resources, (pp. 37-65). Tucson, Arizona: The University of Arizona press.

Acheson, J. M., & Brewer. J. F. (2003). Changes in the territorial systems of the Maine Lobster Fishery. In Dolsak, N. & E. Ostrom (Eds.), The Commons at The Millennium (pp.37-60). Cambridge, Mass: M. I. T. Press.

Acheson, J. M. (2003) Spatial Strategies and Territoriality. In J. M. Acheson (Ed.), Capturing the Commons: Devising Institutions to Manage the Maine Lobster Industry, (pp. 24-56). Hanover, Maine: The University Press of New England.

Affard, J., and Hudon, C. (1987). Embryonic development and energetic investment in egg production in relation to size of female Lobsters (*Homarus americanus*). Canadian Journal of Fisheries and Aquatic Science 44(1), 157-164.

Batty, M, and Xie, Y. (1994). From cells to cities. Environment and Planning B, 21, 31-48.

Berger, Thomas., Goodchild, M., Janssen, M. A., Manson, S. M., Najlis. R., and Parker, D.(2001). Methodological considerations for Agent-based Modeling of Land-Use and Land-Cover Change. In D. C. Parker., T. Berger., and Manson. S. M. (Eds.). Agent-Based Models of Land-Use and Land Cover Change: Report and Review of an International Workshop Irvine, California, USA October 4-7, 2001 (pp. 7-25). LUCC Report Series No. 6. Belgium: LUCC International Project Office.

Berkes, F., (1989b). Cooperation from the Perspective of Human Ecology. In F. Berkes (Ed.), Common Property Resources: Ecology and Community-Based Sustainable Development (pp. 70-88). London: Belhaven Press.

Bousquet, F., Cambier, C., Mullon, C., Morand, P., and Quensiere, J. (1994). Simulating fishermen's society. In Nigel Gilbert, & Jim Doran (Eds.), Simulating Societies : the computer simulation of social phenomena (pp.143 -163). London: UCL Press.

Bousquet, F., and C. LePage. 2004. Multi-agent simulations and ecosystem management: a review. Ecological Modeling, 76(3-4), 313-332.

Cadigan, S. (1999). Failed proposals for fisheries management and conservation in Newfoundland. In Dianne Newell, & Rosemary Ommer (Eds.), Fishing Places, Fishing People: Traditions and Issues in Canadian Small-Scale Fisheries (pp. 55-79). Toronto: University of Toronto Press.

Canadian Broadcast Cooperation News on line staff. (March 15, 2000). [On-Line]. Retrieved March 9, 2004 from World Wide Web: Http:// www.cbc.ca/stories/2000/03/07/canada/cod000307.

Canadian Broadcast Corporation news online staff (April 24, 2003). [On-Line]. Retrieved March 9, 2004 from World Wide Web: http://www.cbc.ca/stories/2003/04/23/canada/cod_closures030423.

Carter, M. R., Macrae, I. V., Logan, J. A., and T. O. Holtzer, (1998). Population Model for *Melanoplus sanguinipes* (Orthoptera: Acrididae) and an Analysis of Grasshopper Population Fluctuations in Colorado. Environmental Entomology, 27(4), 892-901.

Clarke M. E., Rose. K.A., Levine D.A., and W.W. Hargrove. (2001). Predicting climate change on Appalachian trout: Combining GIS and individual-based modeling. Ecological Applications, 11(1), 161-178.

Collins, Roanne., and Jon. Lien. (2002). In Our Own Hands: Community-based Lobster Conversation in Newfoundland (Canada). Biodiversity, 3(2), 11-14.

Comeau, M., Landsburn, W., Lanteginr, M., Mallet, M., Mallet, P., Robichaud, G., and F. Savoie. (1998). Lobster (*Homarus americanus*) tagging project in Caraquet (1993) - tag return from 1994 -1997. Canadian Technical Report Fisheries and. Aquatic Sciences, No. 2216.

Couclelis, H. (1985). Cellular worlds: a framework for modeling micro-macro dynamics. Environment and Planning A, 17, 585-596.

Couclelis, H. (1988). Of mice and men: What rodent populations can teach us about complex spatial dynamics. Environment and Planning A, 20, 99-109.

Couclelis, H. (1989). Macrostructure and Microbehavior in a metropolitan area. Environment and Planning B, 16, 141-154.

Davis, Anthony., and John. R. Wagner, (2001). "Who knows? On the importance of identifying "experts" when researching local ecological knowledge (LEK)". In Manuscript from Social Research for Sustainable Fisheries. Antigonish, N.S: St. Francis Xavier University Press.

Davis, R., J. Whalen, and B. Neis. 2002. "From Orders to Borders: Efforts Toward a Sustainable Co-managed Lobster Fishery in Northeastern Newfoundland." Paper presented at the "Ocean Management Research Network (OMRN) National Conference: Research, Management and the Human Dimension". Ottawa, Ontario. October 25-27, 2002.

Doran, J. (1997). From Computer Simulation to Artificial Societies. Transactions of the Society for Computer Simulation International 14, 69-78.

Doran, J. (2001). Intervening to Achieve Co-operative Ecosystem Management: Towards an Agent Based Model. Journal of Artificial Societies and Social Simulation, 4(2), 1-21.

Drogoul, A., and Ferber,. J. (1994). Multi-agent simulation as a tool for studying emergent processes in societies. In Nigel Gilbert & Jim Doran (Eds.), Simulating societies: the computer simulation of social phenomena (pp. 127-142). London: UCL Press

Englene, G., White, R., and Uljee, I. (1997a). Integrating constrained Cellular automata models, GIS and decision support tools for urban and regional planning and policymaking. In H.Timmermans (Ed.), Decision Support Systems in Urban Planning, (pp.125-155). London: E & FN Spon.

Ennis, G.P. (1982). The Newfoundland Lobster fishery: A Review of Statistics, Stock Status and Current Management Considerations. Canadian Manuscript Report of Fisheries and Aquatic Sciences, No. 1666.

Ennis, G.P., Collins, P.W., and Dawe. G. (1982). Fisheries and Population Biology of lobsters (*Homarus americanus*) at Comfort Cove, Newfoundland. Canadian Technical Report of Fisheries and Aquatic Sciences, No. 1116.

Ennis, G.P. (1984a). Territorial behavior of the American lobster Homarus Americanus. American Fisheries Society 113 (3), 330-335.

Ennis, G. P. (1984b). Incidence of molting and spawning in the same season in female lobsters, *Homarus americanus*. Fisheries Bulletin. 82, 529-530.

Ennis, G. P., Collins. P. W., and Dawe, D. (April 1989). Fisheries and Population Biology of Lobsters (*Homarus americanus*) At St. Chads-Burnside, Newfoundland. Canadian Technical Report of Fisheries and Aquatic Sciences, No. 1651.

Ennis, G. P., Collins. P. W., Dawe. G., and Squires, W. R. (1994). Fisheries and Population Biology of Lobsters (Homarus americanus) at Bellburns on the Northwest Coast of Newfoundland. Canadian Technical Report of Fisheries and Aquatic Sciences, No.1997.

Ennis, G. P. (1995). Larval and Postlarval Ecology. In J. R. Factor (Ed.), The Biology of the Lobster: *Homarus americanus* (pp.23-43). San Diego, California: Academic Press.

Ennis, G. P., and Fogarty, M. J. 1997. Recruitment overfishing reference point for the American lobster, *Homarus americanus*. Marine and Freshwater Research 48(8), 1029-1034.

Ennis, G.P., Collins, P.W., Badcock, GD., and Collins, R. K. (2003). An update on the Newfoundland Lobster Fishery and its Recent Management. Canadian Science Advisory Secretariat (CSAS) Research Document 2003/036.

Fogarty, M.J. (1995). Populations, Fisheries and Management. In J. R. Factor (Ed.), The Biology of the Lobster *Homarus americanus* (pp.116-121). San Diego, California: Academic Press.

Fisheries Resource Conservation Council (FRCC). (1995). A Conservation Framework for the American Lobster. Report to the Minister of Fisheries and Oceans, 95.R.1. Ottawa, Ontario: FRCC.

Franklin, Ursula. (1990). The Real World of Technology. CBC Massey Lectures. Toronto: Canadian Broadcasting Corporation.

Gendron, Louise. (1997). Lobster of the Inshore Waters of Quebec. DFO Science Branch, Stock status Report C4-5. DFO Science Branch, Laurentain region.

Gendron, Louise., Camirand, Réjeanne., and Archambault, Joseé. (2000). Knowledge Sharing between Fishers and Scientists: Towards a better understanding of the status of Lobster Stocks in the Magdalen Islands. In Barbara

Neis and Lawrence Felt (Eds.), Finding Our Sea Legs. (pp. 56-71). St. John's: ISER Press.

Gilbert, G. N. and Troitzsch, K. G. (1999). Simulation for the Social Scientist. Open University Press: Milton Keynes, Bucks.

Great Britain and British Admiralty. Hawkes Bay to Ste. Geneviéve Bay: Including St. John Bay [Hydrological Chart]. 1:73,000 chart # 4680. Ottawa, Ontario: Canadian Hydrographic Service, First Canadian Edition 1959, reprinted 1976.

Grzetic, Brenda. 2004. Women Fishers These Days. Halifax, Nova Scotia: Fernwood Books.

Grimm, V. (1999). "Ten years of individual-based modeling in ecology: what we have learned and what could we learn in the future?". Ecological Modeling, 115, 129-148.

Hames, R., (1987). Game Conservation or Efficient Hunting? In B. McCay & Acheson, J. M. (Eds.), The Questions of the Commons: The Culture and Ecology of Communal Resources (pp. 92-107). Tucson, AZ: University of Arizona Press.

Horne. John. K., Schneider, David. C. (1995). Spatial Variance in Ecology. Oikos 74, 18-26.

Kloppenburg, Jack. (1991). Social Theory and the De/Reconstruction of Agricultural Science: Local Knowledge for an Alternative Agriculture. Rural Sociology, 56(4), 519-548.

Lawton, Peter and Lavalli, Kari.l. (1995). Postlarval, Juvenile, Adolescent and adult Ecology. In. Jon Robert factor (Ed). The Biology of the lobsters *Homarus americanus*. (pp. 47-88). San Diego, California: Academic Press.

Lomuscio, A. (1999). Intelligent agents-introduction. Crossroads 5(4), 2.

McCauley, E., Wilson, W. G., and DE Ross, A. 1992. Dynamics of Age-Structured and Spatially Structured Predation-Prey interaction: Individual-based Models and population-level Formulations. American Naturalist. 142(3), 412-442.

McCay, Bonnie. J., and Acheson, J.M.(1987). Human Ecology of the Commons. In B. J. McCay and J. M. Acheson (Eds.) The Question of the Commons: The Culture and Ecology of Communal Resources, (pp. 1-36). Tucson, Arizona: The University of Arizona press.

Milon L.W., Larkin, Sherry. L., and Ehrhardt, Nelson. M. (1999). Bioeconomic Models of the Florida Commercial Spiny Lobster Fishery. Florida Sea Grant

Report Number 117. FLSGP-T-99-002. Gainesville, Florida: University of Florida.

Neis, B. and Kean, Rob. (2003). "Why fish stocks collapse." In Reginald Byron (Ed.). Retrenchment and Regeneration in Rural Newfoundland. Toronto: University of Toronto Press.

Neis, B. *et al.* (1999). Fisheries assessment: what can be learned from interviewing resource users? Canadian Journal of Fisheries and Aquatic Science.56, 1949- 1963.

O'Sullivan, D., and Haklay, M. (2000). Agent-based models and individualism: is the world agent based? Journal of Environment and Planning A, 32(8), 1409-1425.

Palmer, C. T. (1992). The Northwest Newfoundland Fishery Crisis: Formal And Informal Management Options In the Wake of the Northern Cod Moratorium. ISER Report no.6.

Palmer, C. T. (1993). Folk management, "soft evolutionism' and fishers' motives: Implications for the regulation of the lobster fisheries of Maine and Newfoundland. Human Organization, 52(4), 414-420.

Palmer, C. T., and Sinclair, P. (1997). The Fall, 1988- 1992. In C. T. Palmer, and Peter Sinclair. (Eds.). When the Fish are gone: Ecological Disaster and Fisheries in Northwest Newfoundland. pp.61-76. Fenwood Publishing: Halifax Nova Scotia.

Palmer, C. T., and Sinclair, P. (1997). The closure, 1993-95. In C. T. Palmer, and Peter Sinclair. (Eds.). When the Fish are gone: Ecological Disaster and Fisheries in Northwest Newfoundland. pp.77-86. Fenwood Publishing: Halifax Nova Scotia.

Philipps, M. (1989). Dynamical behavior of cellular automata under constraints of neighborhood coherence. *Geographical Analysis 21,* 197-215.

Portugali, Juval. (2000). Self Organization and the city. New York: Springer-Verlag Heidelberg.

Railsback, S. F., Harvey B. C. (2002). Analysis of habitat-selection rules using an individual-based model. Ecology, 83 (7), 1817-1830.

Rowe, SherryLynn. (1999). Size, Structure, movement, and survival of American lobsters *Homarus americanus*, Populations in areas with and without commercial Harvesting. M. Sc. Thesis. Memorial University of Newfoundland.

Rowe, S., & Feltham, G. (2000). Eastport Peninsula Lobster Conservation: Integrating Harvesters' Local Knowledge and Fisheries Science for Resource Co-management. In Barbra Neis & Lawrence Felt (Eds.), Finding our sea legs: Linking fishery people and their knowledge with science and management to fisher people,(pp. 237-245). St. John's: ISER Press.

Schelhorn, T., O'Sullivan, D., Haklay, M., Thurstain-Goodwin, M. (1999). STREETS: An Agent Based Pedestrian Model. Presented at computers in Urban Planning and Urban management, Venice, 8-11 September; available at http://www.casa.ucl.ac.uk/~david/Anagent.pdf..Working Paper series ;no. 9. Centre for Advanced Spatial Analysis (CASA). University College London, London.

Sendova-Franks A.B., and Van Lent. J. (2002). Random walk models of worker sorting in ant colonies. Journal of Theoretical Biology 217(2), 255-274.

Social Research for Sustainable Fisheries, (2001). "Who'll be left fishing? The dilemma of recruitment in small boat fishing. St. Francis Xavier University, Antigonish, N.S.

Somerton, D, A. (1980). Fitting straight lines to haitt diagrams: a re-evaluation. Journal Cons. Int. Explor. Mer, 39, 15-19.

Sugden, R. (1989). Spontaneous order. Journal of Economic Perspectives, 3(4), 85-97.

Squires. H. J. (1970). Lobster (*Homarus Americanus*) Fishery and ecology in Port Au Port bay, Newfoundland, 1960-65. Proceedings of the National Shellfisheries Association, 60, pp22-39.

Sutinen, Jon. G., and Gates, John. M. (1995). SIMLOB: The Resource and Harvest Sector Components of the North American Lobster (*Homarus americanus*) Market Model," Final Report to the National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA.

Templeman. W. (1939). Investigations into the life history of the lobster (*Homarus americanus*) on the West Coast of Newfoundland, 1938. Newfoundland Department of natural resources; Research bulletin no 7. Printed by Robinson & Co., Ltd. St John's Newfoundland.

Templeman, W. (1940). Lobster tagging on the west coast of Newfoundland, 1938. Newfoundland Department of Natural Resources, Residential Bulletin (fish) 8.

Thébaud, O., and Locatelli, B. (2001). Modeling the emergence of resource-sharing conventions an agent-based approach. The Journal of Artificial Societies and Social Simulation, 4 (2), 40-53.

Tobler, W. (1979). Cellular geography. In S. Gale and G. Olsson (Eds.) Philosophy in Geography, (pp. 379-386). Dordrecht, Holland: Reidel Publishing Company.

Troitzsch, K.G. (1997). 'Social Science Simulation-Origins, Prospects, Purposes', in Conte R., Hegselmann R. & Terna P. (Eds.) Simulating Social Phenomena, (pp. 41-54). Springer, Berlin.

Wahle, R.A. (1988). Recruitment and body size-dependent habitat selection and predator impact on early benthic phase American lobsters (*Homarus americanus* Milne Edwards). American Zoology, 28, 14.

Wahle, R. A., (1990). Recruitment, habitat selection, and the impact of predators on early benthic phase of the American lobsters (*Homarus americanus* Milne Edwards) Ph. D. dissertation, University of Maine.

Wahle, R. A., and Steneck. R. S., (1991) Recruitment habitats and nursery grounds of the American lobster *Homarus americanus*: a demographic bottleneck? Marine Ecology Progress Series, 69, 231-243.

White, R. and Englene, G. (1993a). Cellular dynamics and GIS: modeling spatial complexity. Geographical Systems 1, 237-253.

White, R. and Englene, G. (1993b). Fractal urban land use patterns: a cellular automata approach. Journal of Environment and Planning A, 25, 1175-1199.

White, R. and Englene, G. (1994). Urban systems dynamics and cellular automata: fractal structures between order and chaos. Chaos, Solutions, and Fractals 4, 563-583.

White, R., Engelen, G., and Uljee, I. (1997). The use of constrained cellular automata for high-resolution modeling of urban land-use dynamics. Environment and Planning B, 24, 323-343.

White, Roger. (1997). Cities and Cellular Automata. Discrete Dynamics in Nature and Society 2, 111-125.

White, R., Straatman, B. and Engelen, G. (2004). "Planning Visualization and Assessment: A Cellular Automata Based Integrated Spatial Decision Support System". In M. Goodchild and D. Janelle (Eds.) Spatially Integrated Social Science (pp. 420 – 442). Oxford, New York: Oxford University Press.

Wilder, D. G. (1953). The Growth Rate of American Lobster (*Homarus americanus*). Journal of Fisheries Research Bulletin Canada, 10, 371-412.

Wu, F. (1998a). An experiment on the generic polycentricity of urban growth in a cellular automatic city. Environment and Planning B, 25, 731-752.

Wu, F. (1998b). SimLand: A prototype to simulate land conversion through the integrated GIS and CA with AHP-derived transition rule. International Journal of Geographical Information Science, 12, 63-82.

Wu, F. L., and Martin, D. October (2002). Urban expansion simulation of Southeast England using population surface modeling and cellular automata. Journal of Environment and Planning A, 34 (10), 1855-1876.

Yamanaka . T., Tatsuki. S., Shimada. M. (2003). An individual-based model for sex-pheromone-oriented flight patterns of male moths in a local area. Ecological Modeling, 161(1-2), 35-51.

Appendix A

<u>**Demographic and Strategy Interview Schedule**</u>

"I am a master's student at MUN studying the lobster fishery of the St John Bay area. I am interested in developing a computer simulation model that mimics the movements and fishing strategies of the fishery based largely on information from harvesters such as yourself." Read consent form here.

Demographical information

What community do you live in?

What Community do you fish out of?

How long have you been fishing lobster as your main species?

Do you fish by yourself? If not, who fishers with you?

Do you fish 425 traps out of your boat or is another license holder sharing your boat?

What proportion of boats do you think are fishing 850 pots?

Movements of harvesters*:* *"I am looking at an old nautical chart and a sketch map by Ian parsons. I just wanted to get a general feel for where the grounds are, and how/when you decide to move your traps."*

Would you set all your traps the first day the season opened?

At the beginning of the season what general areas would you set the traps?

How do you know where to go? Is it from experience, traditional areas, charts, GPS and sounders, landmarks, following others? What is most important?

At the beginning of the season where would you set your traps? Would you check these traps in the same order all the time? *Route information*

At what depths would you set the traps at this time of the season?

How far apart would you set two lines?

Do you haul all your traps everyday?

How long would you leave the traps at these depths? Would it depend on the number of lobsters you were getting? How low would it have to go before you move them? Is catch the only factor involved, how important is it in making the decision to move?

What week would you move your traps into shallower water? Would this depend on catch? Are there certain traps you would move first like the ones that were producing the least number of lobsters?

You couldn't move them all the one-day right? Are there certain depths you would move to during this week? How far would they be from the previous traps?

Would there be a time when all your pots eventually ended up at these depths?

When would it be time to move what week of the season typically? Where would you move the traps?

What depths would the pots be in now? Would this be your last move of the season? How close to shore or around the islands would you be at the end of the season?

I know some fisherman leave some traps out in deeper water just in case? Do you do this? How many traps would you leave out in deeper water?

The last couple of weeks do you fish for any other species? If yes than what do you fish for? When you are involved with another fishery how often do you haul traps now?

Once the season is over do you take all your traps in the last day? If so what routes do you follow? **Or** do you start taking the least productive traps in sometime before the last day? When?

Communication between fishers

Do you think there are spatial differences where the traditional fishermen put their pots and where the people who obtaining licenses after moratorium put their pots?

Are there any fishing grounds that you share with fishers that fish out of other communities in St John Bay? *I saw a map Ian Parsons developed looked like a little mixing around Hare Island!*

If there is an area where you share fishing grounds is it first comes first serve?

How much would you tell a fisherman that fishes from another community about your catch, for example would you just say that you had a good day or would you not tell him anything?

Would the amount of info you tell him increase or decree if the fisherman was fishing from the same community as you? I guess you would tell your relatives and friends a little more than some one from somewhere else?

If I have time:
In a study on another lobster fishy I was reading it had a list of things they thought were important influencing catch. I thought some of the things would be higher up in the list. I will read the list from most important to least important influences on catch. First is season, # pots, skill I guess this has something to do with how long in fishery but I'm not sure, type trap, boat, type bottom, depth. Do you think these are in the right order?

Where do you think territory or the fishing grounds fit into this list?

Demographic and Fishing Strategy Interview Schedule

Interview # ________
Interviewer ____________________
Date ______________

1a Demographic Information

For this first part of the interview, we want to find out more about the people who harvest lobster in this area—how old they are, their background and the background of their family in the fishery, education levels, etc.

1) Age ___________
2) Gender M _____ F _____
3) Community where born? ____________________
4) Where currently living? ___________________
5) Father's occupation _______________
6) Mother's occupation __________________
7) Marital Status single, married, divorced, common law, widowed (circle)
8) Occupation __________________
9) Spouse's occupation ______________
10) Number of children _____________
11) Ages of children _________________
12) Do any of your children fish for a living? Yes ________ No ________ If yes, how many? ________
13) Your education level < Grade 8 Grades 9-11 Graduated High School
14) Post-secondary Training? Describe

____

<u>1b General Fishing Experience</u>

In the next part of the interview, we will ask you some questions about your experience with the fishery—where you have fished, for how long, and about who you fish with.

How many generations has your family been in fishery? 1 2 3 >3 generations

15) Always community based? Yes _____ No ______ If no, explain:

____

16) Age when you started fishing ______
17) Location where you first fished ______
18) Sectors in which you have fished? Inshore/longliner/offshore
19) Any gaps in fishing career? Yes ______ No _____ If yes, when? How long?
20) Last season fished ________
21) Who did you fish with when you started? __________________
22) Who taught you how to fish? _________________
23) Formal training in fishing? Yes ______ No __________ If yes, what training?

____

24) How many years did you fish as a crewmember? _________
25) Skipper? _____________
26) Are you currently Skipper? _________ Crew? _________ Both ________ (explain)

____

27) Size of crew you fish with when you fish for lobster? ______________
28) If fishes lobster with others, are these family members? Yes _______ No ______
29) If family, what relation are they to you? ______________________________

1c Experience with the lobster fishery

30) Did you fish commercially for lobster before licenses were required? Yes _____ No _____

31) Where did you get your first lobster license?______________________________

32) During what year did you get it? _______

33) Have you purchased a lobster license every year since that year? Yes ____ No_____

Explain

____

34) Have you fished for lobster every year since getting your first licence?
Yes ____ No ____
If no, explain ____

Section 2:Lobster Fishing Strategy

Section 2a: General

35) How many traps did you fish from your boat when you first started?
____

36) How many do you now fish from your boat? ____________

37) Please describe any major changes in the number of traps fished?____

38) Do you fish one lobster license from your boat? Yes ______ No ____
If no, how many do you fish from your boat? ________________________
What year did you start fishing more than one license from your boat? __________
Why did you start doing this?
____
____
____

39) What proportion of people from the community you fish out of, fish two licenses ______ three licenses ________ or four licenses out of one boat? ______

40) Would you know the proportion of people from other communities in St. John Bay who are fishing more than one license from one boat? Yes _____ No ______
If yes, what proportion? _____________

41) When you first started fishing for lobster, how did you decide where to fish (i.e. traditional knowledge, trial and error, followed others?
____

Section 2b Fishing areas

42) At that time, in what areas did you fish for lobster? (Boundaries, adjacent to which communities, islands, rocks, shoals etc.)
____ > Can you help me draw these areas on this map and indicate that they were your fishing areas when you stared?

43) Generally speaking, where do you fish for lobster now?

____

____

__________ **Can you help me draw these areas on this map and indicate that they are your present fishing areas?**

44) Have there been any changes in the locations where you fish for lobster over your career (different islands, shoals, fishing larger areas? Yes ______ No ______ **When** did these changes occur?

45) If yes, roughly what changes?

____

____

______________**Changes should be easily understood on the map before** moving on.

Why did these changes occur?

____

____

____

45.5) Would you travel to these different areas in the same order (sequence of areas) everyday? If no what would this depend on? Please explain.

____

____

____

____

Section 2c: Importance of lobster income

46) When you first started fishing for lobster, roughly what percentage of your fishing income came from selling lobster?

< 30% _____ 30 - 50% ____ 51 – 75% _____ > 75% _______

47) At present, roughly what percentage of your fishing income comes from selling lobster?

< 30% _____ 30 - 50% ____ 51 – 75% _____ > 75% _______

48) Please discuss any changes in the relative importance of lobster income to your enterprise over your career.

____
____
____

Section 2d: Fishing licenses

The next part of the interview asks about other fishing licences you hold in addition to your lobster licence.

49) Fishing licences currently owned?

____

50) Are any of these supplementary licenses? Yes _______ No ______

Which?

____

Are any permits? Yes _____ No _______

Which?

____

51) Do you have core status? Yes _______ No _______ Explain

____

52) Have you sold any licenses in the last 10 years? Yes ____ No ____ If yes, which? ____

53) Do you fish for species for which you do not have a Licence, i.e. as a crewmember?

Yes ______ No ______

If yes, explain:

____

Section 2e: Fishing Activities

The next set of questions is about your lobster fishing, i.e. how you approach fishing for lobster including when and how you set your pots etc.

How much wind would keep you off the water when: A). Fishing lobster B). Fishing other species?

____

_

54). Explain your approach to setting your traps at the start of the season when you entered the lobster fishery (proportion of traps in each of your general areas).

____

____

____

____

55). How do you find the locations for your pots (land marks, GPS, compass)

____

___

Is this different from the start of your career? Yes ____ No ____
Please explain?

____

____

_____

If there has been a change in the general proportion of traps you set in your general areas at present, how do you decide the proportion of lines you will set on each of your lobster fishing areas now?

____

_____

If catch is a factor, how far back do you refer to in order to make a decision (last couple days, last couple of years, both etc)?

____

_____

When you move your traps within general areas do you decide where to move your traps, the number of traps to move?

____

_____

____

____

If catch is a factor how many lobsters per line before you move and how far back do you refer to in order to make a decision?

____

_____

How would decide to move your traps out of an area?

56) At the start of the season, do you check all of your traps everyday? Yes ____No ______

If no, how many do you check? ______
Why do you check that many?

____ ______

____ _____

Does this change during the season? Yes _____ No _____
If yes, describe how the number of pots you check daily changes over the season? What does it depend on: catch, price of lobster and other species?

____ ______

____ ____

57) Does your route you take to get from one area to another (zigzag, straight line, in a circle, direction of travel) change from day to day during the season? Yes ___ No ____
Please explain

____
____
____

What does this depend on?

____
____

58) At the start of the season, at what depths would you set your traps? _________

59) Does this change during the season? Yes ____ No ____
Please explain (Change to what depths, what week of the season does it usually change, why change)____
____
____

What does this depend on?____
____
____

60) Have you always fished the same number of traps/ line? If yes, how many?________ If No, when was it different and why did you change your approach?____

____

____

Distance between pots? __________ Between lines? _________
Other (explain)

____

61) How does this change during the season? Yes ____ No ____
Please describe____

____

Has it changed since you started fishing lobster? Why the change?

____

____

62) Do you leave any traps in depths that are shallower or deeper than the majority of the rest of your traps, just in case? Why?

____

63) Do you take all your traps in the last day of the season? Why or Why not?

____

If before then, why do you take them in at that time (putting a lot of effort into another fishery, low lobster catch, already qualified for EI)?

____

Section 2f: Competition for Lobsters

64) When you first started fishing for lobsters, how was it decided where people would put their pots?

First come, first served ______
Community territories _______
Individual territories ______
Follow others___________
Community territories but then first come, first served ______
Other

____

If territories, were these passed on? What rights did people have? What if they didn't fish one year? Sold their license?

____

65) Has this changed since you started fishing? Yes ____ No ____
Please explain

____

66) At the start of the season, roughly how many other boats are fishing for lobster in the same areas as you? ______________

Would there ever be a situation when it was too crowded to set traps? Explain?

____

What would you do with the traps you were going to set in the crowded area?

____

67) At the end of the season, roughly how many boats are fishing in the same area? ________

68) Has the number of boats lobster fishing in your area changed in the past 15 years or so? Yes ___ No ______. If yes, describe the change (amount of change, numbers, timing)

____

69) Has the number of fishermen lobster fishing in your area changed in the past 15 years or so (or since you started fishing lobster) Yes ______ No _____ If yes, describe the change (amount of change, numbers, timing)

____

70) What communities do the fishermen who fish on the same grounds as you do come from?

____

____

71) Has this changed in the past 15 years (or since you started) Yes ____ No ____
Please explain

72) Would you describe your lobster fishing area as more or less crowded than 10 or 15 years ago (or since you started)? More ______ Less______ the Same______

Please describe what you have observed

73) Do you have to worry about others putting pots in areas that you have traditionally fished or does it work on first come first serve basis for everyone? Yes ____ No_____
Please explain

74) Is this a change from early years in your lobster fishing career? Yes ___ No ____

Please explain

75) What impact, if any, do you think the degree of crowding in your lobster fishing area has had on your landings?

Section 2g: Fishing other species on lobster grounds

76) Do you participate in any other fisheries during the lobster season? Yes____ No ____ When______________________________?

77) If yes, what species?____

78) How does this affect the amount of effort (number of traps checked, frequency of checking traps) put into the lobster fishery?

79) What does this depend on? Price/ abundance of lobster and other species

80) Are other species fished on or near your lobster grounds? Yes ____ No _____
If yes, what species?

81) How does this affect the amount of effort (number of traps checked, frequency of checking traps) given to the lobster? __________________

What does this depend on?____

82) Are there any gear conflicts between this fishery and the lobster fishery? Yes ____ No ____
Please explain

Section 3: Lobster Conservation

83) What trends have you seen in your lobster landings since you started fishing for lobster?

Catches increasing ______ Catches decreasing ________ Catches constant _______

By what percentage? _____ By what percentage? _____ By what percentage? _____

84) What, in your view, would be required for you to: A). Continue to fish lobster in the future?

B). Change the way you fish lobster in the future (buddy up, shift effort, etc.)

C). Cause you to give up fishing lobster in the future?

85) In general, how optimistic are you about the future of the lobster fishery in this area? (Circle)

Very optimistic **Somewhat optimistic** **Optimistic** **Not very optimistic** **Pessimistic**

86) Describe the conservation measures you currently practice in your lobster fishery (v-notching, berried females, small lobsters, report poachers, handling lobsters with care etc.)

87) Rank the conservation measures you use from most to least important for conservation of stocks

most important __________________________

average importance __________________________

least important __________________________

Any other comments you would like to make about the health of the lobster stocks in this area?

Any other comments you would like to make about the lobster fishery in your area?

Any comments you would like to make about the management of the lobster fishery in your area?

____
____
____

Section 4: Local Experts

As I mentioned at the beginning of this interview, we would like to carry out more detailed interviews about the lobster fishery with approximately 15 experts who fish in St. John Bay. Would you be willing to provide the names of the three harvesters who fish in your area who, in your opinion, are most knowledgeable about the lobster fishery in that area? Feel free to include yourself.

1. ____________________
2. ____________________
3. ____________________

Would you also be willing to provide a few names of retired harvesters who you consider to be most knowledgeable about the history of the lobster fishery in St John Bay?

1. ______________________
2. ______________________

Thank you very much for agreeing to participate in this interview and for your time. I will be out in St John Bay doing these interviews and hopefully going out in the boat with some people in May and June. I will also be planning a return trip to discuss the research findings with local lobster fishermen.

Appendix B

Interview Schedule: Expert/Retiree Combination

If a phone interview was not done with this participant, start with that and then move on to this interview schedule.

Now that we have some background information, we would like to discuss with you your career as a lobster fish harvester. We want to discuss and where appropriate, record on charts changes to the lobster fishery over the course of your career.

Section1: General background:
Do you have any idea of how long people have been fishing for lobster in this area (even for food)?

Do you remember when people started fishing for lobster commercially in this area?

How long have you been fishing lobster in St. John Bay?

Time line
Can you tell me about the first boat you fished for lobster out of, how big it was, motor size etc? Do you remember when you had this boat? Repeat these questions for the other boats he had during their career.

1.0 Now I would like you to describe your lobster fishery when you first started fishing

Change Component: After changes mentioned during the interview find out the reasons for the change, when did they occur, how long did they last, did the change quickly or slowly? What impacts did these changes have?

1. What impact did the changes have on your lobster fishery (boats, gear, navigation equipment, location, fishing strategies) and why those changes have occurred?
2. What impact did the changes have on the lobster resource? What explanations do you have for those changes in the lobster resource (abundance, size, proportion of large, legal size, and small lobsters, recruitment, distribution, etc.)?
3. What impact did these changes have on lobster management in your area, as well as your observations on the reasons for those changes and their consequences for your lobster fishery, that of others, and for the lobster resource?
4. What impact did these changes have on your income, prices for lobsters, relationships within communities, new entrants, and outsider encroachment on your grounds?
5. Any changes in strategy that has occurred. Why did they deicide to do that particular activity? Were there any other contributing factors such as economical, social or ecological etc?

Section 2a: Your fishery:

Gear (number of traps in the water, number pots hauled per trip, pot design, number pots hauled in good/poor weather)
Trap structure (size, doorway, flap, escape mechanism, material made from etc)
Bait (how much bait did you use, source, did you catch it or buy it (price))
Navigation equipment to find traps (GPS, landmarks, sounders, compass, just know where they are)
Hauler(s)
Number of traps per line?
Number fishers /boat (proportion of fishers from community fishes this number fisher/boat)
Number licenses /boat (proportion of fishers from community use this number of licenses/boat)>>>Buddy up system
Number of fishers from each community that fish alone
Crew structure (who fished for lobster out of your boat)
Cooperation among fishermen (degree of information told to family, friends, general group of fisher's)

Refer to Change Component (describe changes and the impacts of those changes outlined in the list where appropriate): refer to the section at the beginning.

Section 2b: Management

Local rules (eat small and berried lobsters, territories)
DFO management (regulations on season start and end, licenses, number of traps, size limits, berried females etc.)
Enforcement (DFO, fishermen, other)
Number of officers? Changes (see change component)?
Number of times DFO enforcement were spotted over the course of the lobster season? Changes?
Number of times you were checked? Changes?

Change Component (describe changes and the impacts of those changes outlined in the list 1-5 where appropriate)

Section 2c: Economics

Price for lobster (price range)
Proportion of fishing income from lobster at that time
Catch rates (good, medium poor season landings, landings/week with X pots, number of crates per season etc.)
How often did you sell?
Size of lobsters
Landings over the season start, middle, end, clustered at beginning and end of season?

Change Component (describe changes and the impacts of those changes outlined in the list where appropriate.

Section 2d: The cod moratorium

During the next set of questions we would like to examine changes in the lobster fishery during the period leading up to and after the cod moratorium, and the most recent year fished.

What other fisheries did you fish(ed) in addition to lobster during these time periods?

Describe the yearly fishing cycle during the above mentioned time periods.
Prompts: when did you fish each species, which species overlapped? To what extent did they overlap? (i.e. Competition over space to put traps?)

Did this change the effort that was being put into the lobster fishery? (Period leading up to and after the moratorium? In 2001?) How has the amount of effort that you personally are giving to the lobster fishery changed since you started? For example the number of lines you could check and the number of times you could check your lines

How did harvesters from these different sectors get along? Do you remember any conflicts?

Can you rank these fisheries in terms of the importance they had to your livelihood when you first started fishing?
What percentage of your income came from each of these species at that time?

Can you rank these fisheries in terms of the importance they have to your livelihood now?
What percentage of your income comes from each of these species now? Any changes in between?

Was lobster important in helping you to obtain cash for supplies needed to participate in any other fisheries? Which one(s)? (When you started? Other relevant periods)?

How important was lobster in helping you to get enough weeks of work to qualify for UI/EI?

Traditionally when did the benefits end? When did first fishing activity begin?
Was there money to start up, fix broken gear, buy bait etc?

Did you experience gear conflict within the lobster fishery (tangled lines etc)? What about gear conflicts between lobster and other species?

Please indicate on the map where you fished for these other species and any changes that have occurred in these areas. USE GREEN COLORING LEAD!

Section 2e: Ecological changes in these time periods

When do you think the number of lobsters in this area has peaked? What observations lead you to think this?
How do you think the number of lobsters has changed since you started fishing? (Explore different periods)

Average number of small lobsters per line?
Average number of berried (spawny) lobsters per line?
Average number of large lobsters?
What depth and bottom types are associated with lobsters? Have you noticed any changes over your career? If so, explain?

What depths, bottom types, bottom structures, are associated with lobsters? Have you noticed any changes over the course of your career?

Are there any other important things about the lobster fishery during this time that we haven't asked about yet?

Section 3: The Mapping Component

After the first major change we also need to ask the questions marked 'during round two'

-Each map should have the date, the map id, and the fisher id.

-Number all drawings on map and speak unique id number into tape.

-Changes over time could be represented with lighter shades of the same color.

Distribution of resource across grounds—get lobster pretty well anywhere.

Section 3a: Experts fishing areas

We want to understand how people tend to divide up lobster fishing areas, whether it be on the basis of first come first served, community or family groups, berths, shared system or something else?

Did you have traditional lobster fishing areas, maybe areas you went with you father or grandfather? Did you have more or less lobster grounds overall in during this period in your career?

Grounds –on chart indicate general boundaries and/or grounds fished for lobster USE BLUE COLORING LEADS
Keep in mind your boundary, the community boundary, and the general boundary.

Could you help me highlight on the map the area where your fishing areas were at the start of your career? Do you have any idea of how many boats would have been on these different areas during this time period? **During Round two:** Indicate any changes in this area that have occurred. (**Use blue pencil**)?

Did the cod collapse change the ways that people divided up the lobster grounds? How?
Are any of these grounds only fished certain parts of the year? (Seasonal movements)

During round two: Can you describe any changes that have occurred in these territories? (Location, boat traffic, lobster harvesting, etc.) When did these changes occur?
Why do you think these changes have occurred?

Routes (circle, zigzag, backtrack, straight line) and sequence of areas (for example go to same order everyday)
Sequence of areas (what does this depend on? I.e. wind direction and speed.

Using the fishing areas indicated could we walk through your general movements throughout the lobster season (in terms of depths and movement to other general areas, when and why you would move) throughout the season? **During round two:** If there have been any changes in areas fished, depths fished or any changes in strategy then describe them (when, how, and why they occurred) and help me indicate these changes on the map?

Were there any areas where you were more likely to get smaller lobsters? **USE BROWN COLORING LEAD!**
What observations led you to think this?
Could you help me draw these general areas on the map, putting the symbol '*SM*' by the map object?

Section 3bCommunity territories and enforcement

-keep in mind the different groups of fishermen and where they are coming from.

Generally speaking where would fishers fishing from your community fish for lobster? **USE PURPLE COLORING LEAD!**

Were these boundaries fixed or were they quite fluid? Was there an overlap between communities anywhere? Which communities? Where? Describe the number of boats on these fishing grounds (numbers)?

During round two: **Indicate any changes in community territories that have occurred during your career.**

Do you think they were more fixed several generations ago? If so, why do you think this was?

Section 3c: New entrants (approximately after 1985)

At the beginning of your career were there a lot of new entrants to the lobster fishery? How many?

During round two: **At this time in your career when there were a lot of new entrants into the lobster fishery**

What happened (reaction of fishers already fishing there)?
How did it get sorted out?
How many new entrants were present? Changes since the mid 1980's?
Did these new comers have licenses to fish these areas?
How did the newer entrants know where to fish? E.g. followed others, did they take over traditional fishing grounds others?
How did these affect community boundaries? Changes?
Traditionally was the enforcement of boundaries handled locally or by DFO?
Changes

Where do you remember these new entrants fishing (if they know, ask them to highlight this on the second map)? **USE RED COLORING LEAD**

If they fished areas already designated to other fishers what would happen?

Poaching areas (USE BLACK COLORING LEAD TO INDICATE ON MAP)
End of mapping component

Section 4: DFO and the Lobster Fishery

Section 4a: relationship between DFO management and the local fishery.

During the first part of the interview we talked about local management rules and DFO management and enforcement. Now I would like to explore the effectiveness of these management issues.

How would you rate DFO's level enforcement of the lobster fishery?
Adequate or Not Adequate

Are you familiar with DFO's current stock assessment process for lobster in this region?
How satisfied are you with this process?
Why or why not?
Has this process changed in recent years? If so, can you describe the changes?

Can you think of any ways that the current stock assessment process might be improved upon?

Do you think that more could be done to incorporate local knowledge about lobster biology and behavior into the stock assessment process?
Do you have any ideas about ways through which this could be done?

What would be the most effective way of providing feedback to DFO?

Do you think that the current enforcement level is sufficient to prevent poaching and protect the lobster population? Can you explain why this you think this is?

What about your grandparents/parents generations? Were there any local conservation rules before government management took over (Berried lobsters, etc.)?

Section 4b: Ideas on Management Initiatives

Have you heard about the efforts of the Eastport Peninsula Lobster protection Committee? If not, I will explain the general background of the Eastport project. Do you think this type of an arrangement would work in St. John Bay? Why or why not?

What would you say are the pros and cons of each of these conservation initiatives? Are they effective? Why do you think so? Any problems? If it has already been implemented when did it start?

a) V-notching
b) Limited access
c) Policing
d) Tagging
e) Education programs
f) Returning small lobsters
g) Trap design (escape mechanism flap, lath spacing rule)
h) Rev-notching
i) Berried lobster
j) Limited entry (fishing areas LFA 14B)
k) Returning large male/large female
l) Increased carapace size from 81mm to 82.5 mm?
m) Upper size limit 127 mm?
n) Logbook>reflections why do it? What is learned?
o) At-sea-sampling> reflections why do it? What is learned?
p) Reducing season length from 12 to 8 weeks
q) Closed areas
r) MPA (Marine Protected Areas)

Have there been any changes in attitude towards any of the conservation initiatives? Why?

Do you think that V-notching, at-seas-sampling, logbooks, and the other conservation practices already implemented should always be observed in this region, or might there be circumstances in which these would no longer be necessary?
If such circumstances might exist, explain what they might be?

Do you think the conservation measures implemented will be enough, too much, or not enough to adequately protect the health of the local lobster population? Why do you feel this way?

Are you satisfied with the overall level of fishing effort in this area, or would you like to see it reduced?
How should this be done (do you think that the number of traps should be reduced (by how much) or the number of licenses be cut back)? Do you have any ideas on how they should cut back licenses?
Do you think that any of these changes would improve the health of the lobster stocks?

Do you think that most harvesters in the area are concerned about the long-term future of the resource?

Are any groups of people that are not as concerned?
Why do you think this might be?

Do you know anyone or particular groups who consciously disregard the rules?
Which recommendations?
Do you have any ideas about why they might do this?

Would you think that illegal lobster harvesting in this area is or has ever been a problem?
If so, do you have any idea of why this might be the case?

Can you think of any additional conservation measures that you would like to see implemented?
If so, what would they be?

What are your hopes for the future of the lobster fishery in the region?

Can you think of any changes that could be made to increase local people's dedication to lobster conservation in this area?

Appendix C

CONSENT FORM #1: CONSENT FOR ONBOARD PARTICIPANT OBSERVATION

Hi. My name is _______________ and I am a graduate student/ Conservation Corps intern at Memorial and a member of the Coasts Under Stress research project. The Social Sciences and Humanities Research Council and the Natural Science and Engineering Council in Ottawa jointly fund the Coasts Under Stress project. The Coasts Under Stress project is exploring interactions between environmental, social and policy changes and the health of resources, people and their communities. The research for my masters thesis, involves studying changes in the lobster resource and lobster fishery in St. John Bay over the past 30 years. This information will help me develop a computer simulation of interactions between lobster harvesters and lobsters. It will simulate the lobster fishery and approaches used by harvesters in the past and present, and lobster and harvester response to hypothetical management initiatives that might me introduced in the future. I am contacting you to see if you would be interested in participating in the research.

Let me explain more fully what the project is about and what I will be asking you to do. The research has several different parts. A Conservation Corps intern and myself have recently been completed phone interviews with lobster harvesters in St. John Bay for my graduate research on interactions over time between lobsters and lobster harvesters in this region. I will also be doing approximately 15 interviews with local experts identified by harvesters and with retired harvesters to get a clear sense of how the fishery, the resource, and lobster management have changed over time and why. I am also mapping the distribution of lobster traps, and movements between areas in some parts of the Bay over the course of the season. This will allow me to compare areas with high numbers of pots with areas that have low numbers of pots, understand harvesters approaches for setting and moving traps, and ask harvesters about changes in that distribution over time. This information will be vital to understanding the underlying processes involved in harvester's approaches and will help me develop the mapping component of the simulation.

I am contacting you today about another part of the study. I would like to spend time on some lobster boats in St. John Bay during the lobster harvest this season. I will be observing the lobster fishery, drawing maps of vessel routes, recording interactions between harvesters and the number of boats on the grounds at different times, and taking notes on my observations. I will also be talking to the harvesters I am out with about their lobster fishery and how that fishery and the lobster resource they depend upon changes over the season and how they have changed since they began fishing for lobster. These on the water observations and conversations will give me important insights into the fishery that can be used in my simulation of the fishery and that will also improve my interviews with expert harvesters. Questions will only be asked at a time when they will not interfere with fishing activity.

Participation in this part of the research is voluntary. Participants may withdraw from the study at any time. The notes and diagrams will be confidential. Information acquired will be used primarily to inform interviews and the modeling exercise. Names will not be used in any reports, presentations or publications resulting from this research. However, because other harvesters will know that I was out in your boat, it might be possible for them to associate a particular observation with you so we cannot guarantee anonymity for this part of the research. For this reason, I will send you and other harvesters I observe a copy of my draft presentation to the community and a draft of the thesis to review prior to finalizing it. At that time, you can request changes to anything in these documents that you feel identifies you and with which you are uncomfortable.

The benefits of participating are limited to the opportunity you will have to influence the findings of the research. I am planning a follow up meeting in the area where local harvesters will be encouraged to provide feedback on the accuracy of the research findings and the interpretation of those findings. They will also be asked to fill in the gaps or correct and information represented properly.

If you are willing to participate, please sign and date this form.

Name (print)____________________Signature ___________________Date __________

Researcher, on behalf of Memorial University ________________________
Signature__________________________ Date______________

If you have any questions or concerns about the research you may contact the Chairperson of the Interdisciplinary Committee on Ethics in Human Research, Dr. Gordon Inglis c/o the Officer of Research, Memorial University, or by phone at 1-709-737-8368.

Appendix D

CONSENT FORM #2: Consent form for Demographic and Strategy interviews with harvesters

Hi. My name is ________________ and I am a graduate student/ Conservation Corps intern at Memorial and a member of the Coasts Under Stress research project. The Social Sciences and Humanities Research Council and the Natural Science and Engineering Council in Ottawa jointly fund the Coasts Under Stress project. The project is exploring interactions between environmental, social and policy changes and the health of resources, people and their communities. The research for my masters thesis, involves studying changes in the lobster resource and lobster fishery in St. John Bay over the past 30 years. This information will help me to develop a computer simulation model of interactions between lobster harvesters and lobsters. I am contacting you to see if you would be interested in participating in the research.

Let me explain more fully what the project is about and what I will be asking you to do. The research has several different parts. For part of the study, I will be spending time on some lobster boats in St. John Bay during the lobster harvest. I will be talking to the harvesters I am out with about their lobster fishery and how it has changed since they began. I will also be mapping the distribution of lobster traps and routes taken by the harvesters in some parts of the Bay in order to identify high concentration and low concentration areas. This information will also help me to understand the underlying processes involved in harvester's decision making in order to develop the mapping component of the simulation.

I am talking to you tonight about another part of the project. This involves carrying out interviews with a random sample of about 50 harvesters who fish in St. John Bay (Local Fishing Area 14B). The list of people I am calling to request an interview was selected from a list of license holders for LFA 14B that was provided by DFO. These interviews will help me develop a profile of who the harvesters are, where they come from, their fishing experience, the other fisheries they participate in, and their views on trends in lobster landings and on lobster conservation. I am also asking these harvesters to provide me with three names of people that fish in their areas that they consider to be most expert on that fishery, and for the names of some local retired harvesters knowledgeable about the history of the local fishery. I will be contacting some of these experts and retired harvesters to see if they would be willing to do a longer, more in depth interview with me about their lobster fisheries.

Participation in this research is voluntary. If you agree to participate, the phone interview will take about 40 minutes of your time. If you participate, your name will not be used in any reports, publications or presentations resulting from this research. We have assigned each interview a number (StJohnBay01) and we will store the list of names and contact information for the people we are interviewing separately from the questionnaires. The list will be stored in a secure cabinet and will not be shared with anyone except members of my supervisory committee and a conservation corps intern who is working with me on this project. The intern will be required to read the ethics proposal, consent and sign an oath of confidentiality.

You are free to participate or not participate, you may decline to answer any question put to you, and you are under no obligation to explain or justify your decision. We think the risks to you of participating in the project are minimal. The potential benefits to you are limited to the opportunity you will have to influence the findings from this research. I will present results from this research at a feedback meeting where you will have an opportunity to comment on the preliminary research results. You can also request a summary of the research from myself c/o Coasts Under Stress, 202 Elizabeth Avenue, St. John's, NF. A1C 5S7.

Would you be willing to participate?

Yes ______ No ________

If you have any questions or concerns about the research you may contact the Chairperson of the Interdisciplinary Committee on Ethics in Human Research, Dr. Gordon Inglis c/o the Officer of Research, Memorial University, or by phone at 1-709-737-8368.

Appendix E

CONSENT FORM #3: CONSENT FOR EXPERT HARVESTERS

Hi. My name is ________________ and I am a graduate student/ Conservation Corps intern at Memorial and a member of the Coasts Under Stress research project. The Social Sciences and Humanities Research Council and the Natural Science and Engineering Council in Ottawa jointly fund the Coasts Under Stress project. The project is exploring interactions between environmental, social and policy changes and the health of resources, people and their communities. The research for my masters thesis, involves studying changes in the lobster resource and lobster fishery in St. John Bay over the past 30 years. This information will help me develop a computer simulation of interactions between lobster harvesters and lobsters. I am contacting you to see if you would be interested in participating in the research.

Let me explain more fully what the project is about and what I will be asking you to do. The research has several different parts. For part of the study, I will be spending time on some lobster boats in St. John Bay during the lobster harvest. I will be talking to the harvesters I am out with about their lobster fishery and how it has changed since they began.

For another part of the project, I recently completed interviews with over 40 lobster harvesters in St. John Bay for my graduate research on interactions over time between lobsters and lobster harvesters in this region. During that interview, participants were asked to identify 3 harvesters they considered to be most knowledgeable about the lobster fishery in their area. You were one of the experts identified by many of the local harvesters. I am contacting you to see if would be willing to participate in an interview.

The knowledge of expert fish harvesters about changes in their lobster fisheries and the lobster resource over the past three decades, including their assessments of what caused these changes, can provide important insights for fisheries science, fisheries management and for conservation. I want to combine this knowledge with scientific and other information in order to develop a computer simulation of interactions between harvesters and lobsters, simulating the economic, social and ecological effects of different management approaches. These interviews, and the other information that I have collected will help to ensure that the computer simulation captures the realities of harvesters' lives.

If you agree to participate, the interview will take about 2 hours of your time. You will be asked about any changes you have observed in the lobster resource and the lobster fishery over your lobster-fishing career. You will also be asked to indicate on a chart of the local area the general areas where you have usually fished for lobster including any changes in those areas over the course of the seasons and over the course of your career. We are also interested in knowing the area fished by other members of your community and changes in that area over time. Your views on the things responsible for those changes, the current state of the resource and the local fishery and the effectiveness of alternative management initiatives will also be discussed.

With your permission, I would like to tape the interview to permit me to concentrate on what you are saying and on asking the right questions, and to ensure that none of the information you provide is lost. If you agree to be taped, we will send you a copy of the tape for your own records. You will also be able to decide what happens to the original tape and transcript at the end of the project.

The list of participants in this part of the project will be shared only with the other researchers involved in this study and with the archivist at the University, should you agree to be taped and to have the interview archived at the University. The interview will be assigned a number (EH001StJohnBay) and the list of names and contact information will be stored separately from the tapes and transcripts from the interviews. If you agree to participate, your name will not be used in any reports, publications or presentations resulting from this research. However, you should be aware that a local person or someone who knows you well might suspect that you provided a particular piece of information.

You are free to participate or not participate, you may decline to answer any question put to you, and you are under no obligation to explain or justify your decision. You get to decide whether or not we tape the interview and, if you agree to be taped, you can ask that the tape recorder be turned off at any time. You can withdraw from the study at any time.

We think the risks to you of participating in the project are minimal. One risk relates to the chart information where you will be asked to indicate, in general terms, your lobster grounds and changes in those grounds. If published, this information might encourage another harvester to fish on your grounds. To minimize this risk to you, we will not be publishing maps showing the grounds of individual harvesters. Instead, we will combine information from the interviews to look for general patterns of change for use in the simulation. We would also combine information from simulations, based on the interviews, to present composite maps of general changes in fishing areas within communities and for the area as a whole.

The potential benefits to you are limited to the opportunity you will have to influence the findings from this research. I intend to present preliminary results from this research during a public meeting in St. John Bay. This will give people like you an opportunity to comment on the research and to identify any gaps or incorrect information that has gone into the making of the computer simulation model. Lastly, you can request changes to anything in these documents that you feel identifies you and with which you are uncomfortable.

If you are willing to participate, please sign and date this form.

Name (print)____________________ Signature ____________________ Date __________

Researcher, on behalf of Memorial University ________________________

Signature__________________________ Date______________

If you have any questions or concerns about the research you may contact the Chairperson of the Interdisciplinary Committee on Ethics in Human Research, Dr. Gordon Inglis c/o the Officer of Research, Memorial University, or by phone at 1-709-737-8368.

Appendix F

Table 1. Associated area numbers for each fishing community of St. John Bay.

Barr'd Harbour	10	11	12	29	30	31	42	44
	51							
Bartlett's Harbour	3	4	5	6	32	35	48	
Castors River North	6	7	32	40	52			
Castors River South	6	7	32	40	52			
Doctor's Brook	12	13	25	29	51			
Eddies Cove West	14	15	16	24	41			
Ferolle Point	2	3	35	36	45			
Eastern Twins	34	35	45	48				
Hummocky Island	24	25	28	29				
Josephine's Cove	7	8	9	40	43	47	52	
Long Point	2	3	4	35	36	45		
Old Port aux Choix	16	17	18	19	20	22	23	24
	39	49						
Port aux Choix	16	17	18	19	20	22	23	24
	39	49						
St John Island	20	21	22	23	24	25	26	27
	38	46						
Tilt Cove	14	28	50					
Whale Island	25	33	34	37	38	43	44	46
	48							

Appendix G

Calibration of Number of lobsters in model

I decided not to use the landings by statistics sections because the data from my first request did not match the data obtained upon the second request. To complicate the situation the second request for landings data from statistical section 48 (St. John Bay) came with a note saying that this was not landings data but data on where the lobsters were sold and utilized. It is important to note that the harvesters can fish one LFA and sell in another. I chose to use the data available for the larger spatial unit 14B and 14C, since this was the only consistent landings data I had when I began calibration, and it was already combined 14B and 14C data. Since later data confirmed that the landings in 14C were very low compared to 14B and the trends in 14B and 14C combined were very similar to trends for 14 B alone I choose to keep the landings data for 14B and 14C.

For the years 2002 and 2003 I could not obtain landings values for 14B and 14C. I did however have landing values for 14B only. Since 14C landings in most years were so small it was decided to use the 14B data, assuming that these values would be only a little lower than data for 14B and 14C combined. For the years 1972 and 1973 no landings data were available. For these years I used the average of all the years 1974-1979, since I knew of no major management initiatives, new licenses or major changes in the effort put on the lobster population that could have occurred over this time period. For years after 2003 I kept the number of lobsters constant at the average value of 2000 to 2003 until the last year of the simulation. The running average of the landings data were used as a basis for the model numbers of lobsters since it showed the same trends as in the actual data. In doing so the trends in the lobsters landings are smoothed but not lost.

In addition to the number of lobsters in the model other factors also had to be calibrated. The value of the parameter q, the probability of a single lobster not being caught, controls the number of lobsters harvested. I ran the baseline model several times in order to set this parameter to an acceptable value that yielded the results of the baseline scenario (Table 1 below). The parameter s (variability in the distribution of lobsters from year to year), and the parameter c (the attraction of lobsters to preferred depth) were calibrated such that the simulation results appeared as they did in reality. Lastly, licensing data from DFO could not be obtained in a reasonable period of time. In order to estimate the number of licenses in the Bay during the years of the study period and thus the number of boats in the model, follow-up phone interviews with harvesters, buyers, and union and committee representatives were completed. These parameters were set to produce the results of the baseline scenario. The baseline scenario was rerun with different random seeds to ensure the model produced similar results.

Mean error calculation.

I took the sum of the differences between the running average calculation and the model catch results divided by the number of years (Σ (landings data (t)- model catch data (t))/ Number of years) = 1352). The ratio of this value to the average landings data (total landings for all year/ number of years) gives a mean error value of 0.25%, which is an acceptable error.

Table 1. Total yearly catch and mean catch per boat: empirical data (5—year running average) and model results (baseline scenario).

	Total yearly catch (number of lobsters)				**Mean catch per boat (number of lobsters)**	
Year	**Landings data in kgs (14B&C)**	**Landings data (number of lobsters)**	**Empirical data (5 year running average)**	**Baseline scenario**	**Empirical data (5 year running average)**	**Baseline scenario**
1972	NA	407755	407755	414076	5378	5241
1973	NA	407755	355060	354610	4605	4489
1974	124835	249670	339674	337862	4388	4277
1975	180799	361598	363327	358059	4591	4476
1976	239357	478714	405181	397835	5100	4973
1977	187615	375230	483072	480001	6154	6000
1978	297636	595272	452183	450251	5772	5628
1979	193023	386046	484032	489941	6202	6049
1980	235389	470778	462246	463931	5948	5799
1981	264957	529914	482317	485420	6068	5848
1982	223129	446258	494834	508891	6283	6058
1983	254165	508330	556277	579306	7152	6897
1984	357122	714244	696861	735958	8658	8269
1985	434004	868008	768693	776354	6470	6018
1986	361914	723828	715281	702792	4915	4476
1987	277003	554006	613517	615408	4158	3707
1988	281358	562716	755483	755373	5070	4523
1989	574863	1149726	823520	817725	5415	4754
1990	379059	758118	855740	845370	5562	4858
1991	329688	659376	694305	687978	4497	3909
1992	332711	665422	593791	594474	3885	3359
1993	228287	456574	564820	564711	3715	3227
1994	286232	572464	553912	563743	3752	3197
1995	316349	632698	600895	596982	3980	3411
1996	298762	597524	614561	609762	4264	3587

1997	306731	613462	525418	519909	3610	2988
1998	232444	365269	433639	423713	3048	2478
1999	205027	322185	323560	323104	2358	1912
2000	180234	283224	313899	316800	2347	1886
2001	214000	336285	299505	313695	2359	1948
2002	177549	279005	332006	341252	2645	2133
2003	242280	380725	326514	333721	2607	2153

Note: Data for 1972 and 1973 could not be obtained from DFO. Therefore I had to use an average value for the remaining years in the 1970's. Landings data comes in the units of tons, the first conversion was from tons to kilograms, the remaining conversions are listed in Table 1 above.

Table 2. Calibrated parameter values for Baseline Model.

Parameter	**Calibrated value**
d_f	15
d_s	5
c	0.05
s	0.01
q	0.9975
Bottom r	0.9
Bottom m	0.45
Bottom st	0.75
Bottom g	0.45
Bottom cr	0.5
Bottom sh	0.5
Delta 1	0.1
Delta 2	0.5
Delta 3	0.75
Delta 4	0.5
Delta 5	0.25
Delta 6	0.75
Delta 7	0.5
Delta 8	0.25
Delta 9	1

Delta 10	0.1
Delta 11	0.1
Delta 12	0.2

Appendix H

Table 1. An example of one boat's characteristics array.

Boat	1			
Barr'd Harbour				
Begin date	1972	9999	1972	
End date	1972	9999	9999	
Areas	10	31		
Traps	0	1500	325	
Buddy-up				
Begin date	1972	9999	1994	
Buddy-up				
End date	1972	9999	9999	
BeginDepth	0	25	18	
EndDepth	0	25	5.5	
TPL	1	15	10	
Wind				
Threshold	0	10	5	
TestLines	0	10	2	
TooCrowded	150	300	200	
Relations	2,Son	3,Brother	4,Brother	5,Brother

**Note that the number preceding the boats relationships refers to the boat that they are related to.

The first row in the boat characteristics array (Table 1) is the boat identification number followed by the community that boat fishes from (row 2). The 'begin date' (row 3) refers to the year that the boat started fishing. The 'end date' is the year the boat stopped fishing. 'Areas' (row 5) are a list of numbers that refer to areas that have been defined on a map. Each boat is assigned areas based on which community he fishes from. The 'Traps' variable defines the number of traps that boat will use the first year he starts fishing. If a boat starts to buddy up the year that he buddies up is entered in the next row' Buddy up begin date', if he stops buddying up the year is entered in the next row 'Buddy up end date'. 'Begin Depth' and 'End Depth' refer to the limits of water depth that the boat will utilize. For example, in the table above this boat agent will prefer to set his lines in 18 fathoms at the beginning of the season, and he will not move his lines into water that is less than 5.5 fathoms. The next variable 'TPL' refers to the number of traps the boat will string together on each of his lines. This variable in addition to the number of traps will determine the number of lines the boat will fish. The next variable 'Threshold' is the number of lobster the boat will allow on a line before he will chose to move it. In the example above if the boat had 5 lobsters per line he would return the line back to the same place, however, if the catch on the line was 4 he would move the line to another position. This variable is called the catch threshold throughout the text of this document. The next variable in the table 'test lines' refers to the number of lines the boat will set in depths other than the preferred begin depth during the first day of the season. These lines are called test lines because the boat is testing the water to see if he can find lobster in different depths, it increases his chances if fishing the lobster by spreading out his lines in different depths. The 'too crowded' variable refers to the number of lines per cell that the boat will tolerate before he moves to another cell. The last variable 'relations' refers to the other boats in the model that this particular boat is related to and it also lists the type of relation.

Table 2. Reliability of the boat agent's relationships.

Relation	**Reliability (unreliability factor)**
Father	1
Son	2
Brother	2
Uncle	4
Nephew	5
In-law	7
Cousin	12
Friend	12
Member of same community	18
Person from another community (other)	25

Appendix I

Table 1. Total yearly catch under no gossip and gossip scenarios (with and without accurate information).

Year	C1=No Gossip (δ12=1)	C2= Gossip (δ12=0.1) and inaccurate information (δ9=10)	C3=Gossip (δ12=0.1) and accurate information (δ9=0)
1972	385023	391248	408451
1973	368629	329272	340390
1974	365241	308745	334449
1975	357511	325010	327428
1976	400260	370199	364134
1977	487161	454402	450381
1978	468434	419047	422516
1979	499986	459164	460243
1980	467787	430689	427783
1981	497854	456783	448725
1982	515263	491373	480118
1983	586206	566541	553186
1984	736537	712509	706852
1985	796150	759475	750310
1986	722976	698111	690123
1987	633087	614176	608570
1988	771132	755380	744720
1989	829806	817695	805167
1990	851330	844902	837579
1991	703104	680810	672835
1992	605183	585685	582662
1993	569908	553225	549657
1994	567959	546541	536791
1995	603919	582157	579976
1996	616364	602096	600593
1997	525407	513266	512830
1998	425368	415902	416331
1999	326063	315685	312346
2000	320359	304905	302630
2001	321710	306487	303831

2002	349307	330938	329629
2003	341466	326759	319156
2004	343961	337782	329533
2005	341999	332447	325795
2006	349095	334713	324458
2007	349260	334615	325129
2008	347012	337663	331224
2009	345779	329913	331622
2010	346245	338165	333483
2011	343748	332157	328684

Table 2. Total yearly catch of high seasonal variability scenarios; one with gossip one without.

Year	High seasonal variation and no gossip (δ 12= 1)	High seasonal variation and gossip (δ 12= 0.1)	Difference C2 – C1
1972	385023	408451	+ 23428
1973	374331	339473	- 34858
1974	373320	331560	- 41760
1975	378535	343812	- 34723
1976	427229	414578	- 12651
1977	552429	558252	+ 5823
1978	499825	536520	+ 36695
1979	535533	450979	- 84554
1980	500101	504453	+ 4352
1981	558571	600750	+ 42179
1982	639526	542371	- 97155
1983	751542	701936	- 49606
1984	832565	853149	+ 20584
1985	944465	928928	- 15537
1986	894217	835858	- 58359
1987	651034	704891	+ 53857
1988	878327	882414	+ 4087
1989	952106	876054	- 76052
1990	978066	943362	- 34704
1991	829194	785905	- 43289

1992	645985	643361	- 2624
1993	584800	672888	+ 88088
1994	637750	616591	- 21159
1995	714544	665764	- 48780
1996	740604	743761	+ 3157
1997	616026	619750	+ 3724
1998	498941	589654	+ 90713
1999	463635	428835	- 34800
2000	351963	438018	+ 86055
2001	320119	416350	+ 96231
2002	454491	518077	+ 63586
2003	391569	515797	+ 124228
2004	464740	495031	+ 30291
2005	496564	514103	+17539
2006	528264	563351	+35087
2007	395517	401420	+5903
2008	431128	451637	+ 20509
2009	414453	502308	+87855
2010	386334	469949	+ 83615
2011	316489	491447	+ 174958

Table 3. Total yearly catch and mean catch under scenarios with and without community territories.

Year	C1= No community territories	C2= Community territories	C2-C1	C3= No community territories	C4=Community territories	C4-C3
1972	414076	410565	-3511	5378	5332	-46
1973	354610	353018	-1592	4605	4585	-20
1974	337862	339522	1660	4388	4409	10
1975	358059	342323	-15736	4591	4389	-202
1976	397835	375114	-22721	5100	4809	-291
1977	480001	460556	-19445	6154	5905	-249
1978	450251	435690	-14561	5772	5586	-189
1979	489941	467688	-22253	6202	5920	-282
1980	463931	439851	-24080	5948	5639	-309
1981	485420	460568	-24852	6068	5757	-311

1982	508891	471587	-37304	6283	5822	-461
1983	579306	550489	-28817	7152	6796	-356
1984	735958	683531	-52427	8658	8042	-610
1985	776354	734669	-41685	6470	6122	-348
1986	702792	663895	-38897	4915	4643	-272
1987	615408	581666	-33742	4158	3930	-228
1988	755373	707613	-47760	5070	4749	-321
1989	817725	761262	-56463	5415	5041	-374
1990	845370	782687	-62683	5562	5149	-413
1991	687978	641135	-46843	4497	4190	-307
1992	594474	545803	-48671	3885	3567	-318
1993	564711	512826	-51885	3715	3373	-342
1994	563743	507576	-56167	3752	3484	-318
1995	596982	549029	-47953	3980	3660	-320
1996	609762	551570	-58192	4264	3858	-406
1997	519909	476335	-43574	3610	3308	-302
1998	423713	389278	-34435	3048	2801	-247
1999	323104	294871	-28233	2358	2152	-206
2000	316800	286605	-30195	2347	2123	-224
2001	313695	288461	-25234	2359	2169	-190
2002	341252	307710	-33542	2645	2385	-260
2003	333721	302030	-31691	2607	2360	-247
2004	346582	309400	-37182	2708	2417	-291
2005	334623	308770	-25853	2614	2412	-202
2006	333549	308774	-24775	2606	2412	-194
2007	333870	296687	-37183	2608	2318	-290
2008	335998	305814	-30184	2625	2389	-236
2009	333340	304628	-28712	2604	2380	-224
2010	338749	298788	-39961	2646	2334	-312
2011	335133	307529	-27604	2618	2403	-215

Table 4. Differences of community catch under the baseline and community territory scenarios for selected years 1976, 1986,1996 and 2002.

Community	**Difference of mean catches: community territories – baseline scenarios**				
	1976	**1986**	**1996**	**2002**	**Trend**
Port aux	+ 963	-936	+225	+14	Variable

Choix					
Old Port aux Choix	+1254	-4	+968	+25	Variable
Eddies Cove West	+ 109	-1560	-127	-316	Variable
St John Island	+520	+2856	+2106	+1600	Always +
Hummocky Island	-1147	-589	-1480	-358	Always -
Tilt Cove	-2493	-758	-2959	-1229	Always -
Doctor's Brook	-263	-782	-2027	-968	Always -
Barr'd Harbour	-33	-1118	-2643	-1236	Always -
Whale Island	+870	+1701	+1070	+1047	Always +
Josephine's Cove	-781	-342	+21	+191	Variable
Castors River South	-1827	-1001	-441	-506	Always -
Castor's River North	-3090	-1063	-683	-371	Always -
Bartlett's Harbour	-723	-729	-877	-473	Always -
Eastern Twins	NA	+1897	+1561	-228	Variable
Long Point	-302	+850	NA	NA	Variable
Ferolle Point	+380	+1649	+1097	+130	Always +

Table 5. Mean catch per boat, 2003-2012, four runs of the each simulation (baseline low and high seasonal variability, and community territory low and high seasonal variability).

Year (run)	Baseline, low seasonal variability	Baseline, high seasonal variability	Community territory, low seasonal variability	Community territory, high seasonal variability
2003 Run1	2434	2840	2211	2489
2004 Run1	2530	3470	2337	3755
2005 Run1	2609	3710	2316	2952
2006 Run1	2575	3854	2312	2747
2007 Run1	2632	3702	2345	3614
2008 Run1	2613	4300	2386	3270
2009 Run1	2672	3093	2354	1889
2010 Run1	2630	3970	2357	3006
2011 Run1	2641	3607	2358	2970
2012 Run1	2646	3536	2355	3861
2003 Run 2	2409	3078	2200	2918
2004 Run 2	2559	4275	2321	4015
2005 Run 2	2577	3945	2308	3083
2006 Run 2	2620	3907	2345	3078
2007 Run 2	2574	3866	2362	3156
2008 Run 2	2560	3345	2411	2977
2009 Run 2	2564	4362	2375	3386
2010 Run 2	2594	4231	2319	3488
2011 Run 2	2582	4267	2315	2705
2012 Run 2	2604	3554	2381	2941
2003 Run 3	2360	3137	2218	2778
2004 Run 3	2508	4426	2296	4024
2005 Run 3	2529	4045	2271	3754
2006 Run 3	2596	3685	2370	3042
2007 Run 3	2579	3439	2329	3449
2008 Run 3	2602	4627	2369	2499
2009 Run 3	2566	4084	2319	3947
2010 Run 3	2620	4410	2347	3752
2011 Run 3	2602	3704	2316	4011
2012 Run 3	2631	3985	2318	3523
2003 Run 4	2369	3366	2267	2005
2004 Run 4	2551	4582	2399	2263
2005 Run 4	2530	4516	2336	3895
2006 Run 4	2550	3577	2396	3382
2007 Run 4	2519	3935	2394	3879
2008 Run 4	2572	3589	2383	3274
2009 Run 4	2571	4030	2344	3365
2010 Run 4	2622	3901	2330	3498
2011 Run 4	2607	3677	2288	3802
2012 Run 4	2626	4053	2386	3546

Table 6. Total yearly catch, 2003-2012, four runs of baseline, trap limit and minimum trap per line scenarios.

Year (Run)	Baseline	Trap limit	Trap limit and minimum TPL
2003 Run1	311580	302893	308868
2004 Run1	323778	290262	294347
2005 Run1	333949	257046	270734
2006 Run1	329540	260793	278191
2007 Run1	336922	260447	273346
2008 Run1	334412	265537	278327
2009 Run1	342069	262808	270625
2010 Run1	336614	269793	273931
2011 Run1	337987	264202	273853
2012 Run1	338686	266003	276349
2003 Run 2	308328	308328	308660
2004 Run 2	327555	290630	288766
2005 Run 2	329891	261832	269609
2006 Run 2	335354	269974	267407
2007 Run 2	329452	263406	271716
2008 Run 2	327652	269776	268796
2009 Run 2	328148	266980	276480
2010 Run 2	332043	266224	273111
2011 Run 2	330525	261968	273888
2012 Run 2	333374	266513	272917
2003 Run 3	302030	302030	308660
2004 Run 3	320969	287266	288766
2005 Run 3	323689	249871	269609
2006 Run 3	332278	266240	267407
2007 Run 3	330123	263149	271716
2008 Run 3	333001	263293	268796
2009 Run 3	328502	261390	276480
2010 Run 3	335324	269668	273111
2011 Run 3	332998	264296	273888
2012 Run 3	336827	265785	272917
2003 Run 4	303186	303186	307968
2004 Run 4	326553	294555	294000
2005 Run 4	323784	259450	270904
2006 Run 4	326400	265574	270762
2007 Run 4	322484	259198	273901
2008 Run 4	329258	265875	277595
2009 Run 4	329076	262135	274981
2010 Run 4	335583	268689	278606
2011 Run 4	333724	266544	274888
2012 Run 4	336117	271342	277838

Table 7. Comparison of the number of traps, lines, traps per line and numbers of lobsters caught per boat in 1996 (no new trap limits), 2004, 2005, and 2011 between trap limit and trap limit and minimum trap per line (minTPL) scenarios.

Boats	Variable	1996 No new trap cut	2004 Trap Cut Only	2005 Trap Cut Only	2011 Trap Cut Only	2004 trap cut and minTPL	2005 trap cut and minTPL	2011 trap cut and minTPL
15 boats doubled up	Traps	850	700	600	600	700	600	600
	Lines	125	121	121	120	121	100	100
	TPL	7	6	5	5	6	6	6
	Lobsters	5161	3234	3126	2510	3436	3876	3005
4 boats (39,23,52, 79)	Traps	850	700	600	600	700	600	600
	Lines	100	94	94	100	94	94	100
	TPL	9	7	6	6	6	6	6
	Lobsters	4027	3190	2087	2645	3201	3252	3066
Boat 61	Traps	850	700	600	600	700	600	600
61	Lines	143	142	142	150	117	100	100
61	TPL	6	5	4	4	6	6	6
61	Lobsters	5138	3597	2926	2352	3385	2824	2506
3 boats(80 ,100, 102)	Traps	850	700	300	300	700	300	300
	Lines	125	117	60	60	117	50	50
	TPL	7	6	5	5	6	6	6
	Lobsters	7267	3263	1396	1469	3256	1270	1104
Boat 157 didn't start until after 1996	Traps	-	700	600	600	700	600	600
157	Lines	-	94	94	100	94	94	100
157	TPL	-	7	6	6	7	6	6
157	Lobsters	-	4931	4882	5092	4951	4502	4558
Boat 171 didn't start until after 1996	Traps	-	700	600	600	700	600	600
171	Lines	-	121	121	120	121	100	100
171	TPL	-	6	5	5	6	6	6

171	Lobsters	-	4050	3522	3438	4158	4142	3178
45 boats one license	Traps	425	350	300	300	350	300	300
	Lines	63	61	61	60	61	50	50
	TPL	7	6	5	5	6	6	6
	Lobsters	2702	1165	1030	1568	1485	1486	1493
8 boats	Traps	425	350	300	300	350	300	300
	Lines	50	47	47	50	47	47	50
	TPL	9	7	6	6	7	6	6
	Lobsters	2304	891	704	1144	1056	1281	1006
5 boats (29, 143-144,156, 166)	Traps	425	350	300	300	350	300	300
	Lines	83	85	85	75	58	50	50
	TPL	5	4	4	4	6	6	6
	Lobsters	3005	1528	1155	1533	1484	1552	1490
30 boats one license	Traps	425	350	300	300	350	300	300
	Lines	71	71	71	75	58	50	50
	TPL	6	5	4	4	6	6	6
	Lobsters	2382	1256	1241	1367	1342	1088	1096
2 boats Double up after 1996 (95, 105)	Traps	425	700	600	600	700	600	600
	Lines	63	121	121	120	121	100	100
	TPL	7	6	5	5	6	6	6
	Lobsters	4610	4908	4256	4230	4834	4527	4742
Boat 99	Traps	425	700	600	600	700	600	600
99	Lines	83	170	170	150	117	100	100
99	TPL	5	4	4	4	6	6	6
99	Lobsters	4063	4648	3717	3903	4712	4401	4343
3 boats (101,162 , 168)	Traps	-	350	300	300	350	300	300
	Lines	-	61	61	60	61	50	50
	TPL	-	6	5	5	6	6	6
	Lobsters	-	1731	1594	1473	1741	1487	1759
Boat 169	Traps		350	300	300	350	300	300
169	Lines		71	71	75	58	50	50
169	TPL		5	4	4	6	6	6

169	Lobsters		2118	2128	1706	2340	2026	1996
Boat 174	Traps		350	300	300	350	300	300
174	Lines		85	85	75	58	50	50
174	TPL		4	4	4	6	6	6
174	Lobsters		2342	2283	2175	2421	2314	2046
2 boats (120, 122)	Traps	425	350	300	300	350	300	300
	Lines	100	106	106	100	58	50	50
	TPL	4	3	3	3	6	6	6
	Lobsters	4125	1879	1660	1529	2185	2063	2467
2 boats (130, 131)	Traps	425	350	300	300	350	300	300
	Lines	83	85	85	75	58	50	50
	TPL	5	4	4	4	6	6	6
	Lobsters	4378	2082	1865	2042	2147	1942	2112
Boat 138	Traps	425	350	300	300	350	300	300
138	Lines	56	53	53	50	53	53	50
138	TPL	8	7	6	6	7	6	6
138	Lobsters	4279	2353	2329	2092	2188	2265	2241

Table 8. Four runs (four random seeds) of closed areas scenario and baseline scenario.

Year, Run	Baseline low seasonal variability	Closed areas
2003 Run1	316210	316210
2004 Run1	324821	313800
2005 Run1	332510	318594
2006 Run1	326553	318260
2007 Run1	328615	320932
2008 Run1	329797	319389
2009 Run1	337229	327353
2010 Run1	330836	320644
2011 Run1	333408	326262
2012 Run1	324555	328569
2003 Run 2	305466	305466
2004 Run 2	329800	319868
2005 Run 2	328718	316545
2006 Run 2	333234	323089
2007 Run 2	333069	324833
2008 Run 2	337277	329495
2009 Run 2	331129	321143
2010 Run 2	337178	322978
2011 Run 2	331544	320733
2012 Run 2	336081	326598
2003 Run 3	304925	304925
2004 Run 3	323663	309779
2005 Run 3	327943	315236
2006 Run 3	330896	326741
2007 Run 3	327788	320006
2008 Run 3	333329	322670
2009 Run 3	329952	321326
2010 Run 3	334697	326113
2011 Run 3	332692	322411
2012 Run 3	337485	330041
2003 Run 4	297708	297708
2004 Run 4	319630	306676
2005 Run 4	317004	308962
2006 Run 4	326906	316497
2007 Run 4	326732	312132
2008 Run 4	331208	321955
2009 Run 4	328504	322200
2010 Run 4	336565	325453
2011 Run 4	335514	320361
2012 Run 4	336438	322249