EXAMINING THE LOCAL LOBSTER (*Homarus americanus*) STOCK OF BONNE BAY, NEWFOUNDLAND UTILIZING AN INTERDISCIPLINARY APPROACH

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Examining the local lobster (*Homarus americanus*) stock of Bonne Bay, Newfoundland utilizing an interdisciplinary approach

By

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Abstract

Over the past two decades, fisheries of Atlantic Canada, in particular those Newfoundland have experienced massive collapses and changes. Micro-scale reconstruction of the development of the Bonne Bay and West Coast fisheries overall decline in landings, changes in the species composition of landings, declines the size of organisms landed, and increases in fishing efficiency over the past As these fisheries developed, changes in the target species and landings composition reveal a shift in the trophic composition away from taxa at high trophic levels, such and salmon, to lower trophic level taxa including herring, capelin and mackerel. was a major decline in Catch per Unit of Effort (CPUE) for lobster and some other species despite increased efficiency. In recent years, with no alternatives, the fishers Bonne Bay increased effort within the lobster fishery. Fishers who had not pursued the fishery or who had not fished to their limit were now doing so. These changes led to unprecedented pressure on the lobster stock. The reconstruction followed by a scientific examination of lobsters located in Bonne Bay, Although lobsters that inhabit cold-water environments (i.e. Northwest Atlantic) sexually mature at larger sizes, increasing fishing pressure makes it more difficult lobsters to survive to maturity and reproduce before being harvested. A study of effect of changes in the fishery on the size of lobsters in Bonne Bay was completed in summer of 2002 utilizing Carapace Length (CL) measurements. Statistical analysis CL measurements found that the CL of lobsters differed significantly in response to depth and location. Males were statistically larger than females, with 75.2% of below the Minimum Legal Size (MLS - a CL of 82.5mm or greater), while 57.3% of

males measured greater then the MLS. Lobsters from deeper inshore waters of Bay were significantly larger than those found in shallow inshore waters. It was that the carapace length of lobsters was significantly linked to the location. The however, failed to find a significant interaction between either explanatory variable (depth, sex, or location) in relation to carapace length (response variable).

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List of Abbreviations and Symbols

NAFO	Northwest Atlantic Fisheries Organization
t	Metric Ton
ICNAF	International Convention for the Northwest Atlantic Fisheries
LEK	Local Ecological Knowledge
EPLPC	Eastport Lobster Protection Committee
DFO	Department of Fisheries and Oceans
CPUE	Catch per Unit of Effort
TL	Trophic Level
GPS	Global Positioning System
GMNP	Gros Morne National Park
CL	Carapace Length
ANOVA	Analysis of Variance
GLM	General Linear Model
PVC	Polyvinyl Chloride
MLS	Minimum Legal Size

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1. Introduction:

In the early 1990's, fisheries on the east coast of Canada experienced catastrophic collapses (Bundy, 2001; Hutchings, 1996; Pauly, 2007). The collapse of the northern Atlantic cod stocks and difficulties in other Atlantic fisheries created a milieu of mistrust related to the ability of government, scientists and stock management regimes to protect Canada's marine resources (Gendron *et al*., 2000). The social and economic ramifications for fishing communities were devastating, leading to a restructuring of the coastal communities that depended on groundfish resources.

With the collapse of the groundfish stocks of Atlantic Canada, total landings of groundfish declined and the overall value of groundfish landings also declined dramatically in the latter half of the 1990's. However, increases in landings and in the economic value of shellfish, including lobster, more than made up for the economic loss of the groundfish (Hilborn *et al*., 2003). By 1996, the value of Newfoundland's fishery landings was greater than prior to the collapse of the northern Atlantic cod. The shift in the composition of Newfoundland's landings suggests an income shift to species such as lobster and shrimp. Therefore, this modification in composition appears to be the result of an interaction between the marine ecosystem and "their product", the fishers, the communities and the government institutions that regulate the fisheries (Hilborn *et al*., 2003; Pauly, 2007).

This thesis is an examination of the impact of a century of fishing on the American lobster (*Homarus americanus*) stock in Bonne Bay, Newfoundland.

This thesis will refer to the lobsters that inhabit Bonne Bay as the Bonne Bay lobster stock due to the fact that it is not a closed "population" of individuals that freely interbreed. Instead, the lobster stock of Bonne Bay is part of the larger west coast of Newfoundland lobster stock complex. The evolution of the fishery on the west coast of Newfoundland involved a pattern of shifting effort across species over time. This shift in target species was accompanied by changes in the behaviour of fishers and in fishery technologies and policies. Overall, fishers became more efficient and increased their effort in fishing, although some reduced their effort. This research begins with an attempt to reconstruct the history of the west coast Newfoundland fisheries since the late 19th Century utilizing historical archival data, local ecological knowledge of fish harvesters', and career history information. Given that landings data suggest an increasing reliance on the lobster fishery, this historical reconstruction provides the context for a biological study of current lobster stock in Bonne Bay, Newfoundland to scientifically determine the effects of fishing practices on lobsters in that area.

1.1 The Newfoundland and NAFO 4R Lobster Fisheries

The Atlantic coast was once described as the greatest lobster grounds in the world (Herrick, 1909). It was stated by Herrick (1909) that with proper management the vast natural resource of American lobster (*Homarus americanus*) should yield an abundance of "fair sized" lobster for generations and possibly even centuries to come. Throughout its range, from Southern Labrador to North

Carolina, intensive fisheries have targeted coastal populations dating back to the early 1870's (Fig. 1.1) (Templeman, 1941; Ennis, 1982; DFO, 2006).

Early landings statistics indicate the Newfoundland commercial lobster fishery began in 1874 with around 68 t landed and experienced rapid growth and development (Templeman, 1941; Dow, 1980; Ennis, 1982). Landings show a sharp increase in the late 1800's with the industry reaching an all time peak in 1889 with 7938 t landed (Templeman, 1941; Ennis, 1982; Ennis *et al.* 1997; DFO, 2006). Following 1889, there was a distinct downward trend in the fishery and by 1924 landings had declined to approximately 340 t resulting in a three year closure of the fishery from 1925-1927 (Herrick, 1909; Templeman, 1941; Templeman, 1966; Ennis, 1982; Ennis *et al.* 1997; DFO, 2006).

By the 1930's, the fishery had reopened. The shipment of live lobster to the U.S. market began and the transition to a live market was complete by the 1950's (Ennis, 1982; DFO, 2006). In the 1950's and 1960's, Newfoundland lobster landings were once again in decline and by 1972, landings had fallen from 2498 t in 1955 to 1238 t (Ennis, 1974 & 1982; DFO 2006). The fishery was characterized by high exploitation rates with low Minimum Legal Size (MLS) in relation to the size at maturity, leaving stocks subject to possible recruitment failure due to overfishing (Ennis *et al.* 1997; Anonymous, 1997). This long-term decline in the Newfoundland lobster landings was mirrored in most Canadian and American lobster fishing areas (Pezzack, 1992; Ennis *et al.* 1997).

In 1976, a limited entry licensing policy was implemented with the aim of controlling the number of fishers participating in the fishery, reducing the number

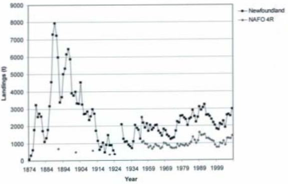


Figure 1.1: Lobster landings for NAFO Area 4R and for the Island of Newfoundland for the period 1874-2008. (Newfoundland Census 1891-1921; Newfoundland Statistical Agency 1955-1959; Northwest Atlantic Fisheries Organization website www.nafo.ca; Department of Fisheries and Oceans Regional Statistics Newfoundland Division www.dfo-mpo.gc.ca)

of traps used, and lessening the amount of effort and fishing pressure on the stock (Ennis, 1982; Ennis *et al.* 1997). The downward trend in landings reversed in the late 1970's, rising to 2592 t by 1979. By 1992, landings had reached a high not seen since 1905, with 3232 t of lobster landed. Ennis *et al*. (1997) noted that in the period following 1992, landings for lobster declined once again. In recent years, lobster landings have increased slightly and in 2008 they reached 2981 t (Lachance, 2009).

The commercial lobster fishery has been a particularly important part of the economy of Newfoundland's west coast since the late 19th Century. The fluctuations in landings for the entire province were seen on a more regional scale although variability at this scale seems to have been less than for the Island as a whole, particularly during the early years (Fig. 1.1). Recorded landings for the West coast of Newfoundland (NAFO Area 4R) declined from 701t in 1891 to 316t by 1921 leading up to the closure of the fishery (Bond, 1893 & 1903; Anonymous, 1923). For the years prior to 1924, the data indicate that, on average, 15.2% of all lobster harvested in Newfoundland were taken from NAFO Area 4R (for years where there are comparable data). For the period 1955-2008, the percentage of lobster harvested from NAFO Area 4R increased to 46.1% of all lobster landed in Newfoundland. A closer examination of lobster landings data also indicates variation over time – prior to 1924, percentages from NAFO Area 4R ranged from 11.7% (1891) to 35.7% (1921); since 1955, percentages from NAFO Area 4R have ranged from 33.9% (1979) to 64.7% (1971) for the years when comparable data are available.

On a smaller scale, lobster have been targeted by the fish harvesters of Bonne Bay since the 19th Century. However, by the mid 20th century the fishery had faded in importance and occupied a secondary position behind cod, salmon, and herring (Newfoundland Census 1891-1921; Pringle *et al*., 1983; Unpublished Research Transcripts #1-7, 2001). In the past, it was viewed as a means to generate cash in order to participate in other fisheries. This pattern changed in the late 1980's and early 1990's with the decline of inshore cod fisheries (Davis *et al*., 2006; Unpublished Research Transcripts #1-7, 2001). Interviews with Bonne Bay fishers seem to indicate that with reduced income from alternative fisheries, the fishers of Bonne Bay like those elsewhere on the West coast, increased effort within the lobster fishery. Fishers began to pursue the lobster fishery more actively than they had done in previous years – those who had not regularly used their lobster license or had not fished up to their limit (in terms of pots) were now doing so. At the same time, high market demand and high prices for lobster, coupled with a decline in the abundance of other inshore species (i.e. herring and mackerel) and their low prices (Anonymous, 1996; Burke and Phyne, 2008), led to pressure on lobster in NAFO Area 4R unprecedented in recent years (Unpublished Research Transcripts #1-7, 2001). This is evidenced by the fact that during this period, the number of pots per fisher in this area increased significantly from what was observed at the turn of the century (e.g. 44.1 pots/fisher in 1920 to 372.5 pots/fisher in 1992)

1.2. Harvester –Resource Interactions

The development of a fishery is typically centered around the presence of a particular species. Research has shown that as fisheries develop, changes in the target species and landings composition reveal a shift in the trophic composition away from taxa at high trophic levels, such as haddock, cod and salmon, to short-lived, lower trophic level taxa (Deimling and Liss, 1994; Pauly *et al.*, 1998; Pauly *et al.*, 2002; Pauly and Palomares; 2005). In a virgin ecosystem, unexploited fish communities are dominated by large, older individuals (Odum, 1969). Generally, exploitation tends to remove these larger individuals (Ricker, 1981) and reduce the number of age classes (Murphy, 1968).

Haedrich (2001) proposed a conceptual model on fisheries development based on the idea that fisheries evolve as the fish community is changed (Fig.1.2). As a fishery develops, it selectively removes an important species. Eventually, the fish community is altered and is no longer able to support the original fishery. Each new fishery evolves as the fish community and its ecosystem change. This modification in the fish community structure caused by fisheries, in turn, leads to changes to the fishery (Haedrich, 2001).

In the short term, the ecological impact on fish communities can be masked by the technological and social dynamism of resource users and their related capacity to sustain catch rates (Neis and Kean, 2003). However, the ability to maintain landings through technological innovation, diversification of the taxonomic composition of landings, seaward expansion and increased efficiency of fishers is limited, as was seen with the collapse of the groundfish

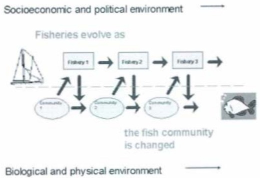


Figure 1.2: Illustrating the interaction between fishers and the fisheries they exploit. The development of a fishery selectively removes an important species. Over time this alters the fish community to a point where it is unable to support the original fishery. Then a new fishery evolves as the fish community and the ecosystem change. Adapted and reprinted with permission from Haedrich (2001, Fig.6).

stocks of Atlantic Canada by the 1990's (Deimling and Liss, 1994; Neis and Kean, 1999; Bundy, 2001). Studies highlighting interactions between fisheries and communities of fish often show the importance of interdisciplinary research that focuses on these interactions and their local, regional and larger scale consequences over time (Mackinson and Nøttestad, 1998; Neis and Kean, 2003). This thesis aims to examine this link between fishers and the lobster stock of Bonne Bay, Newfoundland. By examining how fisheries on the West coast have changed over time, factors that affect the health of lobster in the bay may be identified and their effects can be studied through biological methods.

1.3 Fish Harvester's Local Ecological Knowledge

The concept "Local Ecological Knowledge (LEK)" that has been applied to Newfoundland fisheries appeared in the mid-1980's (Neis *et al.* 1999b). This concept was defined as "...the sum of the data and ideas acquired by a human group on its environment as a result of the group's use and occupation of a region over many generations" (Mailhot, 1993). Until recently, a dualist theory of knowledge prevailed, in which scientific knowledge was sharply distinguished from non-scientific knowledge. Scientific knowledge, often described as objective, analytical, neutral, quantitative and systematic, was portrayed as being a superior form of knowledge. LEK, in contrast, was viewed as subjective, localized, qualitative and anecdotal (Gray, 2002). However, this dualistic viewpoint is no longer accepted (Mackinson and Nøttestad, 1998; Gray, 2002). Given that there is knowledge that scientists do not possess, and that LEK is sometimes more holistic and sometimes more precise than scientific knowledge, it must be viewed as an important complementary form of knowledge to scientific knowledge (Svensson, 1991; foreword to Mailhot, 1993; Mackinson and Nøttestad, 1998; Berkes, 1999; Bear, 2000; Moller *et al*. 2004). The evolution of the use of this type of knowledge within fisheries management has been shown to be important (Mackinson and Nøttestad, 1998; Alcock, Ings & Schneider, 2003).

Gendron *et al*. (2000) describe the importance of gathering contextual information on fishers' backgrounds, social organization, as well as goals and concerns about the lobster fishery in the Magdalen Islands. They note that such an approach can generate information that is essential to understanding the evolution of fishing strategies. It allows the researcher to acquire knowledge regarding fishing grounds (territorial structures), competition and relationships among fishers. LEK research can also gather information on fishers' goals and concerns, which affect their fishing behaviour. Biologists and fishery managers need to be able to document and closely monitor changes to fishing practices and innovations related to fishing practices and strategies in order to successfully monitor, manage and conserve stocks. Management measures designed to achieve conservation goals must take into consideration continual improvements in fishing efficiency (Gendron *et al.* 2000). Better knowledge regarding the evolution of fishing practices will guide resource managers to better choose and assess the relevance and the real efficiency of different protection measures taken to ensure stock conservation. This form of information can help to ensure stock assessment is informed by contextual information (Mackinson and Nøttestad, 1998; Gendron *et al.* 2000).

The lack of appropriate procedures for adequately evaluating fishers' knowledge tends to limit the incorporation of this form of knowledge into traditional fisheries management (Mackinson and Nøttestad, 1998). A major limitation of fisheries science, however, is the nature of the information on the basis of which conclusions and management decisions are often formed. Fisheries science often relies upon sporadic observations (Fig. 1.3) covering large spatial areas whereas local expertise consists of continuous observations of local fishing grounds (Fischer, 2000). Through integrating resource user knowledge with fisheries science, the influences and forces acting on fisheries can be put in a more complete ecological framework.

Davis *et al.* (2003) documented the formation of the Eastport Lobster Protection Committee (EPLPC) by lobster fishers in 1995 in response to a record low catch in1993. Using the LEK of the Eastport fishers, the committee initiated conservation measures aimed at reducing illegal harvesting of undersized and berried lobsters, ensuring trap limits were not exceeded, and established an active V-notching program. In addition, exclusive lobster fishing zones and two closed areas were set up around the Eastport area (Janes, 2009).

By combining LEK with concern for the future of this valued species, the fishers of Eastport appear to have been successful in sustaining the local lobster stock. The EPLPC were able to achieve this success through the use of local knowledge as a management tool (Blundon, 1999). In doing so, the committee

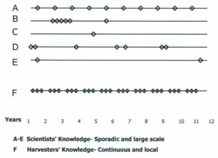


Figure 1.3: Comparison of local and temporal features of fishers expertise and scientific fieldwork. Each point represents an observation within (a) a regular seasonal study; (b) comprehensive study that lasts for a few seasons within a local area with follow-up; (c) short-lived, stand alone study; (d) repeated irregular investigations (i.e. sampling) of an area by scientists; could be of different research teams with different goals and questions; (e) collection of data that occurs over a standard time frame (i.e. census); (f) Fishers continuous knowledge of a particular local area that is collected over a long period of time (Modified from Fischer, 2000 p.43)

was able to encourage more lobster fishers to become active in the protection of their local lobster resources. The education of the harvesters on the economic and ecological importance of these measures was also instrumental to the success of the project (Blundon, 1999; Davis *et al.* 2003).

In research for this thesis, harvesters' LEK was used to help scale-down the results from a historical reconstruction of west coast fisheries, providing insights at a much smaller scale than would otherwise be available given that most scientific research on the west coast occurs at the much larger scale of NAFO Area 4R. LEK provides a way of determining if trends seen on a larger scale are actually present and observed on the much smaller scale of Bonne Bay. This scaling-down through LEK helped to provide a framework through which we could study the biological characteristics observed in lobsters inhabiting Bonne Bay to help determine the overall health of this local stock.

1.4 Research Objectives

This research combines a historical reconstruction of west coast Newfoundland fisheries with efforts to down-scale the reconstruction to a local level using LEK from Bonne Bay fisheries. The completed reconstruction was then combined with results from research using scientific methodologies to conduct a biological study of the local Bonne Bay lobster stock to assess how these fisheries have affected the structure of the stock, on recruitment in this stock, the future health of this stock and possibly leading to suggested changes to current management strategies.

The thesis seeks to answer several research questions. Firstly, is it possible to historically reconstruct catch rates and the dynamics of the fisheries of a region, particularly the west coast of Newfoundland going back several decades? Such a reconstruction would provide scientific researchers with information on how fisheries in an area have changed over time and provide a context for further scientific research. Secondly, given that most scientific research occurs on a fairly small spatial scale, is it possible to take a completed historical reconstruction and scale it down to the spatial scale where lobster biology normally takes place? The ability to scale down a historical reconstruction would provide researchers with other valuable sources of data (i.e. LEK). Thirdly, I wanted to determine if it is possible to use data gathered through a historical reconstruction to help understand biological changes in species traditionally targeted by fish harvesters? By using data culled from the historical reconstruction, can a contextual framework be produced that can help to interpret the biological data collected through the study of lobsters in Bonne Bay?

These research questions were answered using the following framework:
1) A reconstruction of the fisheries of West coast Newfoundland over the past century was completed to determine the dynamics of these fisheries and the associated pressures that have been placed on fish communities in this area, including particularly on the lobster found in area 4R. As part of this, I studied trends in the number of targeted species, shifts in the targeted species and their trophic level over time; trends in overall landings and CPUE for multiple species; and, the changing relative importance of lobster within the major fisheries.

2) To downscale the results from the historical reconstruction from area NAFO area 4R to the level of Bonne Bay, data from career history interviews (LEK) with experienced Bonne Bay lobster harvesters was used. These interviews gathered information about local fishing activities, changes in technology and fishing efficiency, and changes in landings and the size of species harvested over time.

3) A biological examination of the local *Homarus americanus* stock within Bonne Bay, Newfoundland was completed to try to assess the effects of a century of commercial fishing. The analysis involved performing a census of adult lobsters and larval forms to determine the impact the fishery has had on the local stock structure and recruitment.

4) Combining the historical reconstruction, fish harvesters' LEK and scientific research on *Homarus americanus*, allowed for an assessment of the state of health of the lobster stock in Bonne Bay and to identify potential avenues through which more sustainable lobster fisheries might be achieved.

Chapter two summarizes results from the historical reconstruction of fisheries on the west coast Newfoundland for the past century. It studies changes within the ecosystem and their causes. It also looks at the regional changes in fish landings and effort and provides a context for examining the impact these changes have had on the lobster stock complex in this region. LEK interviews with seven retired fish harvesters from Bonne Bay are used to downscale the results from the 4R historical reconstruction to the scale of Bonne Bay (the focus of the more traditional scientific lobster census described in Chapter three). Chapter Three aims to determine how the Bonne Bay lobster stock has survived a century of intensifying fishing pressure and reveals the stock structure that has resulted from it. Chapter Four aims to combine the results of research using these two methodologies and to propose new management schemes and scientific studies that could be implemented locally by fishers in cooperation with DFO and that might contribute to increased knowledge, recovery and to the long term sustainability of Bonne Bay lobster stock and the Bonne Bay lobster fishery.

2. Historical Reconstruction of a Century of Newfoundland West Coast Fisheries and Using LEK to Downscale this Reconstruction to the Bonne Bay Fisheries

The island of Newfoundland is located at the juncture of the north flowing "warm, nutrient-rich Gulf Stream" and the south flowing cold-water, oxygen-rich Labrador Current (Felt and Locke, 1995). The meeting of the Gulf and Labrador currents allowed an abundance of fish and other marine organisms to thrive off Newfoundland. The coastal areas of continents experience strong mixing of the water column, supporting and increasing the amount of primary production in those areas (Felt and Locke, 1995). It is in these highly productive waters that most of the Northwest Atlantic fisheries have occurred. The species that are fished belong to communities that are interrelated within an ecosystem via a complex food web (Pauly and Maclean, 2003). Historical reconstructions of fish landings have documented overall reductions in species complexity and restructuring of coastal ecosystems around the globe (Pauly *et al.* 1998, 2001, 2002). For the North Atlantic, they have shown 'a downward spiral' in overall fish catches, fishing efficiency, the "distribution of benefits to society," and "in the overall abundance of marine life" (Pauly and Maclean 2003). Since the 1990s, fisheries on the east coast of Canada have seen collapses of groundfish stocks such as the northern Atlantic cod stocks, *Gadus morhua* (Steele *et* al. 1992; Bundy, 2001; Bander, 2007). The understanding of the causes of variations in the abundance of species is key to achieving the long-term sustainability of particular species and of the ecosystems in which they live (MacKenzie *et al.* 2002)

Historical reconstructions of fisheries have shown that as they develop, political, cultural, technological and biological factors interact to change the nature of exploitation (Diemling and Liss, 1994). The removal of species from an ecosystem through commercial fishing practices may cause the balance of that particular area, some physical properties, and the structure of the ecosystem to change (Pauly and Maclean, 2003). The response of the industry to this pattern is to increase effort and efficiency through territorial expansion, increasing pressure on 'underutilized' fisheries, and the targeting of new species. Regier and Loftus (1972) referred to this sequence as "Fishing-up". They describe this as an expansion along the shoreline by fishers with more powerful boats shifting effort to new species in response to declining landings (Regier and Loftus, 1972; Deimling and Liss, 1994). Pauly and Maclean (2003) define "the process of chasing predatory fish, their prey, and their prey's prey as 'fishing-down the marine food web.'" With fishing-down, the large predatory fish stocks are depleted and fishers begin to harvest smaller fish species, including more invertebrates in their landings.

Researchers studying resource use have become increasingly aware of the value of including local ecological knowledge (LEK) in historical and scientific studies. (Mailhot, 1993; Mackinson and Nøttestad, 1998; Neis *et al.* 1999a, 1999b). Gathered through interviews, LEK has the ability to generate a wealth of empirical knowledge not otherwise available to researchers (Johnson, 1992; Mackinson and Nøttestad, 1998; Bear, 2000). LEK yields valuable information on commercial, noncommercial and underutilized species. While LEK operates on a much smaller spatial scale than traditional fisheries science, aggregation allows for its use on a larger ecosystem scale. The reverse is also true: LEK can indicate whether trends observed at larger spatial scales are typical throughout an area or whether there are differences at local levels.

Hutchings (1996) illustrates the ways that LEK can be useful in scientific assessments. Local familiarity with the dates of fish species caught in fixed gear can indicate seasonal and directional movements of fish stocks. Fish harvesters can provide information on aspects of stock structure including movement patterns, spawning grounds, juvenile habitat, and spatial patterns in fish morphology. In addition, Hutchings (1996) notes that catch rates may reflect local changes in fish abundance. Neis *et al*. (1999b) expand on the potential for the inclusion of resource user data in fisheries assessment. When collected systematically, LEK can provide significant information on stock distinctiveness, fishing efficiency and catch per unit of effort (CPUE). Tracing the career history of resource users enables quantification of fishing efficiency, specifically capacity, gear quantity, engine power and trip time; offering a more exact indication of changes in fishing effort over several decades. Trends in CPUE on a decadal scale, as indicated by fish harvesters' histories, provide a clearer picture of stock status than information on landings alone (Neis *et al.*, 1999b). In addition, since LEK applies to more than commercial species, useful information relating to underutilized species, important forage species and many aspects of the environment can be assembled through interviewing. This information is valuable from a conservation perspective, as well as in evaluating the overall health of the ecosystem (Hutchings, 1996; Hutchings and Ferguson, 2000b).

Micro-scale historical reconstruction identifies indicators of ecosystem changes and possible factors contributing to ecosystem restructuring. By implementing this technique on a spatial scale smaller than typically applied, our understanding of regional changes in fish populations/stocks will be improved. It can provide a contextual framework within which the impact of ecosystem restructuring on local lobster stocks can be examined. The results of historical reconstruction can aid informed discussions with fishers and their communities for improved stewardship of valued species (Neis *et al.*, 1999a). LEK can complement existing fisheries and historical data by filling in detailed spatial information. The result is a reconstruction of the fishery that mirrors the experiences of many fish harvesters.

The study of the restructuring of the ecosystem on the West coast of Newfoundland with downscaling to the level of Bonne Bay makes it possible to set the context for interpreting results from an intensive, micro-scale scientific investigation of a local lobster stock in the contemporary period. They provide an indication of how what we observe today might differ from the past and why. In Chapter Three I will examine how one species, the American lobster *Homarus americanus*, which has been a consistently targeted species over the past century, has survived the changes in the ecosystem and fishing behaviour of fishers.

2.1 Completing a Historical Reconstruction and Gathering Local Ecological Knowledge

Historical reconstructions of ecosystem changes help to improve the understandings of regional (and broader) changes in fish populations/stocks. They can identify changes within an ecosystem and the events which have precipitated these transformations. Through historical reconstruction on a micro-scale, spatial and temporal changes within fisheries on a finer spatial scale can be examined in an effort to determine the causes and effects of these changes. This form of examination provides a means of identifying the processes associated with marine food webs and their overall effects.

In micro-scale reconstructions, incompatible data is inevitable due to spatial and temporal changes in data collection over time. These challenges are most often encountered due to changes in methods of data collection, as well as changes in the management framework for which the data is collected. With any such change, temporal and spatial 'holes' may emerge that can be difficult to bridge. In some cases, inconsistencies in historical and scientific data can be addressed through employing local ecological knowledge (LEK).

The coupling of a historical reconstruction with LEK was used to reconstruct the fisheries of Bonne Bay and the West Coast of Newfoundland. The West Coast and Bonne Bay and its communities – Neddie's Harbour, Norris Point, Gad's Harbour, Woody Point, Rocky Harbour, and Trout River (Fig. 2.1) – were selected because of a long history and dependence on the fishing industry and lobster in particular.

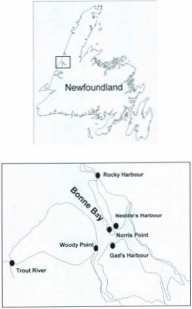


Figure 2.1: Map of Bonne Bay, Newfoundland enlarged from the insert of the island of Newfoundland map. This figure shows the location of communities for reconstruction analysis.

Secondly, much research has been done on the fisheries of East Coast Newfoundland, leaving the West Coast relatively unstudied. Finally, the area fell within the study area of the *Coast under Stress* project which funded this research.

2.1.1 Informational Sources for Historical Reconstruction of the Bonne Bay Marine Ecosystem

For the historical reconstruction of ecosystem change, historical sources of information and data must be identified. In the case of Bonne Bay and the West Coast as a whole, the Newfoundland Census' for the year 1891 (Bond, 1893), 1901 (Bond, 1903), 1911 (Bennett, 1914) and the year 1921 (Anonymous, 1923) provided fishing data and landings data for the turn of the century. For the remainder of the century landings data were gathered from the Dominion Bureau of Statistics (1955-1959) (Anonymous, 1955-1968) and the NAFO Statlandt 21A database (1960 –1999) (Anonymous, and DFO Regional Statistics Division (2000-2008) (Lachance, 2009). All data gathered from these sources were the basis for determining the history of fishery landings for the West coast of Newfoundland and for the reconstruction of effort and CPUE for the fishery in that area.

The LEK of retired fish harvesters in Bonne Bay was used to complete the reconstruction for the past several decades. The direct observations of the resource users span up to five decades and provide a local perspective on changes within the fishery of Bonne Bay that is useful in interpreting landings data for this period. The landings data were examined for changes in landings composition, trends in landings, and relative importance among species. Resource user information was used to corroborate trends in the landings data, to estimate fishing effort and efficiency and, related to this, to interpret how the relationship between landings and the marine ecosystem is modified by fishers.

2.1.1.1 The Importance of Scale

Proper comparison of fisheries data can only be completed with data of similar spatial and temporal scales. The spatial scales of the data available for the reconstruction varied widely. Early fisheries data from the Newfoundland Census' (1891-1921) was collected on a much smaller spatial scale (by census district and community), while more modern fisheries data is collected at much larger spatial scales. Newfoundland fisheries statistics (1955 – 1959) relied upon Statistical Areas K, L, M, and N (Fig. 2.2); failing to collect fishing information at the coastal community level. By 1960, fisheries data were reported on the basis of NAFO Convention Areas (Fig. 2.3). The West Coast of Newfoundland fell under one large area known as NAFO Area 4R, which stretches from the tip of the Northern Peninsula to the southern point of the West coast. Since proper comparison relies upon similar spatial scales, all data have been aggregated up to the largest spatial scale, NAFO Area 4R. The resource user information, which operates on a much smaller spatial scale, was used to scrutinize results from the aggregated landings data to see if changes within the lobster fishery that had been found to occur on a larger spatial scale were likely to be applicable on the smaller spatial scale of Bonne Bay and to develop insight related to trends in fishing effort and efficiency that might influence landings trends.

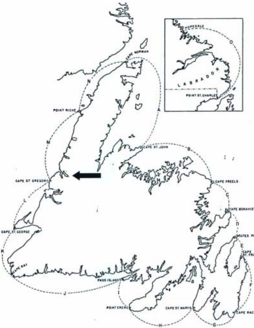


Figure 2.2: Sea fisheries areas as designated by the Newfoundland Government used for the period 1955-1968. Bonne Bay is located in Sea Fishery Area "M" and is indicated by the arrow (Scattergood and Tibbo, 1959).

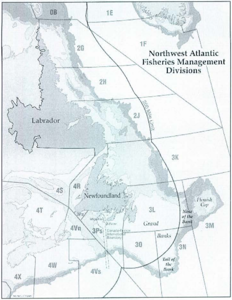


Figure 2.3: A map of NAFO convention areas. NAFO Area 4R ranges from the tip of the Northern Peninsula to Port aux Basque (www.nafo.ca).

2.1.1.2 Newfoundland Census Data

The Newfoundland Census is a commonly used historical data and statistical source. For the late nineteenth and early twentieth centuries, the Newfoundland Census served as the only source for fishing data for Newfoundland. The Newfoundland Censuses of 1891 (Bond, 1893), of 1901 (Bond, 1903), of 1911 (Bennett, 1914) and of 1921 (Anonymous, 1923) provided the historical fisheries landings and gear data for the reconstruction for the period between 1891 and 1921. The censuses were examined for details pertaining to the types of fisheries pursued, gear types and quantity employed within census districts and communities, the number of fish harvesters, and the landings for each species within each coastal community. Examination of landings was used to determine species of greatest commercial value to fishers, while amount of gear employed was used as an indicator of the level of effort and the basis for studying trends in the catch per unit of effort (CPUE).

For the Newfoundland Censuses of 1891-1921, the West coast of Newfoundland was divided into two census districts: St. George and St. Barbe (Bonne Bay was located in the district of St. Barbe). Fisheries data for the districts of St. George and St. Barbe were gathered and aggregated together for totals for the entire west coast.

Historical statistics contained within the census, while useful, have shortcomings. Early censuses lacked standard methods of reporting and data were not collected or verified by a government body (Webb, J., pers. comm., 2001; Webb, 2002). Therefore, historical statistics contained within the Census must be used with caution, particularly when used for a purpose that was not originally intended. However, the information contained within Government statistics can reveal long-term trends that can be augmented by other forms of data.

In addition, historical data were recorded in historical units of measurement (such as "1 Quintal" = 112 lb) (Urquhart and Buckley, 1965). These forms of measurement do not allow for direct comparison with more recently collected fisheries statistics which are collected in metric units. Therefore, all data from the censuses was converted into metric units for comparison purposes (Table. 2.1).

After the census of 1921, the detailed fisheries accounts at small spatial scales gathered by the early censuses were lost. By 1935, the Canadian Dominion Bureau of Statistics census format was adopted by the Newfoundland Government for the decadal census (Webb, J., pers. comm., 2001). Within this new format, data on landings, gear types and quantity, and related fishing statistics were no longer collected at the smaller spatial scale of the individual community. Therefore, the 1935 Census and subsequent censuses were of minimal use as historical sources.

Table 2.1: Table of conversion factors for converting historical measurements into metric units (Newfoundland Census, 1891-1921; Templeman, 1941; Urquhart and Buckley, 1965)

Historical Measure	Imperial Measure	S.I. Measure
1 Quintal	112 lbs	0.0508 t
1 Teirce	300 lbs	0.1361 t
1 Barrel	200 lbs	0.0907 t
1 Case	100 lbs	0.0454 t

2.1.1.3 Newfoundland Statistical Agency (1955-1959)

Following Confederation, collection of statistical information for Newfoundland fell under the jurisdiction of the Newfoundland Statistical Agency for the Bureau of Statistics. Fishery statistics were collected based on zones known as "Newfoundland Sea Fisheries Areas" (Fig. 2.2). The West Coast of Newfoundland was divided into Statistical Areas K., L, M, and N. Newfoundland statistical area M extended from Cape St. Gregory to Pointe Riche encompassing Bonne Bay (Scattergood and Tibbo, 1959).

Landings for Newfoundland Sea Fisheries Areas K, L, M and N were aggregated to give totals for the entire west coast of Newfoundland. The total landings for these areas would comprise a spatial area equal to that of NAFO Area 4R (Fig. 2.3) and of the aggregated Census district information, allowing for a spatial comparison.

Landings were recorded in imperial measure requiring conversion to metric units. Landings were converted from thousands of pounds into metric tonnes (Conversion factor: 2.2045lbs = 1kg; 1000kg = 1t).

2.1.1.4 Northwest Atlantic Fisheries Organization (NAFO) & Department of Fisheries & Oceans (DFO)

Ranging from the tip of the Northern Peninsula to Port Aux Basques, NAFO Area 4R extends the entire length of the West Coast of Newfoundland (Fig. 2.3). This represents the smallest spatial scale for which consistent data have been collected. Landings for all species harvested within NAFO Area 4R by Canadian fishers was gathered from the NAFO Statlandt 21A Database and DFO Statistics Division.

2.1.1.5 Limitations of the Approach

In researching historical trends, many different data sources, each with their own strengths and weaknesses, are used. Therefore, the researcher must be fully aware of the constraints of the data in order to properly use the information. It is also evident that there are many problems with the available information that make it difficult to reconstruct the past on a micro-scale for the early period. The methods with which data are collected today still make it difficult to reconstruct on a micro-scale. There is little available at smaller scales.

Collection methods change over time, as does the intended use of the data. This can make applying the data for new uses difficult. A prime example is the change between the census of 1921 and 1935. For the 1935 census, the Newfoundland Government began to use the census format employed by the Dominion of Canada. This change in data collection resulted in the loss of Newfoundland fisheries information at the local level. Census data collected from 1935 onward no longer held valuable fishing information, at the coastal community level, such as the number and types of nets used for particular fisheries. Therefore, census data was no longer a useful source of fisheries information. This is very problematic considering that the main source of governmental fishing data prior to Confederation was found in the Newfoundland census (Webb, J., pers. comm., 2001).

Within historical work, patchiness in the spatial and temporal scale of coverage is a constant problem, often making a complete picture difficult if not impossible to attain, particularly at small spatial scales. One way to achieve some degree of downscaling is through the collection and analysis of the LEK of experienced fish harvesters. If the period for which information is lacking dates back farther back than LEK can reach other potential sources not used in this thesis such as newspapers, diaries and other forms of government records may be applicable. However, it might never be possible to fully complete a historical reconstruction.

2.1.2 Fish Harvesters' LEK

Local ecological knowledge (LEK) was collected through interviews with seven retired fish harvesters from the Bonne Bay region. These interviews were critical to the overall understanding of the historical processes within fisheries affecting the Bay's ecosystem since "…fishers have a detailed knowledge of their resources, their environment, and their fishing practices (Neis *et al.*, 1999b)".

Interviewees were chosen from a list of retired fish harvesters provided by the local office of The Department of Fisheries and Oceans and Fisheries Committee chairs. During interviews, interviewees were asked to recommend fishers they considered to be local experts on the local fishery. This form of sampling, known as snowball sampling (Neis *et al.*, 1996; Neis *et al.*, 1999b; Hutchings and Ferguson, 2000a), provided a list of potential interviewees. Of the twenty-one harvesters approached, seven agreed to participate with at least one interview conducted in each community of Bonne Bay. The number of interviews was limited by a number of different factors, including the time of year during which the interviews took place. During August 2001, the summer food fishery was ongoing and this prevented a number of fishers from being contacted and/or interviewed. Other problems included getting in contact with people who were employed and thus unavailable for interviews. Only four of the people contacted and asked for an interview refused to take part.

Prior to starting the interviews ethics approval was sought from the Interdisciplinary Committee on Ethics Research at Memorial University of Newfoundland and Labrador. This consisted of an application explaining the purpose of the study, collection methods and how the information collected would be used. The application also contained the interview schedule (a list of the questions that were going to be asked of research participants) (see Appendix A) and consent forms that were to be signed by participants stating that they understood the purpose of the research and that they willingly participated in the interview. The consent forms also allowed those that were to be interviewed to decide what was to be done with the recorded interviews and maps once the research was completed.

The career history interviews followed a semi-structured format allowing for both close-ended questions requiring precise answers and open-ended questions allowing for opinions and stories. Interviews were conducted by two individuals and ranged from one-and-one half to four hours in length and were taped and transcribed. In addition, during each interview, fishers' were asked to record their fishing grounds on copies of navigational charts with a unique identifier for each map object.

The aim was to generate an idea of the changes in catch sizes, the size of individuals of all species taken, and changes in fishery efficiency and CPUE of the fish harvesters over the past several decades. The LEK data combined with landings data were used to downscale data on the larger changes in 4R fisheries to the level of Bonne Bay (the site of the scientific study outlined in Chapter Three), identify possible ecosystem changes, and look for evidence of changes in fishing efficiency and effort and shifting effort across species (so-called 'fishing down' the food web). The interviews also provided valuable information used in designing the biological census of Bonne Bay lobsters discussed in Chapter Three.

2.2 Findings from Historical Reconstruction and LEK

The historical reconstruction of West Coast (4R) fisheries found an overall decline in total landings of all commercial species and shifts in the target species of fishermen across high trophic level species (i.e. Gadoids & Salmonids) and then toward lower level trophic species (i.e. northern shrimp). The LEK of fishers in the Bonne Bay area also showed movement toward harvesting non-traditional target species over their careers and an increase in the total number of species fished by individual fishers to maintain landings and income. Fishers also described an overall decline in the size of fish caught. LEK showed the evolution of inshore fisheries into more efficient harvesting operations able to deploy more gear in less time and with greater accuracy than in the past. The census and landings data indicate an initial increase in the overall landings of fishers due to increases in efficiency and diversification of the species targeted. This increase was followed by a sharp and continual decline in the total landings for NAFO Area 4R beginning in the late 1980's (Fig 2.4). A reversal of this trend has since been observed; the total landings for NAFO Area 4R have been increasing since 1994 most

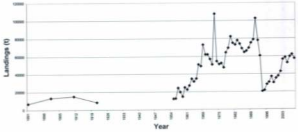


Figure 2.4: Total landings (t) of all commercial species landed in NAFO Area 4R from 1891–2008. (Newfoundland Census, 1891-1921; Newfoundland Statistical Agency for the Bureau of Statistics, 1955-1959; NAFO Statlandt 21A Database, 1960-1999; Department of Fisheries and Oceans Regional Statistics Newfoundland Division, 2000-2008)

likely due to the sporadic reopening of the cod fisheries with small overall quotas and possibly ongoing increases in efficiency and exploitation of commercial species that were not traditionally targeted by west coast fishermen.

2.2.1 Historical Reconstruction

Early fisheries data drawn from the Newfoundland Census show that only four species comprised the commercial landings of West coast inshore fishermen at the turn of the century; Atlantic cod (*Gadus morhua*), herring (*Clupea harengus harengus*), Atlantic salmon (*Salmo salar*), and American lobster (*Homarus americanus*). By the 1950's, the number of species targeted by fishermen had risen from four to eight. The primary commercial species harvested included those listed above plus: Atlantic halibut (*Hippoglossus hippoglossus*), capelin (*Millotus villosus*), Atlantic mackerel (*Scomber scombrus*), and squid (*Illex illecebrosus*). In more recent years, fishers have further expanded their target species to include: redfish (*Sebastes fasciatus* & *Sebastes mentella*), Greenland halibut (*Reinhardtius hippoglossoides*), snow crab (*Chionoecetes opilio*), and northern shrimp (*Pandalus borealis*). The addition of mackerel, squid, capelin, northern shrimp and snow crab by fishermen indicates a shift toward harvesting species which are usually considered to be lower trophic level organisms. The most heavily targeted species over the past century has been Atlantic cod (Fig. 2.5a). Early historical statistics

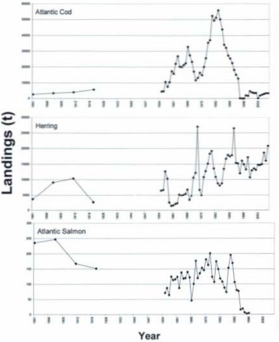


Figure 2.5 (a) to (c): Newfoundland landings (t) in NAFO Area 4R for the period 1890-2008 for various species.

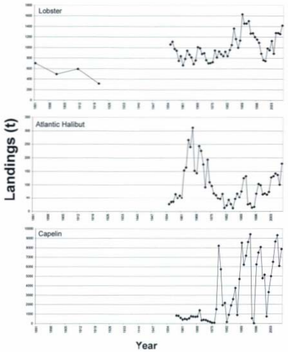


Figure 2.5 (d) to (f): Newfoundland landings (t) in NAFO Area 4R for the period 1890-2008 for various species.

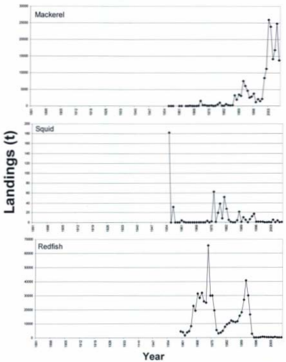


Figure 2.5 (g) to (i): Newfoundland landings (t) in NAFO Area 4R for the period 1890-2008 for various species.

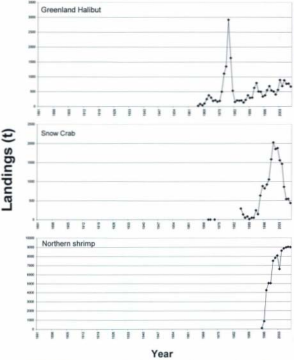


Figure 2.5 (j) to (l): Newfoundland landings (t) in NAFO Area 4R for the period 1890-2008 for various species.

gathered from the Newfoundland Censuses (1891-1921) and aggregated to the 4R level showed that landings continually rose from 2569 t in 1891 to 5624 t by 1921, and 15, 737 t landed in 1961. In 1983, the annual reported landings for Atlantic cod in 4R reached their peak for the century, 55,842 t. This was followed by a sharp and significant decline in landings which preceded the closure and establishment of a moratorium on cod fish after 1993 when 12,711 t were landed by fish harvesters. The cod fishery re-opened in 1997 with reduced landings of 1984 t and has failed to return to anywhere near the record levels observed in the early 1980's.

In terms of landings, herring was second only to the cod fishery during the twentieth century (Fig. 2.5b). Early landings data from the turn of the century show landings of herring exceeding those of cod. Landings for the year 1891 show that 3525 t of herring were harvested. This number rose to 10,408 t by 1911. Over the course of the rest of the century, herring landings on the West coast increased further. This increase was at least partially due to the collapse of the European and Pacific herring fisheries in the 1960's, leading to increased exploitation of the Newfoundland herring stocks and the introduction of purse seiners (Comeau and Bellefontaine, 1981). This increased effort, coupled with the cyclical nature of abundance in this species, led to peak landings in 1973 with 26,995 t landed and in 1991 with 26,437 t landed. Landings have remained relatively stable with 20,771 t of herring landed in 2008.

Salmon landings appear to have peaked around the turn of the century (Fig. 2.5c). The census of 1891 and 1901 showed landings of 236 t and 247 t respectively. Landings fluctuated over the 20^{th} Century with an overall decline in landings from 125 t in 1958 to 46 t by 1968. The commercial salmon fishery was closed in this area in 1992 and has remained closed to the present (Mullins and Caines, 2000; Reddin *et al.*, 2008). With the closure, the federal government closed rivers and bought back licenses from commercial fishers in an attempt to protect the species (Lear, 1993; Reddin *et al.*, 2008).

Landings statistics for the Newfoundland lobster fishery as a whole indicate a peak at 7,952 t in 1889 followed by a collapse and a three-year closure between 1925 and 1927 (Fig. 1.1). There was another pronounced downward trend in landings during the 1950's and 1960's from a high of 2,498 t in 1955 to 1,238 tons in 1972. This downward trend was reversed in the 1970's when landings increased to 2,592 t by 1979 and reached a long-term high (since 1905) of 3,232 t in 1992. Since then, landings have hovered just below 1992 levels. The picture is similar for the West coast of Newfoundland (Fig. 2.5d). Landings for 1891 show 701 t landed, which dropped to 316 t by 1921, four years before the closure. Landings for the coast remained relatively low until the early 1980's, when they began to increase and reached a peak of 1,503 t in 1992. Like the rest of the province, since the peak of the early 1990's, the landings for lobster have been in decline. Landings for 4R then experienced a decrease with only 747 t landed in 2000. This trend has since reversed with 1,418.1 t caught by fishers in 2008.

The first recorded Atlantic halibut landings were seen in 1955 with 27 t landed on the West coast (Fig. 2.5e). Landings quickly rose and reached a historical high in 1966 with 312 t landed. From over 100 t in the 1960's, landings steadily decreased until the mid-1980's, totaling 12 t in 1985. Since then, landings have shown a slow, continual increase with 179 t landed in 2008.

No commercial capelin landings were reported until the 1950's (Fig. 2.5f). Prior to that period, capelin served mainly for personal use as fertilizer, food and as a bait fishery for harvesters. The capelin fishery, while not yet a full-scale commercial fishery first reported landings of 841 t in 1958. Capelin landings remained relatively low until the mid 1970's. Prior to the 1970's, a very small number of inshore fishers' persecuted the capelin fishery for commercial purposes; its landings were typically used for bait and fertilizer (Carscadden, 1983). Observed declines in other prominent capelin fisheries (i.e. Norway and Iceland) led to increased exploitation of Newfoundland capelin stocks in the 1980's and resulted in the growth and expansion of the capelin fishery (Anonymous, 1996). As a result, the capelin fishery became a full-scale commercial fishery and has experienced large fluctuations ever since. Landings rose sharply in 1989 with 8,512 t landed and again in 1993 with 9,426 t harvested. However, the fluctuating nature of this fishery is exemplified by the decrease in landings in 2001, with only 741 t of capelin landed by fishers which was followed by an increase in the 2006 landings of 9,322 t.

Prior to the late 1980's, mackerel landings remained relatively low (E.g. 20 t landed in 1977) and it was not considered a major commercial fishery. The increased importance of this fishery can be seen by the early 1990's when landings start to increase. In 1991, a total of 7,541 t of mackerel were landed in NAFO Area 4R. Landings for mackerel continued to increase with 24,744 t taken in 2007 (Fig. 2.5g).

Squid landings increased in the 1950's and then declined sharply and remained almost non-existent for the remainder of the reconstruction (Fig. 2.5h). The cyclical nature of recruitment in this species and the fact that it requires warmer waters may suggest a reason for its disappearance from the landings record (Templeman, 1966).

The first landings for redfish were recorded in 1960 (4,534 t) (Fig. 2.5i).

The fishery reached its historical high in 1973 with 65,455 t landed. However, by 1978 fishers experienced a 95% decline in landings with only 2,979 t taken. The fishery slowly rebounded and reached landings of 40,661 t in 1991. As was observed after 1973, this fishery once again experienced sharp declines in landings with a historical low of only 2,758 t in 1994. The following year, DFO imposed a moratorium on the redfish fishery which is still in place today (Roy, 1998).

Before the 1970's, there was no directed effort to fish Greenland halibut; recorded landings consisted mainly of by-catch in other fisheries (DFO, 2000). Throughout the 1970's, landings rose dramatically to a record high in 1979 where 2,912 t of Greenland halibut were landed by fishers (Fig. 2.5j). Following this, catches declined sharply, falling as low as 158 t just three years later in 1982. In the intervening decades, landings have only slightly increased, with 669 t landed in 2008.

In the mid 1980's, a new commercial fishery, snow crab (*Chionoecetes opilio*) emerged with first recorded landings of 290 t in 1985. By 2000, the fishery had peaked with 2,027 t of snow crab harvested. However, this peak has been followed by a consistent downward decline in landings with only 423.3 t taken in 2008 (Fig. 2.5k).

The northern shrimp fishery is a relatively new fishery which is typically carried out in the Northern Gulf of St. Lawrence. The first recorded landings for this fishery in NAFO Area 4R was in 1995 with 124 t landed (Fig. 2.5l). Since its inception, this fishery has grown enormously with 9,002 t taken in 2008.

Over the course of the past century, fishers have expanded the number of species targeted in one season for commercial purposes. Throughout this timeframe, landings for several species including cod, salmon, halibut and redfish have collapsed on the west coast. In addition, by the end of the 20th century, several new species were targeted including snow crab, mackerel, and northern shrimp. Landings have also shown that the lobster fishery was one fishery that remained throughout the past century as a part of the fishery for harvesters on the West coast of the Newfoundland. The decline of several main commercial species (i.e. cod) led to increased fishing pressure on the lobster fishery in the late 1980's and declining landings throughout the 1990's. Overall, landings seem to indicate a shift across trophic levels and down trophic levels by fish harvesters, a possible indication of changes in abundance within the ecosystem.

2.2.2 LEK Results

The LEK collected through interviews showed changes to the fishing methods, techniques and gear of Bonne Bay fishermen over their careers. Such data gathered from fishers allows researchers to interpret the changes in landings. Person to person interviews were carried out with all seven fish harvesters; one interview from the communities of Woody Point, Gadds Harbour, and Norris Point. Two interviews were carried out in Trout River and Rocky Harbour. All of the harvesters interviewed were male and all stated that their fathers had fished commercially as well. Their ages ranged from 56 to 91 and all were retired at the time of the interview. Only one interviewee had received any formal fisheries training. Of those interviewed, the oldest had fished from 1918 to 1973 and the youngest from 1960 to 1999. Older harvesters retired in 1960, 1973 and 1989 respectively. Of the remaining, three stopped fishing in 1999 and one finished in 2001. The average number of years fished was 44 years with the maximum number being 55 years and the lowest 39 years. Of these fishers, those who began fishing after

1950 focused exclusively on fishing over their careers while those who began fishing prior to 1950 combined fishing with another occupation such as logging during the off-season.

During interviews, fishers were asked to describe changes in fishing practice during their career. Fishers recalled changes in boats and boat length, engine power, gear used (type and number) and landings. Often, boats used by inshore fishermen remained under 35-ft due to licensing reasons (Neis *et al.* 1999b). Of the inshore fishermen interviewed in Bonne Bay, all increased the size of their boat over the course of their careers but none had boats exceeding 35-ft in length. Meanwhile, the lack of regulations governing engine power allowed no "fixed-upper limit" (Neis *et al.* 1999b), which explains the continued increases in engine power over the course of the careers of the interviewed fishers (Fig. 2.6). Additional research within the Coasts Under Stress Research Project also found that overall, for NAFO Area 4R, as elsewhere, there were dramatic increases in effort and efficiency (Murray, Neis, and Johnsen, 2006). Whalen *et al.* (2004) found similar increases in the St. John Bay lobster fishery on Newfoundland's West coast.

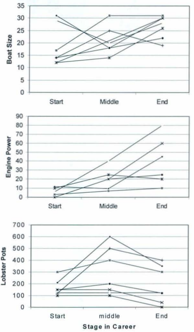


Figure 2.6: Information gathered from the LEK interviews conducted during this research showing the modifications in fishing efficiency (a) boat size vs. period of career (b) engine power vs. period of career (c) number of lobster pots vs. period of career (Unpublished Research Transcripts #1-7, 2001)

The use of electronic devices, such as sonar and navigational aides, became widespread in the 1980's in the Newfoundland fisheries (Neis *et al.* 1999b). However, none of the interviewed fishermen of Bonne Bay implemented these technologies, with some citing cost as a limiting factor. The introduction of mechanical hauling devices, however, was one technological innovation that aided harvesters and increased efficiency by reducing the time needed to check gear. Of the harvesters interviewed, four of the seven had incorporated this device into their fishing gear. All harvesters still fishing in the 1990's incorporated the use of the GPS. This device allows for more precise navigation and location of gear, especially in less than ideal weather conditions (Robins *et al.* 1998).

Interviewees described an informal boundary system, whereby fishers from communities recognize territorial boundaries to avoid conflict between fishers from different communities. As such, there is little movement or expansion of areas exploited by fishers within the confines of the bay.

The LEK gathered in interviews with harvesters revealed increasing boat size and engine power over the course of their careers regardless of when they began their fishing careers (Fig. 2.6). In addition, fishers' increased the number of species exploited over their careers. The fishers' working in the early to middle portion of the twentieth century targeted only four or five species. However, younger fishers' who began their careers in the 1950s and 1960s and fished through to the 1990s, tended to harvest more species than fishers of previous generations. The number of species targeted by younger fishers ranged from five to nine versus the four or five fished by past generations (Unpublished research transcript #1-7, 2001).

In terms of changes in the size of landings, fishers described their landings of most species harvested as declining over the course of their careers. Fishers' also observed a decline in the size of individuals of certain species, such as cod. In terms of the cod fishery, four of the seven interviewees believed that the cod fishery had declined by the mid 1980s – early 1990s. The remaining three interviewees described the cod fishery as extremely variable from year to year. In addition to declining catches, a decrease in the size of cod caught was described by two fishers in the following way:

> *"Oh ya. They went down from big to small...We was getting around, I suppose, 15, 16 inch cod, that was about all. That was from head to tail too."* (Unpublished research transcript #6, 2001)

> *"They were getting smaller and scarcer. Ya. Well, I'll tell ya, we had 5 inch mesh and we had to change to 4 inch mesh in traps. We had to in our cod traps...We had to change our mesh too, as well. I don't know if it was 3⅛ or 2⅞. It was awful small mesh. Ya. And what we used to get out of it was just tom cod."* (Unpublished research transcript # 5, 2001)

The LEK gathered from the interviews revealed changes in the behaviour and possible disappearance of some species from local waters. All seven of the interviewees noted that both capelin and herring no longer spawn within the bay:

"In the spring you would get capelin…Yes, I've seen them rolling up there in the pool you couldn't walk through them. Now, we never see them…It's going on five years, I think." (Unpublished research transcript #2, 2001)

"And the capelin would always be rolling in the thousands there, ya. They always come in regular until the last four or five years. Now, there haven't been any for I'd say the last six years, I guess." (Unpublished research transcript #3, 2001)

"Well, them times [capelin] would almost land around the bay anywhere. Anywhere around the bay there was a bit of beach. The capelin would be landing, on this side, up Lomond everywhere. Now, you can't even get one to eat. No." (Unpublished research transcript #6, 2001)

"Ya, [herring] usually come in all around the bay, ya. Right up the bottom. Mostly on the sand and the shoals. Up Lomond, that way. But the bay would be full of them. You'd see the little ones swimming around, eh? They start off, you would see them right small, and by and by they start to increase. Not anymore. They've been seined up too quick I'd say to spawn." (Unpublished research transcript #6, 2001)

"…I guess after the herring got cleaned up, and all that got scarcer, eh? Well, at least ten or fifteen years ago. When we had to buy [herring] from the plants and

elsewhere that's when the herring got scarcer in this area." (Unpublished research transcript #5, 2001)

"Oh we'd get them in the spring, we used to get'em the one time. You don't very often get'em now in the spring because there is none there really. You have to buy them now [for bait] from the plant." (Unpublished research transcript #5, 2001)

Of the seven fishers, several species were fished by only one or two. Only one fisher targeted halibut and began to fish for this species by long-line beginning in the late 1950's. However, the size of halibut caught began to decrease and he stated that he believed that they were almost fished out by the mid 1960's, when the draggers and gillnets became more widely used. Another fisher targeted lumpfish with gillnets. On average 1000 -1500 lbs/day of roe were landed, however, by 1999, only 100-300 lbs/day were caught. The person interviewed believed that the lumpfish was almost fished-out as well. Three of the seven retired resource harvesters had also fished snow crab. These fishers were the younger of the fishers, having all retired in 1999, and they had fished this species for one to three years prior to retirement. The number of crab pots ranged from 12 to 18 and each fisher was given a quota of 3100-6000lbs. The quota was reached by all fishers within a few days of the fishery opening during the years they fished.

2.2.3 LEK of the Bonne Bay lobster fishery

All interviewees (N=7) described an overall decline in lobster landings over their careers and six of the seven stated that they believed the size of lobsters caught had declined as well:

> *"One time they were good lobsters…when you bring them in you didn't have to put a measure on them, you could look at him and tell he was a good lobster. He's nice and big, well now; they've went down a nice bit, you really have got to check them now when they come in the boat. An odd one yes, well, you could look at him and say well, he's big enough. But for safety's sake, you put the measure on him. But most of them you've got to put the measure on."* (Unpublished research transcript #6, 2001)

> *"I think they gets more smaller than what we used to get. You know they get more small lobsters…We knew just by looking at them"* (Unpublished research transcript #7, 2001)

> *"The first year I started up I did real good. It went down, I had to give it up [in the 1950's]… [Size did not decrease], you know, [they just] got scarcer and scarcer…Big change. I think it went down from about 33[crates] down to probably 7 or 8[for the season]."* (Unpublished researcher transcript #2, 2001)

The season length of their lobster fishery varied widely over the course of the interviewees fishing careers initially declining and then expanding. Harvesters offer two reasons for the changing season length. Firstly, the season is regulated by the Department of Fisheries and Oceans, who shortened the season in recent decades.

> *"First when we started fishing up here it used to be the 20th of April...Then we went to the first of May and then back to the 5th of May...Ya, the season is not as long now. We used to fish to the 12th of July then."* (Unpublished research transcript #3, 2001)

> *"They start ah I don't know sometimes in April right back in the early part. Then they changed it up to May, the 5th of May. Then they went up to the 15th. They they changed it up again. I don't know what it was on the last. It was getting shorter everytime."* (Unpublished research transcript #6, 2001)

> *"Ya, you started in May and cut off sometime in June. I just don't know the date. I think it was the 15th of May you used to start, you had two weeks lobster fishing before you start [fishing cod] I think...Good lobster season would be gone by that point, the first week is always the best."* (Unpublished research transcripts #4, 2001)

> *"[Start fishing for lobster] the 20th of April until the 15th of July...Then start fishing cod then, ya."* (Unpublished research transcript #5, 2001)

The season duration of the lobster fishery was also dictated by the more lucrative cod fishery during earlier years. In those years, for many, the lobster fishery served as a means of generating income early in the fishing season. Given its position as a shoulder fishery, it was often abandoned with the arrival of the capelin and the cod migration and therefore, not fully exploited for its entire season. All of the harvesters stated that once the capelin arrived they would remove their lobster gear from the water and prepare for the start of the cod fishery. This was described by several of the fishers:

> *"Well, right after I suppose we fished lobsters for a month, and after that we take them up and wait for the capelin to come, and after the capelin come we set out cod traps then."* (Unpublished research transcript #1, 2001)

> *"Ya, you started in May and cut off sometime in June. I just don't know the date. I think it was the 15th of May you used to start, you had two weeks lobster fishing before you start I think...Good lobster season would be gone by that point, the first week is always the best ."* (Unpublished research transcript #3, 2001)

> *"After July. Well, sometimes the last of June, the middle of June if there were no lobsters, you put that ashore then grab your gear, your trawl gear, whatever eh? Then when the capelin come in and the fish [cod] come with it, you put your traps out."* (Unpublished research transcript #6, 2001)

In terms of gear, transcript data show all but one lobster fisher increased the number of pots he fished over the course of his career (Figure 2.6). Some fishers did describe voluntarily decreasing the number of pots fished toward the end of their careers, while others decreased the number of pots towards the end due to reductions in trap limits introduced by the Department of Fisheries and Oceans.

> *"Ya, well the first year [1980] he [his son] fished with me, I know we had 670 [pots]..Then we started cutting them down. I don't know what year we started cutting then down. We went down to 450, then 400, then 350 and then 300."* (Unpublished research transcript #3, 2001)

> *"They gave us four hundred. Four hundred was the limit. Now it's only 350. I think it is only 350 now...It was coming down, they were putting limits"* (Unpublished research transcript #5, 2001)

> *"But I had 400 pots...They cut it back to 300. But she's still 300 now. Ya. That's more then you can tend in a day. You bait them up and leave them for a couple of days, you fish better."* (Unpublished research transcript #6, 2001)

Overall, the information gathered from interviews describes a fishery with increased technological efficiency such as increases in boat size and engine power, as well as in the amount of gear employed allowing an expansion of harvest areas and with more species targeted than ever before. However, the increased effort and efficiency has not resulted in increased overall landings. In recent years it was associated with a decrease in the size of fish caught, the disappearance of some species and declining overall landings.

2.2.4 Changes in CPUE for the Lobster Fishery

The catch per unit of effort (CPUE) for lobster (lb/trap per season) was calculated from trap and landings data gathered from the Newfoundland Census, International Convention for the North Atlantic Fisheries (ICNAF) and NAFO. The calculated CPUE for the early portion of the reconstruction revealed a drop of 77.5% from 102.9lb/trap in 1890 to 23.2lb/trap in 1920 (Fig. 2.7). During this period, the number of fish harvesters in 4R increased from 92 to 252, the number of traps employed rose from 1,900 to 9,697, and the average number of traps per harvester for this period of the reconstruction was 37.95 (Table 2.2). The greatest number of traps (13,199) and largest landings recorded for this period (88.3 t) occurred in 1910. However, CPUE for this year was only 27.8lb/trap per season.

CPUE for Area 4R for recent decades, derived from data gathered from the DFO statistical division, show that over the 1980's and 1990's, there were slight fluctuations in CPUE but it remained well below levels seen in previous decades (Fig. 2.8 & Table 2.3). Peak CPUE years were 1994 and 1995 with CPUE reaching 8.58 lb/trap and 8.67 lb/trap respectively. The lowest levels for this period were in the mid to late 1980's with 5.03lb/trap per season and 5.62lb/trap per season in 1987 and 1988 respectively. By early 2002, CPUE for fishers on the West coast of Newfoundland had risen slightly to 8.11lb/trap. The data show that the number of traps employed on the West coast of

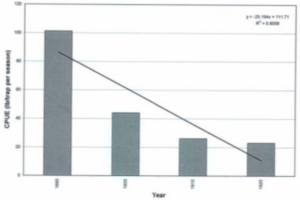


Figure 2.7: The average CPUE of lobster fishermen on the West coast of Newfoundland for the period 1890-1920; calculated from data gathered from the Newfoundland Census' 1891-1921.

Table 2.2: Table of the total number of fishers, traps, traps/fisher, landings (t) and CPUE (lb/trap per season) for Bonne Bay, Newfoundland for the period 1890-1920 (Bond, 1893 and 1903; Bennett, 1914; Anonymous, 1923).

Year	# of Fishers	# of Traps Employed	# of Traps per Fisher	Landings (t)	CPUE (lb/trap per season)
1890	92	1,900	20.7	87.3	102.9
1900	261	6,423	24.6	128.5	44.8
1910	232	14,454	62.3	183.9	28.5
1920	252	11,102	44.1	117.2	23.6

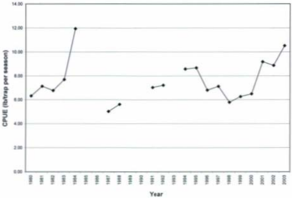


Figure 2.8: The yearly CPUE of Newfoundland lobster fishermen in NAFO 4R for the period 1980-2003. These calculations were performed from data gathered from the Department of Fisheries and Oceans Regional Statistics Newfoundland Division (www.dfo-mpo.gc.ca).

Newfoundland increased and peaked in 1992 with 459,300 in use. Similarly, the average number of traps per fisher for this period was 326.8. By 2002, the number of traps in use had declined to their lowest levels for this time period to 236,025. The decrease in the number of traps in use was coupled with a continuous decline in the number of licensed lobster fishers to 767 in 2002 from 1422 licensed lobster fishers in 1980 on the West Coast. However, these declines were coupled with an overall rise in the number of traps per fisher from 205.3 in 1980 to 307.8 in 2003.

The CPUE data for the Bonne Bay area, gathered from the fish harvester interviews, show a decrease from the middle of the 20th century up to the present (Fig. 2.9). Interviewee #5, who fished from 1952 to 2001, typifies this decline in CPUE. Early in his career, he averaged 16.7lb/trap each season. This had dropped to 12.3lb/trap during the late 1960's and the early 1970's and fell even further to 8.3lb/trap at the end of his career. Fishers who began fishing prior to the 1950's also saw a decline. For example, interviewee #2, who fished between 1935 and 1960, experienced a drop from 30lb/trap early in his career down to 25lb/trap mid-way through his career and then finally down to 8lb/trap at the end of his career.

The CPUE from both the historical census data and the interview LEK data show that the declines in lobster landings which were seen at much larger spatial scales were also found in the local data. The decline in CPUE from the census data shows the decline in lobster landings that led to the closure of the fishery between 1925 and 1927 across the Island of Newfoundland. The drop in the CPUE of interviewee #2 follows another period of depressed lobster landings province wide that occurred in the late 1960's and 1970's.

Table 2.3: Table of the total number of lobster fishers, traps, traps/fisher, landings (t) and CPUE (lb/trap per season) for NAFO area 4R for the period 1980-2003 (Department of Fisheries and Oceans Regional Statistics - Newfoundland Division www.dfo-mpo.gc.ca)

Year	# of Fishers	# of Traps	# of Traps per Fisher	Landings(t)	CPUE(lb/trap per season)
1980	1422	291,980	205.3	837	6.32
1981	1347	285,290	211.8	922	7.12
1982	1272	273,094	214.7	839	6.77
1983	1258	273,624	217.5	955	7.60
1984	972	194,245	199.8	1052	11.94
1985	-	-	-	1363	-
1986	-	-	-	1164	-
1987	1231	437,700	355.6	999	5.03
1988	1231	446,300	362.6	1137	5.62
1989	-	-	-	1629	-
1990	-	-	-	1456	-
1991	1233	457,300	370.9	1457	7.02
1992	1233	459,300	372.5	1503	7.20
1993	-	-	-	1266	-
1994	1218	326,975	268.5	1272	8.58
1995	1132	305,750	270.1	1203	8.67
1996	1120	373,725	333.7	1153	6.80
1997	1122	339,050	302.2	1059	7.12
1998	1113	336,800	302.6	884	5.79
1999	875	269,300	307.8	765	6.26
2000	822	253,550	308.5	747	6.49
2001	769	236,475	307.5	984	9.18
2002	767	236,025	307.7	950	8.87
2003	766	235,775	307.8	1125	10.52

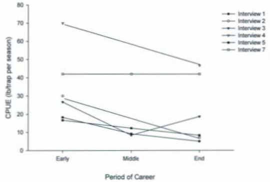


Figure 2.9: CPUE (lb/trap per season) changes throughout the careers of interviewed fishermen from Bonne Bay (Unpublished Research Interviews #1-7).

2.2.5 Linking LEK and Historical Reconstruction

The results from the LEK and historical reconstruction data mirror each other in very similar ways and show that the trends and changes that were occurring at the much larger spatial scale of the entire West coast (NAFO Area 4R) were occurring on the much smaller spatial scale of one bay and among individual fishers in Bonne Bay. Overall, both sets of data show that overall landings for the study area were in decline. As the landings for the coast began to decline in the early 1980's, the number of species targeted by fishers (five of seven interviewees were still fishing) expanded. In addition, the size of individuals of various species that were caught was described by fishers as being smaller than those caught earlier in their careers (e.g. cod, lobster, herring, and halibut).

2.3 Discussion

Efforts to understand larger components of ecosystems and their interactions have increased in recent decades (Odum, 1977; Jørgensen, 2002). An ecosystem consists of both biotic and abiotic components which work in tandem to sustain this functional unit (Jørgensen, 2002). An ecosystem approach allows researchers to examine the effect of changes within components (i.e. fish stocks) due to abiotic influences (i.e. fisheries) have had, are having, and will have on that ecosystem. Through the reconstruction of the fisheries of Bonne Bay and the West coast of Newfoundland, potential causes and effects can be identified and the impact of a century of influence on stocks can be determined.

A common method of describing an ecosystem is in terms of the feeding interactions between component species (Pauly *et al.* 1998, 2001, and 2002). For example, with the trophic level (TL) defined as 1 + the mean TL of their prey, in marine systems the bottom of the food web consists of algae (TL=1); herbivorous zooplankton feed upon the algae (TL=2); large zooplankton or small fishes, feed on the herbivorous zooplankton (TL=3); large fishes (e.g. cod) whose food is generally a mixture of low and high TL species (TL=3.5-4.5) (Pauly *et al*., 2002). Since fisheries tend to remove large, slower-growing, higher TL species first, the mean TL of remaining species is lowered (Deimling and Liss; 1994; Pauly *et al*., 2002). In reducing the mean TL of an ecosystem, fishers are said to be 'fishing down' the marine ecosystem.

The marine ecosystem of the West coast of Newfoundland has been "fished-down'. This historical reconstruction has shown that over the past century, resource users have increased their effort and efficiency through technological innovations in materials and gear, size of boats and engine power. Concurrently, the composition of landings by harvesters has changed to incorporate new species. The incorporation of these new species such as mackerel and snow crab indicates a shift from higher trophic level species to lower trophic level species. In addition, overall landings have declined from the early 1980's. By 2002, this trend had stabilized with 42,874.5 t total landings, 80.0% of which consisted of snow crab, herring, mackerel and shrimps. This is just 26.7% of the 78,599 t landed in 1990 and 24.6% of total landings for 1980. In 1960, 23.9% or 5934 t of landed species were comprised of just two of these lower trophic level species - herring and redfish. Even earlier in the century, the only such species that was targeted by fishers was herring comprising 29.5% of the total landed value of 8642.47 t for 1921. While the percentage of total landed value by lower trophic level species did not decline significantly between 1890 and 1921, it is significant to note that the number of species in this category targeted by fishers increased from one at the turn of the century to four by the end of the 20th century, another indication of the increased effort expended by fishers to maintain landings.

For the Bonne Bay region and the West coast more generally, the American lobster has been impacted by this restructuring of fisheries. The loss of other commercial species and restructuring led, in the 1980's and early 1990's, to increased fishing pressure on lobster stocks. Landings for American lobster were already showing signs of decline, beginning in the early 1990's. The American lobster served as a secondary species for fishers for much of the twentieth century. However, with the loss of the main commercial fishery, Northern cod, harvesters turned their attention to other species to fill the void, including lobster.

2.3.1 Target Species

In the "fishing-down" sequence, the diversification of taxa harvested occurs as fishers shift effort between species, across and down trophic levels in response to declining landings of traditional commercial species (Deimling and Liss, 1994; Webb, unpublished; Pauly *et al*., 2002). The increase in the number of species targeted comes alongside "…improvements in fishing technology and increased mobility of fishers, changes in markets, product distribution, management measures and changes in relative abundance of taxa" (Deimling and Liss, 1994).

The "fishing-down" sequence involves an expansion of fisheries into new fishing grounds, which typically are farther removed from home port and market centers. Fishing these new grounds may involve moving along shore or offshore as fishers increase their mobility through increased boat size and engine power (Deimling and Liss, 1994). Within Bonne Bay itself, however, such shoreline expansion is not able to occur as the Bay itself is fully exploited already. It is also limited by informal and formal territorial boundaries that limit where fishers from one community are able to place gear. Given this, fishers who are located in the communities of Trout River and Rocky Harbour have the greatest opportunity to expand their harvest area given that they are located on the outside of the bay's entrance. Those fishers from communities inside the bay, have resorted at various times throughout their careers to fishing much farther northward and southward on the west coast. Some fishers described how they would go fish in St. John Bay, St. Paul Bay, or in the Bay of Islands area.

Shifts in target species coincide with changes in species abundance as measured by landings data over the past century. In the late 1800's and early 1900's, there were four species targeted commercially: North Atlantic cod, herring, salmon, and lobster. Of these, herring and cod were considered the most important with the remaining two acting as shoulder fisheries. However, by mid-century, the number of species targeted by inshore fishers had risen to eight; those listed above plus capelin, mackerel, squid, and halibut. The increase in the number of species targeted is indicative of the increased effort fishers had put into maintaining their incomes and trying to qualify for Employment Insurance during the off-season.

By the 1990's, fishers were targeting snow crab to sustain landings and income. Typically, exploitation leads to a diversification of taxa harvested as fishers shift effort to other species in response to declining landings on "preferred" species with increasing effort (Deimling and Liss, 1994). As a result, fishers' shifted effort to species that were previously underutilized or spurned by harvesters.

2.3.2 Interpreting changes in CPUE of the lobster fishery

Effort and efficiency data for this research was gathered from the interviews completed with retired resource harvesters, historical data sources and from the Department of Fisheries and Oceans. Overall, data collected indicate a continuous increase in the amount of gear employed by fishermen, until regulations such as trap limits were set. The maximization of the amount of gear harvesters were able to fish was coupled with new technological innovations. This marriage served to increase the effort and efficiency of fishers.

Over the course of the past century, the CPUE of lobster fishers on the West coast of Newfoundland has declined from peak levels at the turn of the century to their lowest levels in recent years. At the turn of the century, fishers' expended very little effort and reaped large landings in return resulting in increasing numbers of fishers' and traps in use. This resulted in a dramatic decline in the CPUE from 102.0lb/trap per season to 23.2lb/trap per season by 1920. In more recent decades, this trend has continued and resulted in even lower CPUE levels. Over the 1980's and 1990's, fishers' CPUE fluctuated but remained low, while the number of active fishers' and traps employed declined. The low CPUE with less traps and fewer licensed active fishers than at the turn of the century coupled with lower landings than seen at the turn of the century suggests that the exploitable biomass, those lobsters that are larger than the minimum legal size, is smaller than in previous decades.

Whalen *et al*. (2004) collected interview data from active harvesters in St. John Bay, located on the Northern Peninsula of Newfoundland, in the spring of 2002 offers further insight into the changes in effort by lobster fishers in recent decades. Individual landings in the area have decreased from a high in the early 1990's. The average catch in the Bay for 2002 was approximately 2500lbs per license, resulting in a CPUE of 5.88lb/trap. However, in the mid 1980's, that amount was more than double this value. Effort has increased in terms of the number of fishermen. The number of fishermen in 1972 was approximately 75, and in 2002 it was approximately 160 (but was higher than this in the period immediately after the cod moratorium). Another indicator of effort, the number of traps were the highest in Newfoundland with each license allowed 425 from 1996 until present (Whalen *et al*., 2004). The pattern for St. John Bay is somewhat different from that of Bonne Bay and the West Coast as a whole. Fishers in St. John Bay also experienced a decline in CPUE, however, while the numbers of lobster harvesters in Bonne Bay and the West Coast declined as a result, the numbers of fishers for St. John Bay more than doubled during the same period. In addition, the fishers in St. John Bay had the highest trap limit of all Lobster Fishing Areas (LFA) in Newfoundland allowing them to utilize the largest number of traps. Therefore, while the trend for the West Coast and as was seen in Bonne Bay, when CPUE for lobster fishers declined the number of active fishers also declined. However, this was not the case for St. John Bay, where numbers more than doubled during the same period.

Deimling and Liss (1994) found that the "fishing-down" sequence resulted from interactions between increased markets and improved technology linked with patterns of abundance of particular taxa. Technological improvements increased fishing efficiency and allowed fishers' to exploit a greater number of species. The fish harvesters of Bonne Bay were the beneficiaries of improved gear design and improved materials used in the construction of the gear. Durable materials such as nylon allowed gillnets to soak for longer periods of time and also reduced the damage to gear (Neis *et al.*, 1999b). Modern metal lobster traps provide fishers with traps that last longer. These new traps are able to withstand damage that traps often receive in stormy conditions. Also, the new metal traps resist damage from wood boring marine organisms such as *Limnoria lignorum* and *Teredo navalis*, which reduced the number of seasons (to two or three), a trap could be used (Hooper, R. 2003; pers. comm.). Metal traps, reduced time demands of harvesters prior to the start of the lobster season when harvesters typically repair and build new lobster traps. This has aided in the development and expansion of the snow crab fishery (Hooper, R. 2003; pers. comm.).

Modifications and changes helped harvesters increase catches by reducing time spent on gear repair and lost catches due to damaged gear. This also allowed fishers to fish more gear, more efficiently than ever before. The introduction of mechanical haulers reduced the time needed to haul and empty gear (Neis *et al.*, 1999b) and therefore, increased the amount of gear that a fisher could set and haul in a single day. The introduction of the use of the GPS also increased the efficiency of the fishers' reducing time lost and allowing for increasing numbers of gear to be fished.

Closer examination of the CPUE data in relation to the continual increases in efficiency offers great insight and meaning to the CPUE data itself. Over the course of the past century, fishers continually increased levels of efficiency by modifying techniques and applying new technologies, while experiencing continually declining levels of CPUE. It would appear that the modern stabilization of CPUE levels is due to increases in efficiency of active fishers coupled with the decline in the total number of fishers targeting lobster. In addition, given technological advancements and a reduction in fishers, the fact that CPUE levels have failed to increase may mean that the exploitable biomass for these areas is not increasing and is not sustainable at current levels.

2.4 Conclusion: Fishing Down the West Coast Marine Ecosystem

This reconstruction of the marine ecosystem of Bonne Bay (micro-scale) and the West coast of Newfoundland (macro-scale) found that the coastal waters appear to have been fished down over the past century leading to the virtual disappearance of upper trophic level species and a growing reliance on lower trophic level species.

The loss of the higher trophic level fishes is one of the key indicators of the restructuring of an ecosystem. The Atlantic halibut fishery was a key commercial species in the mid 20th Century for some harvesters. By 1966, however, landings had peaked at 312 t and declined to a historic low of 12 t by 1985. In more recent years, landings have fluctuated between 67.8 t in 2000 and 178.7 t in 2008. Atlantic cod was another high trophic level species that was targeted heavily, not just on the West coast, but throughout the species range. Decline of this species led to the closure of the commercial fishery in the early 1990's. The loss of these higher trophic level species is reflected in the increase in the number of lower trophic level species (i.e. capelin) that are now targeted by the inshore fish harvester.

With all this restructuring, species that were previously considered secondary or shoulder fisheries have increased in terms of importance with fishermen. Landings data show fisheries such as mackerel and shrimp making up a majority of the landings. Another such fishery is the lobster fishery. Over the course of the past century, this fishery served as a means of generating income early in the fishing season for participation in the "main" fisheries (i.e. cod fishery). With the loss of the major fishery, fishers turned and began to increase effort on this species as it became their primary source of fishing income. CPUE and landings for this species have declined over the century with limited recovery in some areas in recent years. The impact of this most recent increase in effort by fishermen on lobster stocks in Bonne Bay will be examined in the next chapter.

3. Biology of lobster (*Homarus americanus*) of Bonne Bay, Newfoundland: The effect of a century of fishing

3.1. Introduction:

The American lobster, *Homarus americanus* H. Milne-Edwards, 1837 (Crustacea: Decapoda), is found throughout the coastal waters of the Northwest Atlantic from North Carolina (35°14'10"N, 75°31'53"W) to Southern Labrador (51°43'00"N, 56°25'00"W) (Herrick, 1895 & 1909; Cooper and Uzmann, 1980; Aiken and Waddy, 1986; Ennis *et al*., 1997). The southern Labrador lobster population consists of a few individuals struggling to survive the cold conditions. Commercial stocks end in northern Newfoundland. Exploitable commercial concentrations of lobster are found from the intertidal zone to depths of 700m. Northern populations in the Gulf of St. Lawrence and Newfoundland are restricted to approximately 30m depth by cold seawater temperatures. They live on a variety of substrates, from rocky boulder bottoms to eel grass beds, from exposed shorelines to protected waters (Herrick, 1895; Phillips *et al*., 1980; Aiken and Waddy, 1986; Miller, 1995). Since the 19^{th} century, the lobster fishery has remained a fishery of great economic importance to inshore fishers (Cooper and Uzmann, 1980; Phillips *et al*., 1980; Pezzack, 1992; Ennis *et al.* 1997). Hooper (1975) noted that lobster were very common throughout Bonne Bay and that they are the most important component of the local commercial fishery, as well as, the local ecology. In recent decades increasing demand for lobster, its rising value and increased efficiency have not resulted in increased landings of this extremely valuable commercial species (Phillips *et* *al*., 1980; Parsons, 1993; & Anonymous, 1998; Unpublished research transcripts #1-3, 6, 2001; Hillborn *et al.*, 2003).

As discussed in Chapter Two, the lobster fishery has experienced both technological and social changes over its history. Technological advances such as the mechanical hauler, depth sounders and synthetic materials have transformed this into a highly competitive fishery (Miller, 1995), while the advent of GPS (Global Positioning Systems) has revolutionized navigation and reduced time lost by resource harvesters, searching for their gear. Such advances have enabled fishers to improve their ability to hunt for this species through increased effort and efficiency. The effect of increased fishing effort on lobster populations/stocks is of great importance to scientists, stock managers and resource users. Over the past one hundred years, lobster landings have fluctuated greatly (Fig. 1.1) from the historical high of 1889 to the three-year closure of the fishery by 1925, and to the highs of the late 1980's and early 1990's. Recently, however, landings have once again, begun to decline (Ennis *et al.* 1997), that is similar to the collapse that occurred in the early twentieth century (Templeman, 1966; Ennis *et al.* 1997), raising concerns over the health and sustainability of inshore lobster populations. Declining abundance of the other main commercial species such as the Atlantic cod and fishery closures led to further intensification of fishing pressure on lobster up to the late 1990's. However, relatively little is known what impact recent increases in fishing intensity and restructuring of the coastal ecosystem has had on this species that until recently was considered a "shoulder" fishery by fishers.

There are several factors that must be taken into consideration when studying changes to lobster stocks. These include: (1) the harvest of undersize lobsters, (2) poaching or out-of-season harvesting, (3) lobster by-catch in other fisheries and (4) habitat damage/destruction.

This chapter will discuss the result of a biological examination of the Bonne Bay lobster stock. Prior to this research, all other lobster studies focused on populations on the northeast coast of Newfoundland, with the exception of some of Templeman's general lobster biological research in the 1930's and 1940's. The aims of this portion of the research are:

1) To perform a modern census of the lobsters within Bonne Bay. The aim will be to ascertain the impact of increased levels of fishing effort discussed in the previous chapter through biological means.

2) To determine from the survey, specific areas more heavily targeted by fishers within the bay.

3) To perform a larval census within Bonne Bay. This will be crucial to determine whether or not lobster larvae are widespread and or abundant throughout the bay. This will be an indication of the sustainability of this stock.

4) To examine larval stages found to determine if there is a foreign larval source as well as an internal source from the lobster population within the bay.

3.2. The Northern Environment

The American lobster's geographic range extends from the Strait of Belle Isle (51°43'N 56°25'W) to Cape Hatteras, North Carolina (35°14'10"N 75°31'53"W). Within this geographic range, the species exhibits broad thermal tolerance, -1.8°C to

30.5°C (Cooper and Uzmann, 1980; Lawton and Lavalli, 1996). Where cooler water temperatures persist for a greater portion of the year, growth is slowed and sexual maturity occurs at larger sizes and greater ages (Lawton and Lavalli, 1996).

Bonne Bay is a fjord (Fig. 2.1), located midway up the coast of Newfoundland in Gros Morne National Park (GMNP), extending between 49°26' and 49°35'N latitude and 57°43' and 58°W longitude (Hooper, 1975). Being near the northern limit of the geographic range for this species; depth distribution of Bonne Bay lobsters is limited by cold water and they are seldom found in water deeper than twenty-five meters (Hooper, 1975 & pers. comm., 2002).

Bonne Bay can be divided into two distinct components. Outer Bonne Bay and the South arm form part of the trough extending 10km offshore. The maximum depth of the steep-sided trough is 150m between Eastern Head and Salmon Point. Offshore shallows, less than 50m deep, form a sill, isolating deep outer waters from the deep Gulf of St. Lawrence waters. The slopes are steepest along the southwest shore and slightly less along the northeast (Hooper, 1975).

The East Arm of Bonne Bay is a separate trough. Deep East Arm waters are isolated from outer Bonne Bay waters by a shallow (15m) sill 500m west of the narrow (500m wide) Tickle. The cross section of the East Arm is typically 'U' shaped with very steep slopes to a maximum depth of 230m. More gentle slopes occur at the north and south ends (Hooper, 1975).

Seawater temperatures for Bonne Bay are generally sub-zero in the first four months of the year. After the ice cover has gone, the timing of which may vary substantially between years, the body of water begins to warm. Peak temperatures, between 16° to 20°C, are generally reached in later July or early August. Water temperatures begin to decline slowly during September and October. During November, the temperature rapidly cools to 2° or 3°C after which cooling slows again (Hooper, 1975).

Normal oceanic salinities typically average about thirty-five salinity units. Surface values in the Gulf of St. Lawrence, off Bonne Bay, usually range between twenty-nine to thirty-one salinity units. Within Bonne Bay itself, salinities range from zero at the river mouths to thirty-two or more in the Gulf of St. Lawrence, at the mouth of the Bay (Hooper, 1975). The East Arm tends to be less saline than the outer area of Bonne Bay and the Northern shoreline experiences lower salinity than the Southern shoreline. Because organisms live, grow and/or reproduce optimally at a given salinity, it is a governing factor in the distribution of most species (Hooper, 1975; Ennis, 1995).

At the northern limit of this species range in Newfoundland, lobster populations may not spawn during certain years because summer water temperatures may remain too low (Aiken and Waddy, 1986). In these years, there may be a decrease in the recruitment to the standing stock because of lower molting frequency of lobsters smaller then MLS. As well, the colder water temperatures reduce the amount of activity of lobsters and therefore, reduce the catchability and landings to the fishery.

3.3. Methodology:

Sylvie Vincent (1993) described the need for the incorporation of traditional and local ecological knowledge in natural science:

> "It is no longer considered acceptable to describe an environment, or to analyze the transformation it undergoes, without paying heed to the knowledge of the people who live in it. The reason is simple: this is knowledge that scientists do not possess, knowledge which is more holistic but sometimes more precise, which is organized according to different principles, and which is founded on decades of – sometime centuries - of observation, comparison, trial and error."

Therefore, this form of knowledge has the ability to assist traditional research methodologies and provide a new perspective on the environment (Fischer, 2000).

In the previous chapter an examination of the Local Ecological Knowledge (LEK) and archival data provided the contextual framework for understanding the evolving role of the lobster fishery on Newfoundland's West coast and in the Bonne Bay area. Fisher knowledge of Bonne Bay was also used to identify study sites in the Bay. Through the study of the interview transcripts and scientific observations from Hooper (1975) regarding the distribution of American lobster within the Bay, twelve study sites in the harvest area were identified. These sites spanned the areas of the bay identified by the retired fishers as lobstering grounds. They extended from the interior of the East Arm to the outer reaches of the mouth of the Bay (Fig. 3.1). Observations on bottom topography at each site were completed by diver observations by Dr. Robert Hooper, Kara Rogers, and William Coffey.

3.3.1 Lobster Census of Bonne Bay:

Surveys of lobster abundance could use many different techniques and sampling gear, however, each approach has advantages and disadvantages. Diving censuses can offer data of a high quality; however, high cost, depth limits and habitat area that can be evaluated serve as limitations. Towed nets or dredges are a possibility, but the high quality of the information gathered is limited to trawlable bottom and this approach can have selection biases, as well as being highly destructive and should, therefore, be avoided. Another alternative would be the use of underwater, remote cameras. The data often obtained through this means is of moderate quality in terms of limited size and sex data that is not readily quantifiable and limited by the habitat and visibility. The most cost efficient sampling gear that gathers high quality data is a trap survey. The ability to fish any habitat without limits of depth and visibility make this type of sampling the best method (Smith & Tremblay, 2003).

At each site, a lobster trap was placed at approximately 20m depth and two other traps were placed at a depth of 6m. Each trap was marked at the surface with a buoy. The traps were a two-compartment design constructed of plastic coated wire mesh. The traps measured 90cm long, 45cm wide, and 35cm high with wire mesh squares measuring 3.5cm x 3.5cm, and a hoop size of 12.5cm. The escape vent for undersized lobsters was closed off to prevent the escape of sub-legal lobsters.

Fishermen described using a few different types of bait: cod heads, herring, or squid. For this survey, the traps were baited with either cod (heads) or herring. Cod bait was obtained free of cost at the local fish plant in Rocky Harbour or from local fishermen. For the period between August 26 and September 4, herring was used as bait due to the unavailability of cod. Once the traps were baited they were set at the predetermined depth with a buoy to the surface at each site.

For the period July 13-19 and August 18 – September 6, lobster traps were hauled and checked each day with the exception of August 23 and 24, 2002, due to storms. On August 28, 2002, it was not possible to check pots at Murphy's Oil Skins (Site G in Fig. 3.1) due to local wind conditions at that site making water conditions too dangerous to haul the traps.

When the traps were checked, the lobsters caught were sexed (if female was berried, that was noted as well), carapace length (CL), total length (TL), and depth caught recorded in a Rite in the Rain® waterproof field notebook. This was completed at each site for every lobster caught. Once the measurements were taken, a small portion of the second uropod on the left side of the telson was clipped, marking the lobster to avoid re-measurement.

The CL measurement involved measuring from the posterior margin of the left eye socket, along the mid-line, to the rear of the carapace using calipers that measured to three decimal places. The measurement of the TL was done using a carpenter's measuring tape, measuring from behind the left eye-socket to the centre of the tail fan when the lobster is laid completely flat. The sex of the lobster was determined examining the sexual pleopods as described by Herrick (1895).

Once all the data were collected the CL measurements were statistically analyzed using the ANOVA technique in the General Linear Model (GLM) using ©MINITAB Version 12.1. The model equation used was:

$$CL = \beta_O + \beta_L \cdot L + \beta_S \cdot S + \beta_D \cdot D + \beta_{LSD} \cdot L \cdot S \cdot D + \epsilon$$

Where the response variable is carapace length (CL) and the explanatory variables are location (L), sex (S), and depth (D). The measurements were examined in relation to the location from which they were sampled, the depth they were captured and sex. The statistical analysis was set-up to determine the significance of each factor in relation to CL. As well, interactions between explanatory variables that might influence the size of lobster were considered.

3.3.2 Larval Census:

Marine benthic invertebrates with meroplanktonic lifecycles are dependent upon planktonic larval supply for determining the spatial recruitment potential for adult populations (Metaxas, 2001). Once released into the water column, larvae may remain in the adult habitat or may be transported to new habitats and long distances via currents and/or strong winds (Metaxas, 2001).

In lobsters found in colder water at the northern end of the geographic range of this species, such as those around the coast of Newfoundland, embryonic development requires a full twelve months allowing for the release of larvae during the summer months when water temperatures have warmed sufficiently (Ennis, 1995). Once hatched, the American lobsters undergo a 6-8 week planktonic phase. This phase includes three larval stages plus one post-larval stage where the transition from a planktonic form to a benthic form occurs (Ennis, 1995). The four planktonic stages of *Homarus americanus* are neustonic for most of their planktonic phase (Harding *et al*., 1987; Field *et al*., 2000).

Early larval research has shown that larval and postlarval forms are concentrated at or near the upper meter of the ocean (Herrick, 1909; Harding *et al*., 1982; Harding *et al*, 1987; Ennis, 1995; Miller and Reeves, 2000). Estimates from plankton samples estimate that between 78-96% of the postlarval forms are concentrated in the top 0-0.8m of the water column (Annis, 2005; Harding *et al*., 1982; Harding *et al*, 1987). However, it is not clear how intra-stage behaviour or environmental changes would effect vertical distribution and abundance of the larval and postlarval stages (Annis, 2005). Therefore, the plankton sampling of larval and postlarval forms of *Homarus americanus* in Bonne Bay consisted of both vertical and horizontal surface plankton tows.

For each of the twelve sites (Fig. 3.1), three sets of horizontal and vertical tows were completed through August and early September of 2001 representing a total of the seventy-two samples. Surface tows were completed at each site using a plankton net with an opening of one meter across, a filtering length of 200 cm and a 10 cm diameter weighted PVC cod-end collector and mesh of 200 microns. Each tow was run for two minute time periods at a speed of $1m \cdot s^{-1}$. The two minute time period was selected because longer time periods resulted in a clogging of the mesh preventing filtering of water through the net. Each surface tow was run parallel to the shoreline for the determined time period. The study area, Bonne Bay, is prone to high winds which disturb the surface water causing mixing of the upper surface waters. Therefore, vertical tows were completed from a depth of 20m to the surface at each site using the same plankton net with a 10 cm diameter opening, weighted PVC cod-end collector.

The tows were completed in the morning between 5:30 AM – 12:00 PM. It has been reported that a majority of larvae are found in the upper 60 cm during the early morning and later afternoon when the amount of light that penetrates the sea surface is lowest (Harding *et al*, 1982). Completion of plankton sampling early in the morning was due to light morning winds since speculation is that "wind-induced turbulence" alters the vertical distribution of larvae in the water column (Harding *et al*., 1982).

Once the samples were collected, they were placed in 500 ml Mason jars and were fixed with approximately 2 ml of Lugol's Iodine until the sample resembled weak tea. Ten millilitres of formaldehyde (2% of the total solution volume) was added to preserve the sample. The jars were inverted to completely mix the solution. Samples were sorted and examined for lobster larvae using the identification criteria given in Herrick (1895), Charmantier and Aiken (1987), Ennis (1995), and Lawton and Lavalli (1996). Data on the presence or absence of larvae was also gathered from a previous study completed in Bonne Bay by Dr. Pedro Quijon, who completed plankton tows in Bonne Bay between 1999 and 2001.

3.4 Results:

The data collected from the catch-and-release portion of the studied revealed the overall composition of the lobsters inhabiting Bonne Bay after the fishing season. The data showed that, on average, of the lobsters sampled, female lobsters were well below the Minimum Legal Size (MLS) for harvest while most males measured fell at or above the MLS of 82.5mm.

3.4.1 Catch-and-Release Results:

Figure 3.2 illustrates that the overall stock composition, determined from observations at all sites at all depths, showed a majority of females have a carapace length (CL) less than that of the MLS for harvest. Of all the females measured during this research, 75.2% were smaller than 82.5mm. The majority of males examined were larger than the MLS, with 57.3% of males captured above 82.5mm. The overall size range in carapace lengths of females (N=392) ranged between 52.08 and 110.32mm, with the average being 78.80mm. Female lobsters found in shallow water (N=261) ranged from 52.08 to 110.32mm with an average of 77.93mm. Female lobsters in deep waters (N=131), ranged between 59.32 and 100.95mm carapace length with an average size of 80.52mm. The overall size range in carapace length of males (N=775) ranged between 54.13 and 119.69mm, with the average being 84.46mm. Male lobsters caught at shallow depths (N=469), ranged in carapace length from 54.14 to 110.32mm, with an average measurement of 83.28mm. Male lobsters found in deep water (N=306), ranged in carapace measurement from 65.59 to 119.69mm with an average measurement of 86.28mm (Table 3.1).

Analyzing size-frequencies in relation to depth provides another perspective. Figure 3.3A shows a similar trend to that found in Figure 3.2., with only 20.0% of female (N=250) and 53.1% of male (N=469) lobsters caught in the shallow depths exceeding the MLS. Of lobsters trapped in deeper water (Fig. 3.3B), a large discrepancy can be observed between the percentage of females (33.1%; N=142) and males (63.7%; N=306) exceeded the MLS.

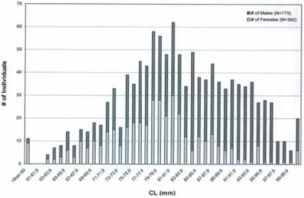


Figure 3.2: Size-Frequency histogram of the carapace length (CL) for all individual lobsters measured.

MLS = 82.5 mm; 59% of females and 35.1% of males fall below MLS (N=1167)

Table 3.1: Comparison of the average CL (mm) of lobsters by sex and depth at the twelve selected sites in Bonne Bay, Newfoundland

Sample Site	Female		Male	
	6 meters	20 meters	6 meters	20 meters
Sandy Head (A)	80.15	85.02	88.73	90.92
Decker's Cove (B)	80.54	83.46	86.01	86.68
Wild Cove (C)	77.49	77.02	83.79	83.96
Wigwam Point (D)	77.07	82.23	81.47	84.63
Green Point (E)	79.39	79.99	82.19	86.03
Pinnacle Rock (F)	81.69	83.70	83.55	85.15
Murphy's Oil Skins (G)	76.65	79.83	82.23	85.06
Munch's Point (H)	78.11	78.56	81.15	86.39
Curzon (I)	77.70	75.62	81.25	83.61
Rattling Brook (J)	81.04	82.24	82.41	86.23
Gadd's Harbour (K)	75.88	82.06	81.33	89.73
Burnt Point (L)	75.08	82.82	83.81	84.46
Average	77.93	80.52	83.28	86.28

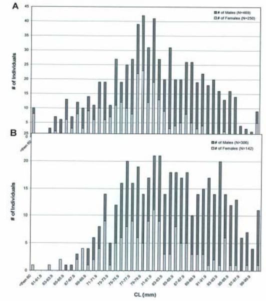


Figure 3.3: Size-frequency histograms of CL measurements at two different depths. Totals gathered from measurements of all 12 sites. (A) CL measured from lobster caught in 6 meters of water (B) CL measured from lobsters caught in 20 meters of water.

An examination of average carapace lengths by sex at each depth revealed that the average size of female lobsters was well below the average size of male lobsters. Measurement of lobsters trapped in shallow waters showed that the average size of males and females was 83.28mm and 77.93mm respectively. Of lobsters measured from the deep traps, the average size of males and females was 86.28mm and 80.52mm respectively.

Statistically, when the size (response variable) of the lobster was analyzed against depth (explanatory variable), it was shown that carapace length varies significantly in relation to depth ($F_{1,1153}$=19.1; P=0.000). Statistical analysis of the carapace length in relation to the sex was proven to be statistically significant ($F_{1,1153}$=69.47; P=0.000). It was also shown that carapace length differed significantly in relation to its location within the bay ($F_{11,1153}$=2.55; P=0.003). However, when these explanatory variables were studied for possible interactions which could have an effect on lobster, none were found to be statistically significant (Table 3.2).

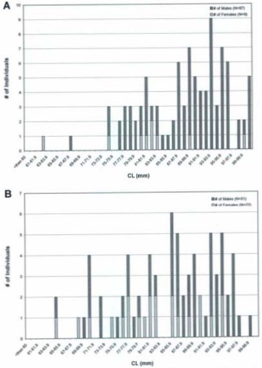


Figure 3.4 (A) to (B): Size-frequency histograms of all lobsters measured at each of the twelve study sites in Bonne Bay, Newfoundland.

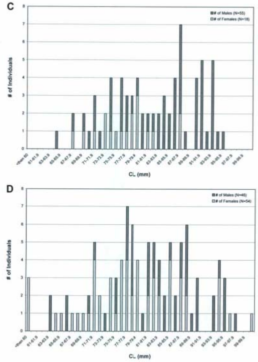


Figure 3.4 (C) to (D): Size-frequency histograms of all lobsters measured at each of the twelve study sites in Bonne Bay, Newfoundland.

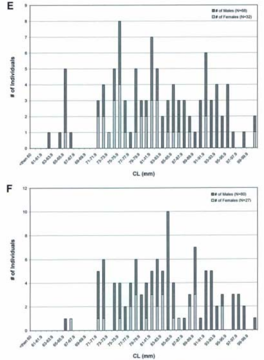
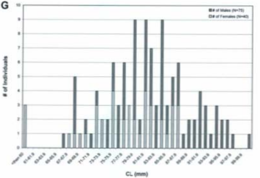


Figure 3.4 (E) to (F): Size-frequency histograms of all lobsters measured at each of the twelve study sites in Bonne Bay, Newfoundland.

G



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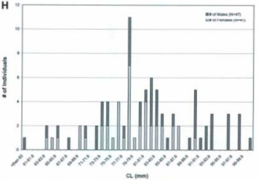
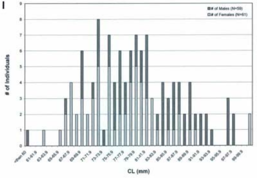


Figure 3.4 (G) to (H): Size-frequency histograms of all lobsters measured at each of the twelve study sites in Bonne Bay, Newfoundland.

I



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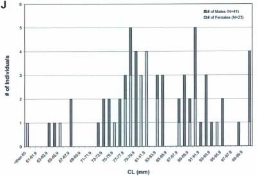
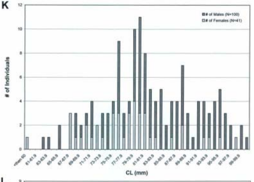


Figure 3.4 (I) to (J): Size-frequency histograms of all lobsters measured at each of the twelve study sites in Bonne Bay, Newfoundland.

K



L

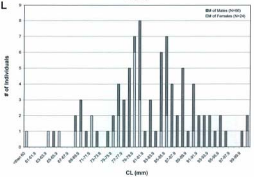


Figure 3.4 (K) to (L): Size-frequency histograms of all lobsters measured at each of the twelve study sites in Bonne Bay, Newfoundland.

Table 3.2: ANOVA for size for the lobsters captured at the selected sites in Bonne Bay, Newfoundland.

	DF	Seq SS	Adj SS	Adj MS	F	P
Depth	1	27.7927	13.5982	13.5982	19.10	0.000
Sex	1	78.2782	49.4552	49.4552	69.47	0.000
Location	11	37.1228	19.9449	1.8132	2.55	0.003
Depth*Sex	1	0.1826	0.3566	0.3566	0.50	0.479
Sex*Location	11	5.1074	5.4802	0.4982	0.70	0.740
Depth*Location	11	11.6104	11.6104	1.0555	1.48	0.132
Error	1130	804.4272	804.4272	0.7119		
Total	1166	964.5212				

Examination of each site individually yielded further results (Fig. 3.4 A-L). Sandy Head (Site A; N=96), located near the sill of the fjord, is a bar consisting of mixed boulders, gravel and sandy patches (Fig. 3.1). The bottom undulates with rows of boulders and trenches due to the presence of ice in winter. The presence of ice lowers salinity and kills sea urchins (*Strongyloncentrotus droebachiensis*), allowing for the growth of kelp (Laminaria spp.) in this area of the bay. This productive area experiences strong currents, with ebb tides being the strongest. The strong ebb tide carries low salinity water from estuaries in the East Arm (Fig. 3.1). In this area, overall, 33.3% and 77.0% of females (N=9) and males (N=87), respectively, measured larger than the MLS. Of female lobsters, 16.7% of the shallow (N=6) lobsters and66.7% of the deep (N=3) lobsters were greater than the MLS. For males, 71.7% of shallow (N=53) water lobsters, and 85.3% of deep (N=34) water lobsters were greater than the MLS. While, lobsters at this site appeared to grow larger than the MLS regardless of depth, males tended to be larger than the MLS more often than females. When examined statistically, ANOVA using the GLM, variation in size was proven not be significant with respect to depth ($F_{1,94}$=2.05; P=0.155), but was shown to be significant in relation to sex ($F_{1,94}$=7.09; P=0.009).

Decker's Cove (Site B; N=73) lies on the North side of the Bay leading to the St. Lawrence. It consists of a bedrock outcrop on an exposed shoreline. The bottom is quite steep preventing waves from breaking and much wave energy reflects back offshore. Therefore, this site is energetically more sheltered due to the lack of wave energy breaking onshore (Fig. 3.1). In this area, 36.4% and 68.6% of females (N=22) and males (N=51), respectively, measured larger than the MLS. Of female lobsters, 27.3% of shallow (N=11) lobsters and 55.5% of the deep (N=11) lobsters were larger than the MLS. For males, 65.5% of shallow (N=29) lobsters and 72.7% of deep (N=22) lobsters measured were larger than the MLS. The lobsters at this site appeared to grow to be larger than the MLS regardless of the depth found or the sex. The statistical analysis of ANOVA using the GLM found that size was not affected by the depth the lobster inhabited ($F_{1,359}$=0.23; P=0.630) or by sex ($F_{1,359}$=2.03; P=0.155).

Wild Cove (Site C; N=73) is a sheltered area with a sandy, gravel bottom with scattered boulders on the North side of the Bay (Fig. 3.1). This sheltered site allows for the growth of kelp, increasing the overall productivity of this site. Lobsters in this cove have been observed digging through sediment for infauna, a dietary source (Dr. Robert Hooper, pers. comm., 2002). Overall, 11.1% of females (N=18) and 61.8% of males (N=55) measured larger than the MLS. Of females, 13.3% of shallow (N=16) and 0% of deep (N=3) lobsters measured greater than the MLS. Most of the females measured (N=18) were, below 82.5mm. Of males, 62.9% of shallow (N=35) lobsters and 60.0% of deep lobsters measured greater than the MLS. At this site, a majority of the females measured were below the MLS. For males, the opposite was true. However, for both sexes, the number of individuals greater than the MLS did not vary greatly with depth. Statistical analysis of ANOVA using the GLM found the sex of the lobster significantly affected the carapace length ($F_{1,71}$=10.27; P=0.002). Also, depth was shown to not have a significant effect on the carapace length ($F_{1,71}$=0.34; P=0.562).

Wigwam Point (Site D; N=100) located midway out towards the mouth of the Bay, on the North side, has a bottom topography which consists of bedrock for the first seven to ten metres (Fig. 3.1). At the base of the bedrock is a boulder platform, followed closely by a sandy platform, after which the bottom drops off quickly. This site is relatively exposed to both wind and wave action. This area of the bay experiences alternations between the presence of kelp and sea urchins. In years of heavy ice coverage, the sea urchins are crushed, allowing for greater kelp beds to grow the following spring/summer. Currents at this site are generally at their strongest during ebb tides. This site also experiences ice formation during the winter months which tends to lower the salinity of the water and crush marine life in the shallow waters near the ice foot. In this area, 29.6% of females (N=54) and 52.2% of males (N=46) measured larger than the MLS. Of females, 25.6% of shallow (N=39) lobsters and 40.0% of deep (N=15) lobsters measured greater than the MLS. For males, 50.0% of shallow (N=26) and 55.0% of deeper (N=20) lobsters were larger than the MLS. The number of individuals greater than the MLS increased in the deep lobster sample. Also, in relation to the MLS, more males then females exceeded the MLS. Statistical analysis of ANOVA using the GLM found that the size of the lobster differed significantly by depth ($F_{1,97}$=4.63; P=0.034) and sex ($F_{1,97}$=4.02; P=0.048).

Green Point (Site E; N=100) is the most exposed site of all twelve (Fig. 3.1). The bottom is predominately bedrock with channels and crevices, and drops in a step-like fashion. Due to the exposed nature of this site, it experiences strong wind conditions. Strong Westerly and North-Westerly winds have a great impact on this site. Like other areas of the bay, kelp located in this site has to compete against sea urchins. In this area, 21.9% of females (N=32) and 54.4% of males (N=68) measured larger than the MLS. Of females, 16.7% of shallow (N=18) lobsters and 28.6% of deep (N=14) lobsters measured greater than the MLS. Of males, 50.0% of shallow (N=42) lobsters and 61.5% of deep (N=26) lobsters measured greater than the MLS. Generally speaking, males at this site grew larger and exceeded the MLS in comparison to the females. The number of lobsters greater than the MLS for both males and females did not vary greatly with depth. Statistical analysis of ANOVA using the GLM found that size differed significantly in relation to sex ($F_{1,97}$=4.66; P=0.033), but not in relation to depth ($F_{1,97}$=2.28; P=0.137).

Pinnacle Rock (Site F; N=107) lies on the South side of the bay, near the mouth, protecting it from Westerly winds (Fig. 3.1). The bottom consists of a steep scree slope with boulders. At 30-35 metres depth, the bottom changes into a sandy slope. It is, however, affected by North-Westerly winds. Overall, 44.4% of females (N=27) and 55.0% of males (N=80) measured greater than MLS. Of females, 55.0% of shallow (N=20) lobsters and 42.9% of deep (N=7) lobsters measured greater than the MLS. Of males, 52.3% of shallow (N=44) lobsters and 58.3% of deep (N=36) lobsters measured greater than the MLS. For lobsters sampled at this site, a large number of males and females measured greater than the MLS. Also, there does not appear to be a large difference in the number of females and males that measured greater than the MLS. Statistical analysis of ANOVA using the GLM found that depth ($F_{1,104}$=1.06; P=0.306) and sex ($F_{1,104}$=0.88; P=0.352) did not significantly affect the carapace length.

Murphy's Oil Skins (Site G; N=115) a large rocky outcrop consisting of predominantly bedrock, is an extremely steep site (Fig. 3.1). This site is similar to the Pinnacle Rock site with the exception that it is slightly more sheltered from wind. Diving observations show that this site does not contain good shelter for lobsters in terms of natural rock formations. However, there is a lot of good boulder shelter nearby so lobsters don't have to travel far for shelter. Kelp is present at this site, allowing for some shelter for lobsters. Overall, 22.5% of females (N=40) and 52.0% of males (N=75) measured greater than the MLS. Of females, 23.3% of shallow (N=30) lobsters and 20.0% of deep (N=10) lobsters were larger than the MLS. Of males, 47.5% of shallow (N=40) lobsters and 57.1% of deep (N=35) lobsters measured greater than the MLS. The histogram (Fig. 3.4 G) and the data for this site show that more males than females reach and exceed the MLS at both the shallow and the deep sites. Statistical analysis of ANOVA using the GLM found that the sex ($F_{1,113}$=15.7; P=0.000) of the lobsters and the depth ($F_{1,113}$=6.79; P=0.01) where they are located significantly affects the carapace size of the lobster.

Munch's Point (Site H; N=88) is a relatively steep slope consisting of boulders and sediment (Fig. 3.1). This site is slightly more protected. The presence of boulders and sediment provide good natural shelter for lobster at this site. Overall, 22.0% of females (N=41) and 51.0% of males (N=47) measured greater than the MLS. Of females, 15.4% of shallow (N=26) and 33.3% of deep (N=15) lobsters measured greater than the MLS. Of males, 44.0% of shallow (N=25) and 59.1% of deep (N=22) lobsters measured greater than the MLS. The data for this site seem to indicate that males reach and exceed the MLS more than females. However, the data do not clearly show any trends in size in relation to depth. Statistical analysis of ANOVA using the GLM found that carapace length did not differ significantly with depth ($F_{1,347}$=1.33; P=0.250). However, it was shown to vary significantly with the sex of the lobster ($F_{1,347}$=8.97); P=0.003).

Curzon (Site I; N=120) is a relatively flat sedimentary shelf consisting of sand, gravel, and scattered boulders (Fig. 3.1). Being further inside the bay allows for more protection at this site than at others on the South side of the bay. This site, through the presence of boulders and kelp, provides good natural habitat for lobsters. Overall, 14.8% of females (N=61) and 47.5% of males (N=59) measured greater than the MLS. Of females, 17.1% of shallow (N=41) and 10% of deep (N=20) lobsters measured greater than the MLS. Of males, 43.2% of shallow (N=37) and 54.5% of deep (N=22) lobsters measured greater than the MLS. The measurements collected at this site fail to exhibit a significant increase in size with increased depth. In terms of sex, more males achieved and exceeded the MLS than females. Statistical analysis of size in relation to depth and sex by ANOVA using the GLM, showed that size was related to sex ($F_{1,117}$=10.76; P=0.001) but not to depth ($F_{1,117}$=0.01; P=0.915).

Rattling Brook (Site J; N=64) resembles Pinnacle Rock with a steep scree slope with boulders and the presence of kelp beds. This site offers good shelter for lobsters. The currents at this site tend to oscillate, depending on the tides and the wind direction. At this site, both ebb and flow currents may be strong possibly due to local topographic reasons (Fig. 3.1). Overall, 34.8% of females (N=23) and 56.1% of males (N=41) measured larger than the MLS. Of females, 30.8% of shallow (N=13) and 40% of deep (N=10) lobsters were larger than the MLS. Of males, 52.2% of shallow (N=23) and 61.1% of deep (N=18) lobsters were larger than the MLS. The measurements of lobsters at this site indicate that there is not a large difference between the sexes in carapace length, and that depth does not seem to affect size with both males and females reaching sizes in excess of the MLS. Statistical analysis of ANOVA using the GLM found that neither sex ($F_{1,61}$=0.97; P=0.330), nor depth ($F_{1,61}$=1.36; P=0.248) were significantly related to the carapace length measurement.

Gad's Harbour (Site K; N=141) lies in the East Arm of the Bay. The bottom consists of rock outcrops, boulders, and gravel; optimal habitat for lobsters. This site experiences back eddies from strong currents that flow past the site and allow for the entrainment of plankton (Fig. 3.1). Diver observations note many lobsters seen at this site and a large number of small lobsters (defined as less than the MLS). Overall, 19.5% of females (N=41) and 51.0% of males (N=100) measured greater than the MLS. Of females, 8.0% of shallow (N=25) and 37.5% of deep (N=16) lobsters measured in excess of the MLS. Of males, 39.4% of shallow (N=71) and 79.3% of deep (N=29) lobsters measured greater than the MLS. The data for this site shows that both sexes had double the percentage of individuals with measurements greater than the MLS at the deeper depths. The data also reveal that the number of males greater than the MLS was double the number of females greater than the MLS. Statistical analysis, of ANOVA using the GLM, supports these observations with both depth ($F_{1,138}$=28.32; P=0.0.000) and sex ($F_{1,138}$=17.73; P=0.000) shown to significantly affect the carapace length.

Burnt Point (Site L; N=90) also lies in the East Arm of Bonne Bay (Fig. 3.1). This site experiences strong reversible currents with the ebb being stronger than the flow current. The bottom is a shoal consisting of shingle-like bottom with scattered boulders and rock outcrops. Overall, 20.8% of females (N=24) and 57.6% of males (N=66) measured greater than the MLS. Of females, 5.9% of shallow (N=17) and 57.1% of deep (N=7) lobsters measured greater than the MLS. Of males, 61.4% of shallow (N=44) and 50.0% of deep (N=22) lobsters measured greater than the MLS. The data suggest that while there is a marked difference in size in relation to sex, the difference in size in relation to depth is not as clear. Statistical analysis of ANOVA using the GLM found that the size of lobsters at this site differed significantly with respect to sex ($F_{1,88}$=11.82; P=0.001). However, depth was shown to not affect carapace length ($F_{1,88}$=1.93; P=0.169).

3.4.2 Results of the larval study:

The larval study was aimed at collecting and identifying lobster larvae at each of the twelve sites. The larvae were to be examined for stage of development. The goal was to determine if larvae at sites near the mouth of the bay were at a later stage of development or the same stage of development as those found at sites in the interior of the bay. This would indicate different larval sources. Larvae at a later stage of development would be older and therefore have probably been carried to Bonne Bay from another location. While larvae that are at an early larval stage would most likely be from the Bay or from a source relatively close to the Bay. Unfortunately, none of the seventy-two plankton samples collected in 2002 or samples collected in 1999-2001 yielded lobster larvae or post-larval forms at either stage of development

3.5 Discussion:

Statistical analysis of the data gathered from the census of the lobster stock sampled for the entire bay found that carapace length (CL) of lobsters differed significantly in response to variables of sex, depth and location. Statistical analysis revealed that males were significantly larger than females; lobsters from the deeper inshore waters of Bonne

Bay were significantly larger than those found in shallow inshore waters, and that CL differed significantly by the location. The statistical analysis, however, failed to find a significant interaction between either explanatory variable (sex, depth, or location) in relation to carapace length (response variable). Of the statistical analysis completed for each site nine of the twelve sites found that CL differed significantly in response to sex, while, only three of the twelve sites found that CL differed significantly in response to depth. The second phase of the study involved larval census of *Homarus americanus* within Bonne Bay, completed between 1999 and 2002. However, no larvae were found in samples taken within the bay.

3.5.1 Significance of sex and carapace length:

Natural mortality levels, for the American lobster, of 2 to 8% (Lawton and Lavalli, 1996) are greatly exceeded by fishing mortality in which 90% of lobsters greater than the MLS are taken by the fishery each year (Campbell, 1980; Ennis, 1986; Fogarty, 1995; Landers *et al.* 2001). In addition, all inshore Canadian stocks are harvested below the size giving the maximum yield per recruit (Thomas, 1973; Miller, 1995). With such high exploitation rates for a fishery that is not managed under a quota system, recruitment to the standing stock – the proportion of stock that is of commercially legal size – is through growth into the commercial size range. The impact of such high rates of fishing mortality on lobster populations and the selection pressure exerted by extremely efficient fisheries can greatly alter the basic structure of a population. For example, stocks which experience high age/size-specific mortality rates, such as highly exploited stocks, may increase their fitness through decreasing the size at sexual maturity, relative to less exploited stocks. The benefit of early reproductive maturation is that it allows individuals to increase the probability that they will successfully produce offspring to sustain the population (Landers *et al.* 2001). Recent studies in Long Island Sound, United States found that the size at sexual maturity had decreased in response to intense fishing pressure (Landers *et al*., 2001).

The size of female lobster at sexual maturity is known to be strongly influenced by external factors like sea temperature. For example, maturation of females occurs at smaller sizes in the warmer inshore waters of New England and at larger sizes for populations of deep cold-water lobsters offshore in the Gulf of Maine (Aiken and Waddy, 1980; Fogarty and Idoine, 1988). Given that Newfoundland is the northern limit of the geographic range for this species, any differences in water temperature are most unlikely to significantly affect the size at maturity as greatly as for those populations in much warmer water in the southern end of the species' range. In addition, the colder water temperatures of Newfoundland slows the growth rate of lobsters, to compensate for this environmental factor, lobsters located in Newfoundland waters reach maturity at smaller sizes . In comparison with populations in warmer water temperatures, the size at maturity is likely to be smaller in colder water than in warmer water (Templeman, 1936; Aiken and Waddy, 1980).

Study of the composition of a population can reveal the status of recruitment into the standing stock (Ennis, 1986). In Chapter Two, retired resource harvesters of Bonne Bay described decreases in the size of the individuals of various species harvested, such as Atlantic cod and lobster over their career. Hooper (1975) noted that most of the lobsters in Bonne Bay were less than 1kg (2lbs) due to the fishery. The largest lobster observed in this study was only 5kg. The data gathered from the census of the Bonne Bay lobster stock found that 75.3% of females measured had CL less than 82.5mm, the Minimum Legal Size (MLS) for harvest. Given that the census was taken after the closure of the fishing season, it is apparent that a majority of all legal sized females are taken in any given year. However, the percentage of commercially viable females remaining (24.7%), in a highly exploited stock, strongly suggests that this number presents an estimate of post harvest population plus moulting, while 57.3% of male lobsters measured greater than 82.5mm. This difference is significant and of critical importance. Male lobsters reach sexual maturity at smaller sizes (40 to 45mm CL) then female lobsters (~80.0-81.0mm) (Aiken and Waddy, 1980). This fact combined with the evidence from the Bonne Bay stock that males are able to grow to sizes larger than the MLS, while the average size of females fell below the MLS would suggest that many females are not able to grow to larger sizes and produce recruits for more than one year, if at all. This is a critical problem because the younger a female lobster is, the fewer eggs are produced and the less likely recruitment will be successful (Aiken and Waddy, 1980; Ennis *et al.* 1997).

Given that trapping is not sex selective, the difference between the sexes in terms of CL may also be due to earlier and more frequent moulting/growth of males after the closure of the fishing season while females may moult/grow later in the season. This may explain the large difference on average between the sexes since each moult increases the carapace length by 15% (Aiken, 1980). Therefore, with an increase of approximately 15% of CL with each moult, it can be expected that a majority of the females would be available for harvest the following year. This failure to allow females to attain sizes greater than the MLS of 82.5mm at such extreme exploitation rates may be exerting selection for slower-growing, earlier maturing lobsters over time. The increased fishing mortality coupled with selection pressure may lead to a reduction in the size at maturity for this stock.

3.5.2 Significance of Depth and Carapace Length:

Ennis (1983) stated that lobsters in Newfoundland waters change depth distribution seasonally, with lobsters being restricted to a shallower depth in summer months than in the winter months. In addition, it has been observed by resource harvesters that over the course of the lobster season, as the water temperature increases, lobsters generally move into shallower waters to occupy warmer water. However, there is very little known regarding the movement of lobsters on the bottom of the vertical range. Given that as the water temperature warms over the course of the summer season, it is possible that lobsters may also move into deeper waters following the increasing thermocline depth during the latter part of the summer and early fall.

Cold water limits the depth distribution of Bonne Bay lobsters, with lobsters seldom seen below 25m depth (Hooper, 1975; pers. comm., 2002). The resource users stated that, following the lobsters, fishers' move their lobster traps into shallower waters closer to shore as the season progresses in order to take advantage of this movement (Unpublished Research Transcript #1-7). Statistical analysis showed that there was a significant difference in carapace length between lobsters found at shallow depths of 6m and those found at 20m depth. Lobsters that were trapped in deeper waters were shown to have carapace lengths that were, statistically speaking, significantly larger than those at the shallower depth.

The difference in size in relation to changes in depth within a small depth range raises possibilities for fishing selection pressures. The fact that fishers are moving inward toward the shore allows those lobsters that remain at the deeper depths to escape a portion of the fishing season and fishing effort. This allows for an increase in the probability that those lobsters will exceed the MLS and attain larger carapace lengths than lobsters that move into the shallower waters over the course of the fishing season. Therefore, lobsters that are predisposed to remain in deeper cooler waters of Bonne Bay increase the probability that they will successfully produce recruits.

3.5.3 Significance of Location and Carapace Length:

Statistical analysis of data gathered from the Bonne Bay lobster stock found that location significantly affected the carapace length. Carapace length of lobster has been shown to vary significantly between stocks that are separated geographically (Campbell and Robinson, 1983; Cadrin, 1995). The data collected during the course of this field study seems to indicate that this may be true on a much smaller spatial scale, within Bonne Bay.

Habitat architecture has been shown to influence local diversity (Littler *et al.* 1983), body size (Hacker and Steneck, 1990), recruitment (Connell and James, 1991), population size structure (Howard, 1980) and survival of species in marine communities (Heck and Thoman, 1981; Bologna and Steneck, 1993). Habitat complexity can consist of both biotic and abiotic elements. While biotic elements such as kelp beds have great influence on community structure, changes in the habitat structure also result in changes in the species composition of an area (Wharton and Mann, 1981). For the American lobster, complex habitat has been shown to increase population density due to shelter availability (Cobb, 1971; Cooper and Uzmann, 1980; Wahle and Steneck, 1991). The literature suggests that lobsters are highly dependent upon natural shelters during their lifecycle. For example, post-larval lobsters rely on coarse sediments for protection from predators during settlement (Botero and Atema, 1982; Ennis, 1995); as they grow and develop they must find and create new shelters.

Lobsters occupy a narrow strip of seabed between 9 to 12 feet depth (Ennis *et al.* 1997). They can be found on almost any bottom type, preferring bottoms composed of boulders and rocks, especially those that also house kelps that can serve as shelter for the lobster (Wharton and Mann, 1981; Bologna and Steneck, 1993; Acheson and Steneck, 1997). Rock, cobble, and gravel substrates are critical areas for the postlarvae, juvenile and adolescent stages. The intertidal zone, often considered essential lobster habitat, serves as a critical nursery area. The close proximity to shore areas means that these areas are heavily impacted by human activities such as pollution and fishing.

Given the impact that fishing has on a population/stock, factors that lead to a reduction in effort may lead to an increase in the size of lobsters in those areas. An examination of all sites revealed that the sites with the largest carapace measurements were all located on the North side of the bay, with the exception of the Pinnacle Rock site. Watson (1974) and Hooper (1975) documented the prevailing wind conditions of the Bay. Winds were basically westerlies throughout the year; with winds more south-west during the summer months and more west-north-west in the winter. With the lobster season occurring in the early summer months, wind direction is generally from the south-west which results in heavy winds blowing onshore on the North side of the Bay. Such strong onshore winds often damage pots and make daily checks difficult, if not impossible, at times. Such difficulties may have lead to a reduction in effort in this area, allowing a greater chance at escaping the fishery and producing recruits.

3.5.4 Larval census:

Larval surveys by Dr. Pedro Quijon (1999-2001) and for this research (2002) found no lobster larvae in the surface waters of Bonne Bay (Quijon, pers. com., 2003). This research was aimed at exploring the sources of larval recruits for Bonne Bay. Plankton samples were taken throughout Bonne Bay extending from the inner East Arm, out towards the mouth of the Bay on both the northern and southern sides of the bay and into the South Arm. With the collection of lobster larvae, each could be identified to stage of development: Stage 1 (8mm), Stage 2 (9mm), Stage 3 (11mm), Stage 4 (post-larval stage) – with transformation from early larval forms to post-larval settling occurring in approximately six to eight weeks (Herrick, 1895; Ennis, 1995). By determining stage of development, it would be possible to establish approximately how long the larvae had been in the water column. If there were distinct differences in the stages found, this would indicate that there is more than one larval source supplying the bay with recruits. However, the lack of larvae found seems to indicate that larvae are rare in the surface waters of Bonne Bay, despite a survey of the adult lobsters found many berried females.

Larval behaviour has an impact on the success or failure of plankton surveys. All larval stages possess little horizontal swimming ability, but are reported to move vertically in order to remain near parental grounds (Ennis, 1995). Bonne Bay has a surface circulation which flushes the upper ten meters of water every three to eight days (Hooper, 1975). With such strong flushing forces, it is not likely larvae are retained within the bay without vertical movement. At the same time, this flushing force also causes large volumes of water to enter the bay. It is thought that this introduction of water would carry larval recruits from external sources, replacing local recruits that are removed. Therefore, while local larvae may not be evident within the surface waters of Bonne Bay, larvae from foreign populations/stocks should still have been found within the upper few meters.

The lack of larvae collected may be due to wind effects. Wind is extremely important to the marine ecology of Bonne Bay. It governs movement, mixing, and water circulation patterns in the Bay (Hooper, 1975). Harding *et al.* (1982) speculated that "wind-induced turbulence" altered the vertical distribution of larvae in the water column. Given that strong winds are common in Bonne Bay (Anions and Berger, 1998), it may result in the mixing of the surface waters, forcing larvae into deeper water on a continuous basis.

The failure to acquire larvae for comparison and analysis has led to a re-examination of the techniques and methods used in this study, especially the vertical sampling technique. The ability to improve the chances of capturing larvae may be improved by increasing the number of vertical samples of the water column at each of the twelve sampling site in Bonne Bay, which would cover more of the water column not previously sampled. This modification in sampling technique should increase the probability of sampling individuals that undergo some form of daily vertical migration, as well as, those driven into deeper waters by adverse surface sea conditions. However, given that previous studies (Harding *et al.*, 1982; Harding *et al.*, 1987; Annis, 2005) have shown that the planktonic phases of *Homarus americanus* spend a large portion of time within 0-0.8m, a large number of samples, all without larvae, seem to demonstrate that lobster larvae were not widespread or abundant within Bonne Bay. A further modification to larval survey which might help to improve chances of finding larval recruits would be to extend the survey further and sample outside the mouth of the bay. Given the restrictions of the size of our boat, we were not able to complete tows outside the mouth of the bay for safety reasons.

3.6. Conclusions and Findings:

This research was conducted with the aim of understanding the impact of increased fishing pressure on the structure and health of lobster in Bonne Bay, Newfoundland. The results from this biological study found that the lobster of Bonne Bay had significant differences in size between the sexes. As well, the size of lobsters was shown to vary with depth and location in the Bay.

The data suggest that there is a significant difference in carapace measurements with respect to the sex of the lobster. The results showed that females were, on average, smaller than males. The average carapace measurements of female and male lobsters in Bonne Bay were found to be 78.80mm and 84.46mm, respectively. This may indicate that there may be a decrease in the size at sexual maturity of female lobsters, increasing fitness, as a response to increased fishing pressure. The difference between the sexes may also be attributed to sex-based differences in the timing and frequency of moulting.

Given that moulting increases size by approximately 15% (Aiken, 1980; Pezzack, 1992), earlier moulting by males may account for male carapace measurements being on average larger than female measurements.

Through statistical analysis, depth was shown to significantly affect the carapace length of lobsters. Deeper lobsters were shown to have significantly larger carapace measurements. Over the past one hundred years, fishing effort has increased and expanded fishing into areas that once served as refugia for lobsters. However, the behaviour of fishermen may be creating another form of refugia. Fishermen move traps further inshore as the season progresses to target lobsters that move into the warmer waters. This movement of traps decreases the fishing pressure on those lobsters that remain in the deeper inshore waters, suggesting a possible behavioural modification allowing lobsters that remain in deeper water to grow larger. However, lobsters within Bonne Bay usually don't have to walk great distances to change depth significantly, which may mean that larger lobsters are more effective predators at depth than smaller lobsters. In either case, their recruitment success is increased allowing each lobster to produce recruits for a longer period of time before they too are harvested.

Statistical analysis indicated that there was an interaction between a lobster's location and its carapace measurements. Overall, the data show the sites which had the largest carapace measurements were all located on the north side of the bay with the exception of Pinnacle Rock. Such a distinct difference would suggest that habitat on the north side of the bay is more suited to lobsters offering wider food sources and shelter. As well, the prevailing south-west summer wind conditions often result in rougher water conditions on the north side of Bonne Bay (Watson, 1974; Hooper, 1975; personal observation, 2001) which may cause more trap destruction and lead fishers to reduce the number of traps on that portion of the coastline. In addition, down-welling of warmer water could also speed up molting on this side of the bay. Both of these factors could be responsible for lobsters on the north side of the bay growing to larger sizes.

In addition to the trapping survey, surface water sampling throughout Bonne Bay failed to yield any larval stages of the American lobster. This lack of larvae in the first meter of the water column would suggest that further surveys should be completed at deeper depths to determine if larvae can be found deeper within the water column. However, the lack of larvae from such a large number of samples demonstrates that they are neither common nor abundant within the Bay.

4. Overall Findings and Conclusions

4.1 The Current State of West Coast and Bonne Bay Fisheries

Throughout Newfoundland, the American lobster is subjected to intense exploitation with the bulk of annual landings comprised of animals that reached commercial size during the previous year. In recent years, landings have been declining in many areas, for much longer and more severely in some than in others (Ennis et al. 1997). Ennis *et al.* (1997) believe that unless the levels of exploitation are reduced, landings will be lower, less stable, and could decline even lower. This research supports the hypothesis that the Bonne Bay stock potentially faces this pessimistic outlook for the future if no changes occur in the management of this fishery.

In this thesis, a historical reconstruction of the fisheries of Bonne Bay and the West coast of Newfoundland for the past century identified shifts in the target species of commercial inshore fishers indicating an interactive restructuring of the marine ecosystem and of fisheries. The reconstruction of the fisheries showed a decrease in the abundance of and loss of fisheries for some higher trophic level species and an overall decline in the volume of landings despite an increase in the range of species targeted reflecting a pattern of "fishing-down" the ecosystem. Combining the historical reconstruction carried out using census and statistical data available primarily at the level of 4R with insights from LEK interviews with experienced fish harvesters in Bonne Bay whose careers reflected these larger spatial scale trends in landings at the scale of the bay helped us downscale the larger patterns to the scale of our biological research on lobster. Fishers had observed a decrease in the size of individuals caught (e.g. American lobster, Atlantic cod, and halibut) over time, as well as, the disappearance of spawning by migratory species such as herring and capelin from the coast of Bonne Bay. The loss of commercial fisheries for many traditional species was associated with increased fishing effort within the lobster fishery in Bonne Bay as elsewhere by the 1980's and with declining CPUE. The historical reconstruction also suggested that CPUE was much lower in recent decades than it had been at the beginning of the 20^{th} century and that harvesters were fishing more traps and fishing much more efficiently than they had been in the past.

The historical reconstruction and LEK interviews presented in Chapter 2 provided the context for a census of lobsters in 12 different lobster fishing locations in Bonne Bay summarized in Chapter 3. This research found that after more than a century of commercial fishing, lobsters in Bonne Bay, overall, are at or near the minimum legal size for commercial sale with very few larger lobsters observed. In addition, the females of the bay were found to be on average smaller than the males with most measuring less then 81.0mm. Data also show that lobsters found at deeper depths and at certain locations within the Bay were larger than their counterparts. The larval study appeared to show an apparent lack of abundant lobster larvae within the Bay. Given that lobster populations depend upon larval recruits as a means of maintaining population sizes, the ability of this population to survive and recruit new lobsters remains unknown. It is possible that larvae could be found much deeper in the water column than is normal because of surface circulation of the Bay and wind driven mixing of the water column but this is not likely given the universal reports of preference of lobster larvae for shallow waters. Another possibility is that Bonne Bay's stock may rely on the immigration of newly settled postlarval lobsters or adult lobsters from populations outside of the Bay. The lack of any observed larval stages may also be a methodological artifact of the sampling strategy. Increasing vertical sampling through out the bay and extending the larval survey outside of the bay may yield more information on the movement of larval recruits into and within Bonne Bay.

This research offers insights into the state of the west coast fisheries utilizing an interdisciplinary approach. It offers evidence that the lobsters of Bonne Bay, Newfoundland are experiencing increasing fishing pressure which appears to be negatively affecting the stock's ability to sustain itself. Such concerns were raised in the Eastport area prior to the establishment of the EPLPC in 1995 (Rowe, 2000; Janes, 2009). Since the establishment of no-take reserves in 1997 (Duck Islands & Round Islands; ~1.8% of lobster habitat) the lobster population in the no-take areas has shown increases in overall size of individual lobsters, increases in % of ovigerous females and increases in population density in the no-take areas (Rowe, 2000; Janes, 2009). The "improvements" seen in no-take areas are exerting a spill-over effect in the surrounding areas where lobster harvesting is still on-going (Rowe, 2000). The positive improvements seem to indicate that the establishment of such no-take areas can offer a simple solution to help enhance the sustainability of a population under intense fishing pressure such as the lobster stock of Bonne Bay.

4.2 Precautionary Principle and Co-management of fisheries:

In recent years, governments have come to the realization that we need to become more cautious with our resources and the natural environment. As a result, the precautionary principle and approach has become acknowledged globally as a means to prevent further environmental degradation (Kriebel *et al*., 2001; Harremoës *et al.* 2002; Manson, 2002). The precautionary principle is a distinctive approach that involves the need for prudent foresight, the need to account for uncertainties in systems and to take action without complete knowledge (Kriebel *et al*., 2001; Manson, 2002).

Traditionally, fisheries management has been regulated by governments which have vested ownership of the natural resources. However, contrary to regulatory efforts, the commons property nature of natural resources often contributes to the overexploitation and destruction of renewable resources (Weeks and Mazany, 1983; Blundon, 1999). For example, fisheries worldwide have experienced declines in landed volumes (Pauly *et al.* 1998; Myers and Worm, 2003) and fisheries managers have looked to alternative management approaches to stem the tide of unsustainable use (Blundon, 1999).

Traditional fisheries management typically relies upon a quantitative approach based on stock assessments and single species models. This style of management, however, is unable to determine maximum sustainable yield until it is surpassed and overfishing has reached severe levels of exploitation (Hilborn and Walters, 1992).

By contrast, alternative management regimes direct efforts at multiple species and ecosystem approaches. Such regimes address the inherent information problems 'by attempting to manage small areas of oceans which are known intimately and scaled appropriately to biological processes' (Wilson *et al.* 1994, p.305). This different approach to management requires a layered approach which incorporates decentralization and community based governance (Wilson *et al.* 1994).

The basic notion of fisheries co-management is premised on the sharing of power between government and resource users. By including fishermen in the decision making process, they will bring to the table their human capital and expertise on local resources including: information on historical catches, bathymetry, weather patterns, gear usage and the interaction of fishermen with the environment (Mackinson and Nøttestad, 1998; Blundon, 1999; Bergmann *et al.*, 2004). Therefore, by combining the precautionary approach with co-management some of the inherent knowledge gaps and needs of society can be filled adequately while providing for a management framework that is knowledgeable and successful.

4.3 Eastport Project and Bonne Bay:

Studying all of the other species gives the scientist insight into changes in the ecosystem as a whole that impact this one species. The biological study confirms these findings and suggests some ways to improve stewardship of this fishery by resource users.

In response to record low catches in 1993, the fishers' on the Eastport Peninsula, Newfoundland formed the Eastport Lobster Protection Committee (EPLPC) in 1995 to establish rules for the protection of the local lobster stocks and bring about a more sustainable fishery (Blundon, 1999; Davis *et al*. 2006). The committee initiated conservation measures aimed at reducing illegal harvesting of undersized and berried lobsters, ensuring trap limits were not exceeded, and established an active V-notching program. In addition, exclusive lobster fishing zones and closed areas were set up around the Eastport area.

The introduction of no-take areas has been shown to affect the species of interest in many different ways. Firstly, the closed area can serve as a source of recruits for the surrounding area which can then leading to an increase in landings in the surrounding waters. No take reserves can also help to maintain genetic diversity and population structure in a region. Such reserves act to counteract the damaging effects of fishing such as directional selection for specific sizes or a particular sex. In Eastport, the establishment of these reserves has been shown to help sustain and possibly enhance the local lobster fishery (Rowe, 2001). Rowe (2002) has found that the mean size over time has increased for males and females and has observed that there are more ovigerous females in the closed area as compared to the surrounding waters.

In 2002, fishers' in the Bonne Bay area were not yet sufficiently alarmed at the state of their fishery to support the establishment of a grassroots effort similar to that of the Eastport Peninsula. More recently, however, Trout River harvesters established a no-take area in their lobstering grounds; there has been v-notching of berried females in the area, and more interest in scientific research on lobster among harvesters. Fishers in this region follow territorial boundaries that prevent fishers' from one community fishing in another communities' fishing area. If a closed region were to be established, fishers' from various communities would have to support the initiative and not venture into the area.

Every area in the bay where lobsters can be found and harvested has experienced heavy fishing pressure in recent years throughout the entire lobster fishing season. A "no-take" area (if appropriately located) similar to that established by the EPLPC could potentially enable lobsters found within Bonne Bay to grow to much larger sizes allowing for greater egg production and potentially, more productive and successful recruitment each year. This would help to ensure that some of the larvae produced each year in that area would have the greatest chance of entrainment and retention within the bay. One possible area which could be established as a no take area would be from Gadd's Harbour across the bay to Burnt Point East extending down the east arm of Bonne Bay. Closing this area would probably generate the least resistance from fishers given there are only a few fishers who target lobsters in this area. This area offers the greatest opportunity for entrainment of larvae of anywhere in the bay, given the surface water circulation created by the sill of the bay. With the water currents in this area, it is possible that most larvae would be kept in the east arm of the bay and not swept over the sill and out to the mouth of the Bay. However, further research would be needed to determine exactly the effect water movement over the sill has on planktonic larvae of the lobster.

Another voluntary technique which has been shown to further increase the reproductive potential of females is v-notching. This practice involves cutting a notch into the right uropod of female lobsters when eggs are present, identifying female lobsters that are capable of reproducing. This practice prevents these lobsters from being landed allowing them to remain in the population longer, to grow to a larger size and potentially producing more eggs as a result (Goetting, 2010). If Bonne Bay fishers, like those of Trout River, actively began the practice of v-notching; this practice would be an effective way to preserve and potentially increase the reproductive potential of this lobster stock.

4.4 Conclusions and Future Considerations

This research has led to the following conclusions:

1. Fishing effort on the lobster stock of Bonne Bay has decreased in recent years. NAFO, DFO and LEK data indicate a decline in the number of fishers' exploiting this resource. It can also be shown that the CPUE of those still fishing for lobster has not increased in response to a reduction in effort.
2. The Bonne Bay population statistically shows a difference in size between the males and females possibly due to selection pressure leading to a reduction in the size of maturity of female lobsters. This difference may also be due to sex-based differences in the timing and frequency of moulting.
3. Carapace length was also shown to increase with depth. This finding may be due to the behaviour of fishermen who, through their fishing practices, may be creating artificial refugia for lobsters. Given that fishers tend to move traps into

more shallow water as the season progresses and that lobsters don't have to move significant distances to change depth significantly; this may contribute to this fact.

4. Larval studies failed to discover the source of new recruits into the Bonne Bay lobster stock. This lack of larvae from such a large number of samples demonstrates that they are neither common nor abundant within Bonne Bay.
5. The implementation of and establishment of a "no-take" reserve in Trout River is a positive first step in the fight for the survival of this fishery. The Eastport project illustrates how extremely successful a co-management project such as the EPLPC can exist with strong support and from the fishers themselves. They must believe in the goals of the project and be fully participatory in working towards those goals and implementing the necessary rules and regulations.

Future scientific studies that should be considered include:

1. Carry out a tagging experiment whereby lobsters found within the bay and outside of the bay are tagged to study the movement/exchange of lobsters between the bay and outside areas. This will provide information on the movement of lobsters within the area and provide further insight into stock structure and sustainability.

2. Complete a concurrent tagging study on the vertical movement of lobsters within the bay over the course of the year. Given that very little is known about the behavior of lobsters at the bottom of their vertical range, this will provide further evidence on the behavioural and structural differences within this stock throughout its habitat in the bay.

3. Complete a trap survey of lobster specifically to study molting behaviour within Bonne Bay. This study will provide valuable information regarding timing of molting in both sexes. This knowledge will aid future studies both in the timing of research and understanding of the data gathered.

4. Further vertical plankton tows should be carried out inside and outside of the bay. This modification should reveal more information regarding the larval and postlarval movements of *Homarus americanus* in relation to the water circulation within Bonne Bay and offer clues to the source of new recruits into this population.

5. Further plankton tows should be carried out outside of the bay, to the north and south to determine if lobster larvae are present in the surface waters in these areas. This may support the hypothesis that the strong flushing of the surface waters of Bonne Bay are removing larvae that are carried into the bay, as well as, those that are produced locally within the bay.

4. Overall Findings and Conclusions

4.1 The Current State of West Coast and Bonne Bay Fisheries

Throughout Newfoundland, the American lobster is subjected to intense exploitation with the bulk of annual landings comprised of animals that reached commercial size during the previous year. In recent years, landings have been declining in many areas, for much longer and more severely in some than in others (Ennis et al. 1997). Ennis *et al.* (1997) believe that unless the levels of exploitation are reduced, landings will be lower, less stable, and could decline even lower. This research supports the hypothesis that the Bonne Bay stock potentially faces this pessimistic outlook for the future if no changes occur in the management of this fishery.

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Appendix A -Interview Schedule

Part A - Ethics:

- Go over the consent form and archival deposit form reading/explaining what each paragraph means. Ask if they would like someone to go over the form with them. If they indicate yes, and there is a third party present, have them read it. If there is no third party present then read the form out to them carefully pausing frequently to ensure that they have understood each section.

- Explain that participation in the interview is completely voluntary, that it will be taped with their permission but that they can turn off the tape at any time and they will decide what happens to the tape, typed transcript and chart from the interview

- Ask them to sign in appropriate places and check off appropriate selections for deposit. Signature indicates that he/she understands what the research is about, understands that it is completely voluntary, and consents to being interviewed. Interviewer also signs on behalf of Memorial University. Leave a copy of signed consent form and archival deposit form with them.

Part B - Demographics:

For this first part of the interview, we will ask some general background questions regarding age, background in the fishery, education, 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, or other

   ____

8) Occupation ________________________________
9) Spouse's occupation ________________________
10) No. of children _____________
11) Do any of your children fish for a living? Yes ________ No ________ If yes, how many? ________
12) Would you/ are you encouraging any of your children to fish for a living Yes ______ No _______
13) Your education level < Grade 8 Grades 9-11 Graduated High School (circle)
14) Post-secondary Training? Describe

   ____

Part C - Fishing Experience:

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, etc. and about who you have fished with.

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

2) Always based in this community? Yes _____ No ______

If no, explain: ____

3) Age when you started fishing? ______

4) Location where you first fished _______________

5) Sectors in which you have fished? inshore/longliner/offshore

6) Any gaps in fishing career? Yes ______ No _____

If yes, when?___________ How long? __________

7) Last season fished ________

8) Who did you fish with when you started? _________________

9) Who taught you how to fish? _________________

10) Are you currently Skipper? _________ Crew? _________

11) Any formal training in fishing? Yes ______ No __________

If yes, what training?____

Vessel History:

The next section of the interview reviews your fishing career starting with details about the first fishing vessel you skippered in your lifetime, what you fished for, gear, fishing locations, etc.. It then asks you questions about your fishery in mid career, and finally your current/last vessel and fishing situation.

1) What was the vessel length & tonnage?
2) What material was the boat built out of?
3) What was the engine type?
4) How many horsepower did it have?
5) Did you use a fish finder/sounder?
6) Did you use a compass or other navigational equipment (GPS)?
7) Did you use a radio?
8) Did you have any other boats at the same time as this boat that you used for fishing?
9) Which was the primary boat?
10) Was there a division of labour between the two boats?
11) What licenses were held when fishing from this boat/species fished?
12) Gear Used for each species--# pots/nets/traps, type, mesh size, distance around, depth, how were each set?

Determining CPUE for beginning of career:

- Ask about the following related about catches:
  - Determine the differences between bad day, good day, and average day with regards to specific gear type, species and location
  - OR what would be considered a good season
  - Trends over time with species landings due to gear changes or changes in season length or over-exploitation
  - Did you experience by-catch

↓

- Ask about the following questions related to effort:
  - Length of the season & number of seasons they fished
  - Type and amount of gear used (depends on the season)
  - At what depth were nets, traps, and line sets deployed
  - Amount fished per year, (determine trap number, gill nets used, mesh size, gear type and design, and number of areas fished, etc.)
  - Determine changes in the types of gear used
  - Use of haulers, did they increase the amount of fish you landed or how fast you fished
  - Use of sounders and their effect
  - Amount of Horsepower that was found on the vessel
  - Ask about the size of the boat and capacity of the boat

REPEAT these questions for mid career and current vessels/gear/species/grounds

Part D - End of Interview Questions:

- Do you have any personal observations on changes or trends in the stocks you fished over the course of your career (i.e. fished out, declining, increasing, environmental problems, etc.)?
- Do you have any personal observations on changes or trends in the size of individuals caught in the stocks you fished over the course of your career (i.e. declining size, increasing size, no change)?
- What was the cause of changes in vessel/gear over time? Ask them to discuss changes—when, why, consequences of changes for their enterprise? Did these changes have any affect on others in community? On the fish stocks/environment?
- Where there were changes in location/depth of where they fished for species over time, ask them to discuss that shift—when, why, how done, consequences for them? Did these changes have any affect on the environment?
- What, in your view, are the things that put fish stocks at risk in this area? Does it vary from fishery to fishery?
- What, in your view, are the things that put fishermen at risk in this area? Does this vary from fishery to fishery?
- Do you have any recommendations you would like to make regarding changes in fisheries science? Fisheries management? Fishing vessel safety?, etc. that you think would promote the health of fish stocks? The long term incomes, employment and health of fish harvesters?
- If there were changes in the species targeted over time, ask them to discuss that shift—when happened, why, etc.?

Appendix B – Lobster Census Data

Female			
CL (cm)	CL (mm)	Depth (m)	Location
5.208	52.08	6	D
5.519	55.19	6	L
5.828	58.280	6	G
5.833	58.33	6	K
5.931	59.31	6	G
5.932	59.32	20	J
5.933	59.330	6	D
5.935	59.35	6	G
5.937	59.370	6	D
6.248	62.48	6	A
6.248	62.48	20	I
6.351	63.51	6	H
6.351	63.51	6	L
6.453	64.53	6	D
6.453	64.53	20	H
6.454	64.54	20	B
6.557	65.57	6	D
6.557	65.57	6	J
6.557	65.57	6	L
6.559	65.59	6	I
6.561	65.610	6	E
6.561	65.610	6	H
6.662	66.62	6	F
6.664	66.64	6	I
6.666	66.66	6	I
6.764	67.64	6	I
6.764	67.64	6	K
6.765	67.65	6	C
6.765	67.65	6	G
6.765	67.65	6	I
6.766	67.66	6	D
6.766	67.66	20	I
6.766	67.66	6	K
6.767	67.67	20	I

6.768	67.68	6	K
6.868	68.68	20	D
6.869	68.69	6	G
6.869	68.69	20	K
6.87	68.7	20	B
6.870	68.700	20	I
6.871	68.71	6	I
6.871	68.71	6	L
6.973	69.73	6	D
6.973	69.73	20	H
6.974	69.74	6	C
6.974	69.74	6	H
6.974	69.740	6	I
6.974	69.74	6	I
6.974	69.74	6	K
6.975	69.750	6	G
6.975	69.75	6	I
6.975	69.75	6	L
7.076	70.760	6	I
7.077	70.770	6	G
7.078	70.78	20	B
7.078	70.78	6	D
7.078	70.78	6	I
7.079	70.790	20	H
7.079	70.79	6	K
7.080	70.800	6	K
7.100	71.000	6	I
7.179	71.790	6	D
7.179	71.79	20	E
7.180	71.800	6	E
7.180	71.800	20	I
7.180	71.800	6	K

7.181	71.81	6	D
7.181	71.810	6	D
7.181	71.81	6	F
7.182	71.82	6	D
7.183	71.83	6	L
7.184	71.84	20	C
7.184	71.840	6	I
7.184	71.84	20	L
7.284	72.84	6	G
7.284	72.84	6	I
7.285	72.850	20	D
7.285	72.85	6	G
7.285	72.85	6	G
7.285	72.85	20	I
7.286	72.86	20	E
7.286	72.86	6	I
7.287	72.87	20	D
7.287	72.87	20	F
7.287	72.87	20	K
7.287	72.87	20	K
7.288	72.88	6	E
7.288	72.88	20	I
7.289	72.89	20	I
7.328	73.28	6	G
7.388	73.88	6	E
7.390	73.900	6	H
7.390	73.900	20	K
7.391	73.91	6	C
7.391	73.91	6	G
7.392	73.92	6	C
7.398	73.98	6	H
7.482	74.82	6	E

7.490	74.900	6	D
7.491	74.91	20	E
7.492	74.92	6	A
7.492	74.92	6	I
7.493	74.93	6	E
7.493	74.93	6	H
7.493	74.93	6	I
7.494	74.94	20	B
7.494	74.940	6	D
7.494	74.94	20	D
7.494	74.94	6	H
7.494	74.94	6	I
7.494	74.94	20	I
7.494	74.94	20	I
7.495	74.95	6	C
7.595	75.95	20	E
7.595	75.950	6	G
7.595	75.95	6	I
7.596	75.96	6	F
7.596	75.96	6	K
7.597	75.970	6	D
7.597	75.97	20	E
7.597	75.97	20	G
7.597	75.97	6	J
7.597	75.97	20	K
7.597	75.97	20	L
7.598	75.98	6	C
7.598	75.98	6	E
7.598	75.980	6	E
7.598	75.98	6	G
7.598	75.98	20	G
7.598	75.98	6	H

7.598	75.98	6	K
7.600	76.000	20	L
7.601	76.01	20	E
7.601	76.01	20	H
7.601	76.010	20	H
7.601	76.01	6	K
7.601	76.01	20	K
7.602	76.02	20	B
7.602	76.02	6	I
7.602	76.02	6	K
7.602	76.02	6	L
7.697	76.970	20	I
7.698	76.98	6	D
7.699	76.99	20	C
7.699	76.99	6	D
7.699	76.990	6	D
7.699	76.99	6	D
7.699	76.99	6	H
7.699	76.99	6	H
7.702	77.02	20	B
7.702	77.02	6	D
7.703	77.030	20	D
7.703	77.03	6	F
7.703	77.03	6	F
7.704	77.04	20	B
7.704	77.04	6	C
7.704	77.04	6	D
7.704	77.040	20	G
7.704	77.04	6	I
7.704	77.04	6	J
7.705	77.050	20	I
7.705	77.05	20	J

7.706	77.06	6	H
7.706	77.06	20	K
7.709	77.090	20	D
7.798	77.980	20	G
7.803	78.03	20	G
7.806	78.06	6	D
7.807	78.07	6	H
7.807	78.07	6	H
7.807	78.07	20	H
7.807	78.07	20	H
7.807	78.070	6	I
7.807	78.070	20	I
7.808	78.08	6	C
7.808	78.08	6	E
7.808	78.080	20	G
7.808	78.08	20	H
7.808	78.08	6	K
7.809	78.09	6	F
7.809	78.09	6	G
7.809	78.09	6	H
7.810	78.100	6	C
7.810	78.100	6	F
7.810	78.100	6	I
7.810	78.100	6	I
7.810	78.100	6	J
7.810	78.100	6	J
7.810	78.100	6	J
7.810	78.100	6	K
7.810	78.100	6	K
7.811	78.11	6	D
7.811	78.110	6	H
7.812	78.120	6	F

7.901	79.01	6	C
7.905	79.050	20	E
7.910	79.100	20	H
7.911	79.11	20	D
7.911	79.110	6	I
7.911	79.110	6	I
7.911	79.11	6	K
7.912	79.12	20	B
7.912	79.120	6	D
7.912	79.120	6	D
7.912	79.120	6	D
7.912	79.12	6	G
7.912	79.12	6	I
7.912	79.12	20	K
7.912	79.12	6	L
7.912	79.12	6	L
7.912	79.12	6	L
7.912	79.12	6	L
7.913	79.13	6	C
7.913	79.13	6	E
7.913	79.130	6	G
7.913	79.13	6	I
7.913	79.13	6	K
7.913	79.13	6	L
7.914	79.14	6	C
7.914	79.14	6	I
7.914	79.14	6	L
7.915	79.15	6	K
8.011	80.11	6	J
8.014	80.140	6	H
8.014	80.14	6	I
8.014	80.14	20	I

8.015	80.15	6	A
8.015	80.15	20	B
8.015	80.15	20	E
8.015	80.15	20	I
8.015	80.15	6	K
8.015	80.15	20	K
8.015	80.15	6	L
8.016	80.16	6	G
8.016	80.16	20	H
8.016	80.16	6	J
8.016	80.16	6	L
8.017	80.17	6	E
8.017	80.17	6	K
8.018	80.18	20	F
8.018	80.18	20	J
8.018	80.18	6	L
8.019	80.19	20	I
8.117	81.17	20	F
8.118	81.180	6	D
8.118	81.18	6	D
8.118	81.18	20	E
8.118	81.18	20	I
8.119	81.19	6	A
8.119	81.19	6	F
8.119	81.19	6	G
8.119	81.19	6	H
8.119	81.19	20	I
8.12	81.2	6	E
8.120	81.200	6	G
8.120	81.200	6	G
8.120	81.200	20	G
8.12	81.2	6	H

8.120	81.200	6	H
8.120	81.200	6	I
8.12	81.2	20	J
8.121	81.210	6	E
8.121	81.21	6	F
8.121	81.21	20	K
8.122	81.22	20	B
8.122	81.22	20	B
8.122	81.22	6	H
8.122	81.22	6	K
8.123	81.23	6	C
8.123	81.23	6	J
8.123	81.23	20	J
8.123	81.23	20	J
8.123	81.23	6	K
8.222	82.22	20	B
8.222	82.220	20	D
8.222	82.22	20	D
8.222	82.220	6	E
8.222	82.22	20	F
8.222	82.22	6	I
8.223	82.23	6	E
8.224	82.24	20	C
8.224	82.24	6	D
8.224	82.24	20	E
8.224	82.240	6	G
8.224	82.24	6	G
8.224	82.24	6	H
8.224	82.24	6	I
8.224	82.24	6	I
8.225	82.25	20	B
8.226	82.26	20	A

8.226	82.26	20	G
8.226	82.26	6	H
8.226	82.26	6	A
8.226	82.26	6	K
8.227	82.270	6	F
8.319	83.190	6	F
8.323	83.23	6	F
8.326	83.26	6	J
8.328	83.28	6	D
8.328	83.28	6	D
8.328	83.28	6	H
8.328	83.28	20	H
8.328	83.28	6	J
8.329	83.29	20	A
8.329	83.29	20	I
8.329	83.29	6	K
8.331	83.310	6	F
8.428	84.280	6	H
8.430	84.300	6	G
8.430	84.300	20	L
8.432	84.32	6	G
8.432	84.32	20	H
8.433	84.33	20	E
8.532	85.32	20	F
8.533	85.33	20	D
8.534	85.34	20	B
8.534	85.34	20	B
8.534	85.34	6	D
8.534	85.34	20	G
8.535	85.35	6	D
8.535	85.35	6	D
8.535	85.35	20	E

8.535	85.35	20	L
8.536	85.36	6	I
8.536	85.36	20	L
8.637	86.37	6	F
8.638	86.38	6	I
8.639	86.39	20	B
8.639	86.39	20	G
8.639	86.39	20	K
8.640	86.400	6	E
8.64	86.4	6	G
8.640	86.400	6	G
8.640	86.400	20	H
8.643	86.43	20	H
8.705	87.05	6	C
8.732	87.32	6	G
8.737	87.370	6	G
8.740	87.400	6	G
8.742	87.42	20	I
8.743	87.43	20	D

8.743	87.43	6	H
8.743	87.43	6	I
8.744	87.44	6	D
8.745	87.45	6	C
8.745	87.450	20	D
8.746	87.46	20	J
8.748	87.48	20	H
8.847	88.47	6	D
8.847	88.470	6	F
8.848	88.48	20	B
8.848	88.48	6	D
8.849	88.49	6	F

8.849	88.49	6	K
8.850	88.500	20	K
8.852	88.520	20	E
8.946	89.460	6	F
8.951	89.51	20	J
8.952	89.52	20	A
8.952	89.520	20	F
8.953	89.53	6	I
8.957	89.57	6	F
9.054	90.54	20	B
9.054	90.54	6	H
9.055	90.55	20	J
9.056	90.56	6	L
9.057	90.57	6	I
9.058	90.58	20	B
9.059	90.59	6	J
9.157	91.57	6	E
9.159	91.59	20	E
9.264	92.64	20	B
9.265	92.65	20	K
9.369	93.69	20	K
9.432	94.32	6	F
9.465	94.650	20	F
9.471	94.71	6	D
9.471	94.71	20	D
9.471	94.71	20	J
9.472	94.72	20	D
9.473	94.73	20	B
9.474	94.74	20	B
9.578	95.78	20	K
9.678	96.78	20	D

9.810	98.100	20	K
9.991	99.91	6	A
10.095	100.95	6	E
10.095	100.95	20	L
10.197	101.97	6	D
10.202	102.02	6	J
10.203	102.03	6	I
11.032	110.32	6	I

Male			
CL (cm)	CL (mm)	Depth (m)	Location
5.414	54.14	6	H
5.831	58.310	6	I
6.245	62.450	6	E
6.246	62.46	6	K
6.348	63.48	6	D
6.349	63.49	6	D
6.350	63.500	6	K
6.351	63.510	6	H
6.351	63.51	6	J
6.453	64.53	6	J
6.453	64.53	6	L
6.454	64.54	6	B
6.455	64.55	6	C
6.455	64.55	6	E
6.555	65.550	6	H
6.557	65.57	6	E
6.558	65.58	6	E
6.558	65.58	6	E
6.559	65.590	20	E
6.559	65.59	6	K
6.56	65.6	6	F
6.560	65.600	6	K
6.659	66.590	6	E
6.659	66.590	6	G
6.660	66.600	20	D
6.662	66.62	6	I
6.663	66.630	6	D
6.761	67.61	6	A
6.766	67.66	20	H
6.767	67.67	6	J
6.767	67.67	6	J
6.768	67.68	6	C
6.868	68.680	6	G
6.869	68.69	6	G

6.869	68.69	6	K
6.869	68.69	6	K
6.871	68.71	6	G
6.871	68.71	6	G
6.871	68.71	6	L
6.972	69.72	6	L
6.973	69.73	6	K
6.974	69.74	6	B
6.974	69.74	6	I
6.974	69.74	20	I
6.974	69.74	20	L
6.975	69.75	6	I
6.976	69.76	20	C
7.076	70.760	6	H
7.077	70.77	20	B
7.078	70.78	6	B
7.078	70.78	20	G
7.078	70.78	6	K
7.078	70.78	6	L
7.079	70.790	6	D
7.088	70.88	20	B
7.089	70.89	20	C
7.180	71.800	20	F
7.18	71.8	6	G
7.181	71.810	20	F
7.182	71.82	6	K
7.183	71.83	6	C
7.183	71.83	6	C
7.183	71.83	20	D
7.183	71.83	6	F
7.184	71.840	6	E
7.184	71.840	20	F
7.184	71.84	6	I

7.184	71.84	6	K
7.184	71.84	6	K
7.279	72.790	6	E
7.282	72.82	20	F
7.284	72.84	20	B
7.284	72.84	6	F
7.284	72.840	6	I
7.284	72.84	20	I
7.285	72.85	6	F
7.285	72.85	6	F
7.285	72.85	6	H
7.286	72.86	6	E
7.286	72.86	6	L
7.287	72.87	6	C
7.287	72.870	6	G
7.287	72.87	20	H
7.287	72.87	20	I
7.288	72.88	6	B
7.288	72.880	6	F
7.288	72.88	6	J
7.387	73.87	6	K
7.388	73.88	20	D
7.389	73.89	20	H
7.389	73.89	6	K
7.390	73.900	20	J
7.391	73.91	6	H
7.391	73.91	20	J
7.392	73.92	6	I
7.491	74.91	20	F
7.491	74.910	6	I
7.492	74.92	20	A
7.492	74.92	6	H
7.492	74.92	6	J

7.492	74.92	6	K
7.492	74.92	6	K
7.493	74.93	6	C
7.493	74.930	20	E
7.493	74.93	6	K
7.494	74.94	6	A
7.494	74.94	6	C
7.494	74.94	20	C
7.494	74.94	6	E
7.494	74.940	20	G
7.494	74.94	20	G
7.494	74.94	6	H
7.494	74.94	6	I
7.494	74.94	6	J
7.495	74.95	6	F
7.495	74.95	20	L
7.497	74.970	6	F
7.499	74.990	6	F
7.590	75.900	20	F
7.593	75.930	6	G
7.595	75.95	20	E
7.595	75.950	20	G
7.595	75.95	6	K
7.596	75.96	20	D
7.596	75.96	20	D
7.596	75.96	20	E
7.596	75.96	6	F
7.597	75.97	20	B
7.598	75.98	6	E
7.598	76.02	20	E
7.598	75.98	6	F
7.598	75.98	6	I
7.598	75.98	6	I

7.598	75.98	20	L
7.599	75.99	20	I
7.600	76.000	20	B
7.600	76.000	6	C
7.600	76.000	6	F
7.600	76.000	20	I
7.600	76.000	6	K
7.601	76.01	20	A
7.601	76.01	6	G
7.601	76.01	20	I
7.601	76.01	6	J
7.601	76.01	6	J
7.601	76.01	6	K
7.601	76.01	20	L
7.602	76.02	20	C
7.602	76.02	20	E
7.603	76.03	6	K
7.603	76.03	20	K
7.677	76.77	6	K
7.679	76.79	6	G
7.698	76.980	20	I
7.699	76.99	6	A
7.699	76.99	20	C
7.699	76.990	20	E
7.699	76.99	20	F
7.699	76.99	6	G
7.699	76.99	6	I
7.699	76.99	6	K
7.699	76.99	6	L
7.702	77.02	6	I
7.703	77.030	6	D
7.703	77.03	20	G
7.704	77.040	6	D

7.704	77.04	6	F
7.704	77.04	6	H
7.704	77.04	6	L
7.704	77.04	20	L
7.705	77.05	6	A
7.705	77.05	6	A
7.705	77.05	6	B
7.705	77.05	20	B
7.705	77.05	6	C
7.705	77.050	6	E
7.705	77.050	6	F
7.705	77.05	20	G
7.705	77.05	6	I
7.705	77.05	20	J
7.705	77.05	6	K
7.706	77.06	20	A
7.706	77.06	6	C
7.706	77.06	6	D
7.706	77.06	6	G
7.706	77.06	6	G
7.706	77.06	20	K
7.706	77.06	6	L
7.801	78.010	6	E
7.801	78.01	6	L
7.804	78.04	20	E
7.804	78.04	20	L
7.805	78.05	6	B
7.805	78.05	6	H
7.805	78.05	20	H
7.806	78.060	6	D
7.806	78.060	20	E
7.806	78.060	6	H
7.806	78.06	6	I

7.807	78.07	6	A
7.807	78.07	20	L
7.808	78.08	6	A
7.808	78.08	6	C
7.808	78.08	6	D
7.808	78.08	20	D
7.808	78.08	6	F
7.808	78.08	20	F
7.808	78.08	20	F
7.809	78.09	6	D
7.809	78.090	20	I
7.809	78.09	20	J
7.809	78.09	20	J
7.809	78.09	20	L
7.810	78.100	6	A
7.810	78.100	20	H
7.810	78.100	6	K
7.811	78.110	6	E
7.817	78.17	6	L
7.909	79.09	20	G
7.91	79.1	6	K
7.910	79.100	20	K
7.911	79.11	6	B
7.911	79.11	6	C
7.911	79.110	6	F
7.911	79.11	20	G
7.911	79.11	6	I
7.911	79.11	6	K
7.912	79.12	6	A
7.912	79.12	6	A
7.912	79.12	6	E
7.912	79.120	20	F
7.912	79.100	6	G

7.912	79.12	6	G
7.912	79.120	20	G
7.912	79.120	20	G
7.912	79.12	6	J
7.912	79.12	20	J
7.912	79.12	6	K
7.913	79.13	6	I
7.913	79.13	20	J
7.914	79.14	6	F
7.914	79.14	20	G
7.914	79.14	6	L
7.915	79.15	6	K
7.992	79.92	6	K
7.994	79.94	6	J
8.012	80.12	20	F
8.012	80.12	20	G
8.013	80.13	20	L
8.014	80.14	6	F
8.014	80.14	6	H
8.015	80.15	6	A
8.015	80.15	6	D
8.015	80.150	6	H
8.015	80.150	6	I
8.015	80.15	6	K
8.015	80.15	6	K
8.015	80.15	6	K
8.015	80.15	6	K
8.015	80.15	20	L
8.016	80.16	6	C
8.016	80.16	20	E
8.016	80.16	6	I
8.016	80.16	6	K
8.016	80.16	6	L

8.016	80.16	6	L
8.017	80.17	20	C
8.017	80.17	6	K
8.017	80.17	6	L
8.018	80.18	6	A
8.018	80.18	20	F
8.018	80.18	20	K
8.019	80.19	6	K
8.111	81.11	6	I
8.116	81.16	6	K
8.117	81.17	6	E
8.117	81.170	6	G
8.117	81.17	6	I
8.118	81.18	6	B
8.118	81.18	6	E
8.118	81.18	20	I
8.119	81.19	20	C
8.119	81.19	6	F
8.119	81.190	6	G
8.119	81.19	20	K
8.120	81.200	6	K
8.12	81.2	6	L
8.121	81.21	6	A
8.121	81.21	6	B
8.121	81.21	6	D
8.121	81.210	6	G
8.121	81.21	6	G
8.121	81.21	20	H
8.121	81.21	20	I
8.121	81.21	6	K
8.121	81.21	20	K
8.122	81.22	6	A
8.122	81.22	6	A

8.122	81.22	6	G
8.123	81.23	20	A
8.123	81.23	20	D
8.123	81.23	6	E
8.123	81.23	6	E
8.126	81.260	20	D
8.150	81.500	20	F
8.219	82.19	20	G
8.220	82.200	6	F
8.221	82.21	20	D
8.223	82.230	6	D
8.223	82.23	20	F
8.223	82.23	20	H
8.223	82.23	6	L
8.224	82.24	20	A
8.224	82.24	20	C
8.224	82.24	20	F
8.224	82.24	6	G
8.224	82.24	20	G
8.224	82.24	20	H
8.224	82.24	6	K
8.224	82.24	6	K
8.225	82.25	6	E
8.225	82.25	6	F
8.225	82.25	6	H
8.226	82.26	6	E
8.226	82.26	20	G
8.226	82.26	6	K
8.226	82.26	6	K
8.226	82.26	6	L
8.227	82.270	20	H
8.227	82.27	20	L
8.23	82.3	6	B

8.326	83.26	20	A
8.326	83.26	6	K
8.327	83.27	20	A
8.327	83.27	6	D
8.327	83.27	20	D
8.327	83.27	20	E
8.327	83.27	20	F
8.327	83.270	6	G
8.327	83.27	20	G
8.327	83.27	6	K
8.328	83.28	6	C
8.328	83.28	20	G
8.328	83.28	20	H
8.328	83.28	20	H
8.328	83.28	20	H
8.328	83.28	6	I
8.329	83.29	6	K
8.330	83.300	20	C
8.330	83.300	6	J
8.330	83.300	6	L
8.331	83.31	6	F
8.370	83.700	6	E
8.425	84.250	20	F
8.427	84.27	6	E
8.428	84.28	20	F
8.429	84.29	20	G
8.43	84.3	6	F
8.430	84.300	6	F
8.43	84.3	6	G
8.430	84.300	6	I
8.430	84.300	6	L
8.431	84.31	6	C
8.431	84.31	6	D

8.431	84.31	6	E
8.431	84.310	6	F
8.431	84.310	20	F
8.431	84.310	6	G
8.431	84.31	20	G
8.431	84.31	20	G
8.431	84.31	20	G
8.431	84.31	6	I
8.431	84.31	20	J
8.431	84.31	6	K
8.431	84.31	6	K
8.431	84.31	20	L
8.432	84.32	20	G
8.432	84.32	6	I
8.432	84.32	6	J
8.432	84.32	20	J
8.432	84.32	6	L
8.433	84.33	6	A
8.433	84.33	6	C
8.433	84.33	20	C
8.433	84.33	6	D
8.433	84.33	6	F
8.433	84.33	6	F
8.433	84.33	6	F
8.433	84.33	6	L
8.434	84.34	20	F
8.434	84.34	6	K
8.434	84.34	6	K
8.434	84.34	6	L
8.435	84.35	6	H
8.435	84.35	20	I
8.435	84.35	20	K
8.533	85.330	6	G
8.534	85.34	6	D

8.534	85.340	6	H
8.534	85.34	6	L
8.534	85.34	20	L
8.535	85.35	20	K
8.535	85.35	6	L
8.536	85.36	6	B
8.536	85.36	6	B
8.536	85.36	6	C
8.536	85.360	20	E
8.536	85.360	6	G
8.536	85.36	6	L
8.537	85.37	20	B
8.537	85.37	6	E
8.537	85.37	20	E
8.538	85.38	20	A
8.538	85.38	6	B
8.538	85.38	20	C
8.538	85.38	6	F
8.538	85.38	20	F
8.538	85.38	20	I
8.538	85.38	20	K
8.538	85.38	6	L
8.540	85.400	6	I
8.590	85.900	6	F
8.635	86.350	6	E
8.638	86.38	20	C
8.638	86.38	20	I
8.639	86.39	20	A
8.639	86.39	6	B
8.639	86.39	20	B
8.639	86.39	20	D
8.639	86.39	6	K
8.639	86.39	6	K

8.639	86.39	20	K
8.639	86.39	6	L
8.639	86.99	6	L
8.640	86.400	6	G
8.64	86.4	6	H
8.640	86.400	20	I
8.641	86.41	20	B
8.641	86.41	6	C
8.641	86.41	6	C
8.641	86.41	6	C
8.641	86.41	6	G
8.641	86.41	6	L
8.641	86.41	20	L
8.642	86.42	6	A
8.642	86.42	20	I
8.643	86.43	20	B
8.644	86.44	20	D
8.645	86.450	6	E
8.739	87.39	6	E
8.740	87.400	6	G
8.742	87.420	6	D
8.742	87.420	6	G
8.743	87.43	6	C
8.743	87.43	20	K
8.743	87.43	6	L
8.744	87.44	6	A
8.744	87.44	20	A
8.744	87.44	20	A
8.744	87.440	6	D
8.744	87.44	20	F
8.744	87.44	20	G
8.744	87.44	6	I
8.744	87.44	20	K

8.744	87.44	6	L
8.745	87.45	20	A
8.745	87.45	6	B
8.745	87.45	6	B
8.745	87.45	6	C
8.745	87.45	6	C
8.745	87.45	6	K
8.746	87.46	20	A
8.746	87.46	20	A
8.746	87.46	6	C
8.746	87.46	20	C
8.746	87.460	6	E
8.746	87.46	20	J
8.746	87.46	20	K
8.747	87.470	6	E
8.748	87.48	20	I
8.843	88.43	6	E
8.844	88.44	6	D
8.846	88.460	6	D
8.847	88.47	6	A
8.847	88.470	6	D
8.847	88.47	6	K
8.848	88.48	6	A
8.848	88.48	20	C
8.848	88.48	6	D
8.848	88.48	6	J
8.848	88.48	6	L
8.849	88.49	6	B
8.849	88.49	20	B
8.849	88.49	6	I
8.849	88.49	6	J
8.849	88.49	20	J
8.849	88.49	6	K

8.744	87.44	6	L
8.745	87.45	20	A
8.745	87.45	6	B
8.745	87.45	6	B
8.745	87.45	6	C
8.745	87.45	6	C
8.745	87.45	6	K
8.746	87.46	20	A
8.746	87.46	20	A
8.746	87.46	6	C
8.746	87.46	20	C
8.746	87.460	6	E
8.746	87.46	20	J
8.746	87.46	20	K
8.747	87.470	6	E
8.748	87.48	20	I
8.843	88.43	6	E
8.844	88.44	6	D
8.846	88.460	6	D
8.847	88.47	6	A
8.847	88.470	6	D
8.847	88.47	6	K
8.848	88.48	6	A
8.848	88.48	20	C
8.848	88.48	6	D
8.848	88.48	6	J
8.848	88.48	6	L
8.849	88.49	6	B
8.849	88.49	20	B
8.849	88.49	6	I
8.849	88.49	6	J
8.849	88.49	20	J
8.849	88.49	6	K

8.849	88.49	6	K
8.849	88.49	20	K
8.849	88.49	20	L
8.850	88.500	6	G
8.850	88.500	20	K
8.850	88.500	6	L
8.850	88.500	20	L
8.851	88.51	6	A
8.851	88.51	6	F
8.851	88.51	6	I
8.851	88.51	6	L
8.932	89.32	20	A
8.946	89.460	20	F
8.948	89.48	6	F
8.950	89.500	6	J
8.950	89.500	6	K
8.951	89.51	6	A
8.951	89.51	6	B
8.951	89.51	20	B
8.951	89.510	20	D
8.951	89.51	6	I
8.951	89.51	20	I
8.951	89.51	6	K
8.951	89.51	6	K
8.952	89.52	20	B
8.952	89.520	6	F
8.952	89.52	6	L
8.953	89.530	6	I
8.954	89.54	6	A
8.954	89.54	6	A
8.954	89.54	20	A
8.954	89.54	20	A
8.954	89.54	6	B

8.954	89.54	20	E
8.954	89.540	6	G
8.955	89.55	6	H
8.957	89.570	20	G
8.960	89.600	20	F
9.054	90.54	20	C
9.054	90.54	6	E
9.054	90.54	20	E
9.054	90.54	6	I
9.054	90.54	20	J
9.055	90.55	20	A
9.055	90.55	6	D
9.055	90.55	6	D
9.055	90.55	20	D
9.055	90.55	6	F
9.055	90.55	20	G
9.055	90.55	6	H
9.055	90.55	6	L
9.056	90.56	6	A
9.056	90.56	6	C
9.056	90.56	20	G
9.056	90.560	6	H
9.056	90.56	6	J
9.057	90.57	6	A
9.057	90.57	20	C
9.057	90.57	6	H
9.057	90.57	20	H
9.057	90.57	6	J
9.058	90.58	6	A
9.058	90.58	20	E
9.058	90.58	20	L
9.059	90.59	6	A
9.059	90.59	6	C

9.059	90.59	20	K
9.067	90.67	6	L
9.158	91.580	20	F
9.158	91.58	6	K
9.159	91.59	6	A
9.159	91.59	20	A
9.159	91.59	20	B
9.159	91.59	6	C
9.159	91.59	6	C
9.159	91.590	20	E
9.159	91.59	20	F
9.159	91.590	6	G
9.159	91.590	20	G
9.159	91.59	20	H
9.159	91.59	6	K
9.159	91.59	20	K
9.160	91.600	20	E
9.160	91.600	20	I
9.160	91.600	6	L
9.161	91.61	20	A
9.161	91.61	6	C
9.161	91.61	20	C
9.161	91.61	20	C
9.161	91.61	6	F
9.161	91.61	6	G
9.161	91.61	6	I
9.161	91.61	6	K
9.162	91.62	6	E
9.162	91.620	20	F
9.162	91.620	6	G
9.163	91.63	20	J
9.164	91.64	6	A
9.165	91.650	6	E

9.166	91.660	20	F
9.184	91.84	6	L
9.260	92.600	6	F
9.261	92.61	20	B
9.262	92.620	20	F
9.262	92.62	20	K
9.263	92.63	20	B
9.263	92.63	6	H
9.264	92.64	6	A
9.264	92.64	6	A
9.264	92.64	6	C
9.264	92.64	20	E
9.264	92.64	6	F
9.264	92.64	6	I
9.264	92.64	6	L
9.264	92.64	6	L
9.265	92.65	20	F
9.265	92.650	6	G
9.265	92.65	20	J
9.265	92.65	6	K
9.266	92.66	20	A
9.266	92.66	6	B
9.266	92.66	6	E
9.266	92.66	20	H
9.266	92.66	6	J
9.267	92.67	6	A
9.267	92.67	20	B
9.267	92.670	6	F
9.267	92.670	6	G
9.267	92.67	20	I
9.267	92.67	6	K
9.268	92.68	20	G
9.268	92.68	6	J

9.271	92.710	6	E
9.354	93.54	20	E
9.362	93.62	6	A
9.363	93.630	6	F
9.364	93.64	6	E
9.366	93.66	20	F
9.366	93.66	20	H
9.366	93.66	6	K
9.367	93.67	20	A
9.367	93.67	6	B
9.367	93.67	20	I
9.368	93.68	6	A
9.368	93.68	20	A
9.368	93.68	20	B
9.368	93.68	6	C
9.368	93.68	6	C
9.368	93.68	20	D
9.368	93.68	20	E
9.368	93.68	20	H
9.369	93.69	6	A
9.369	93.69	6	A
9.369	93.69	6	A
9.369	93.69	6	B
9.369	93.69	20	C
9.369	93.69	20	D
9.369	93.69	20	G
9.369	93.69	20	L
9.370	93.700	6	A
9.370	93.700	20	A
9.370	93.700	6	C
9.370	93.700	20	C
9.37	93.7	6	H
9.370	93.700	20	J

9.370	93.700	6	K
9.370	93.700	20	L
9.371	93.71	20	E
9.467	94.670	6	E
9.470	94.700	6	L
9.470	94.700	6	A
9.471	94.71	6	A
9.471	94.71	6	B
9.471	94.71	6	C
9.471	94.71	20	D
9.471	94.71	20	G
9.471	94.71	6	K
9.471	94.71	20	K
9.471	94.71	20	K
9.472	94.72	6	A
9.472	94.72	20	B
9.473	94.73	6	B
9.473	94.73	6	F
9.474	94.74	20	G
9.474	94.74	20	K
9.475	94.750	20	G
9.477	94.770	6	E
9.574	95.74	6	A
9.574	95.74	6	B
9.574	95.740	20	D
9.574	95.74	6	E
9.574	95.74	20	E
9.574	95.74	20	E
9.574	95.74	6	G
9.575	95.75	6	A
9.575	95.75	6	A
9.575	95.75	20	A
9.575	95.75	20	A

9.575	95.75	6	G
9.575	95.75	6	J
9.575	95.75	6	L
9.576	95.76	6	A
9.576	95.76	20	D
9.576	95.76	6	E
9.576	95.76	20	J
9.576	95.76	6	K
9.576	95.76	20	K
9.576	95.76	20	K
9.576	95.76	20	L
9.577	95.77	6	A
9.577	95.77	6	B
9.577	95.77	20	D
9.578	95.78	6	C
9.578	95.78	6	K
9.657	96.570	20	F
9.673	96.730	6	F
9.677	96.77	20	G
9.678	96.78	6	B
9.678	96.78	6	F
9.678	96.78	20	H
9.679	96.79	6	A
9.679	96.79	20	A
9.679	86.79	20	B
9.679	96.79	6	E
9.679	96.79	6	K
9.679	96.79	6	L
9.680	96.800	20	A
9.680	96.800	20	A
9.680	96.800	6	H
9.680	96.800	20	K
9.681	96.81	6	A

9.681	96.81	6	I
9.681	96.81	20	I
9.681	96.81	6	K
9.682	96.82	20	B
9.682	96.820	6	G
9.682	96.82	20	H
9.683	96.83	20	A
9.683	96.83	6	B
9.683	96.83	6	I
9.783	97.83	20	G
9.783	97.83	6	I
9.783	97.83	20	K
9.784	97.84	6	B
9.784	97.84	6	D
9.784	97.84	6	F
9.784	97.84	20	F
9.784	97.84	20	K
9.785	97.850	20	F
9.785	97.85	20	I
9.884	98.84	20	F
9.884	98.84	20	H
9.885	98.850	20	H
9.886	98.86	6	J
9.887	98.87	6	A
9.887	98.87	20	H
9.888	98.88	6	A
9.889	98.890	20	E
9.889	98.890	20	F
9.971	99.71	6	A
9.988	99.88	20	B
9.991	99.91	20	K
9.991	99.91	20	L
9.993	99.93	20	K

10.092	100.92	20	L
10.095	100.95	6	A
10.095	100.95	20	G
10.193	101.93	20	A
10.197	101.97	6	H
10.198	101.98	20	A
10.201	102.01	20	J
10.202	102.02	20	J
10.304	103.04	6	J
10.516	105.16	20	K
10.618	106.18	20	A
10.721	107.210	20	E
11.032	110.32	6	F
11.969	119.69	20	A