A Biophysical Overview of

Leading Tickles, Notre Dame Bay

Prepared By

environmental research associates

Prepared For

Department of Fisheries & Oceans
NAFC, White Hills
St. John's, Newfoundland
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Acknowledgements

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1.0 Introduction

This report is review of biophysical information for the Leading Tickles, Notre Dame Bay, Newfoundland area. The Leading Tickles area has been nominated by local stakeholders and subsequently identified by the federal Department of Fisheries and Oceans as an Area of Interest (AOI) under the Marine Protected Areas (MPA) Program of the DFO's *Oceans Act*. The present review is intended to aid DFO and local stakeholders in further decision-making as to the eventual status of the area. The following sections contain background information on the MPA Program, the history of the Leading Tickles application, a review of physical (climate, oceanography, geology, ice) and biological (ecosystem, plankton, benthos, fish, seabirds, and marine mammals), including relevant habitat and life history information. The report concludes with some recommendations for future research.

1.1 Background Information

In 1997, Canada adopted the *Oceans Act* making the Minister of Fisheries and Oceans (DFO) the lead federal authority on all oceans related issues. This act enables the development of a comprehensive Oceans Management Strategy, which is based on three main principles: (1) sustainable development, (2) integrated management, and (3) the precautionary approach. This strategy is supported by three tools: (1) Integrated Management (IM), (2) Marine Environmental Quality (MEQ), and (3) MPAs.

The objective of the MPA Program is to conserve and protect areas and resources of special concern. Section 35 of the *Oceans Act* promotes the establishment of MPAs for the conservation and protection of marine resources, species, and habitats; endangered or threatened species and habitats; unique habitats, and areas of high biodiversity or biological productivity. Stakeholders such as coastal communities, environmental organizations, or any other individual or group can approach DFO to propose that an area be considered under the MPA Program. Following a preliminary review, the Minister may identify the proposed site as an AOI.

After a particular area is identified as an AOI, DFO has certain responsibilities to investigate its potential as a MPA in more detail. For a site to be designated as a MPA, it must undergo a critical evaluation process to ensure it meets the criteria of the *Oceans Act*, and the Department must demonstrate how the area will be managed as an MPA. One step in the evaluation of an AOI is the assessment of the area's biophysical characteristics.

Biophysical overviews such as the present document are an important component in the development of MPAs in the Newfoundland region. Biophysical overviews provide baseline information based on published and unpublished sources (such as field surveys, observations, etc.) that will help identify information gaps and guide future research. It is important that the biophysical overviews undertaken for different AOIs are consistent in level of effort and the types of information collected. These overviews can be updated periodically as new or more detailed information becomes available.

1.2 Leading Tickles AOI

The Leading Tickles AOI is located in Notre Dame Bay, just west of the Bay of Exploits and lies in the inshore region of the northeast (NE) Newfoundland Shelf, which extends from White Bay to western Bonavista Bay (Figures 1.1 and 1.2). The NE Newfoundland Shelf is an elongate, relatively narrow shelf of about 120,000 km^2 in area (Keen and Piper 1990).

The primary stakeholder(s) responsible for the nomination of this area was a committee comprised of local fishers from Leading Tickles and Glovers Harbour (Leading Tickles-Glovers Harbour Fisherpersons' Committee). The Town of Leading Tickles was also a sponsor. The proponents specifically recognized the need to conserve and protect local lobster stocks and their associated habitat, numerous capelin beaches in the area, areas identified as important Atlantic cod nursery areas, and habitat important to winter (blackback) flounder (J. Simms, DFO Oceans, pers. comm.). A 50 km^2 area with a boundary following the100 fathom contour was subsequently announced as an AOI in June 2001. There have been a number of reports that have summarized existing information for the study area of Leading Tickles (TLT and LT-GHFC 2000) and the NE Newfoundland shelf and coast (LeDrew-Fudge Associates--LFA 1990). It is not the intent of this document to repeat that material but rather highlight key points and to provide enhancements and updates where appropriate.

The Canadian Parks Service (CPS) conducted a study of what they termed the South Labrador Shelf Marine Region (Strait of Belle Isle to Cape Race), offshore to the 200 mile limit. This study (LFA 1990) reviewed existing information on biological, geological, oceanographic and cultural features with the objective of identifying natural areas or sites of Canadian national significance. The CPS study area was mapped at 1:500,000. Themes considered included geology, oceanography, coastal habitats, commercial invertebrates, marine fish, coastal birds, marine mammals, and cultural aspects. At that time, Leading Tickles was not considered as part of the natural area of Canadian significance identified in Notre Dame Bay by LFA (1990). This decision was based on presence or absence of features such as prime habitat for some species of marine birds, coastal sightings of marine mammals, prime fishing and aquaculture areas, high air temperatures and low frequency of fog and some key archaeological sites.

1.3 Protected Areas in the Study Area

The Leading Tickles study area is subject to three marine area closures: (1) the Atlantic cod moratorium, (2) Atlantic salmon commercial moratorium, and (3) the exclusion of herring seiners over 65' in length (Anderson et al. 2000). Outside the study area, there are at least 15 closures for contamination and one for gear conflicts with aquaculture within Notre Dame Bay (Anderson et al. 2000). Shellfish closure information is available at http://www.atl.ec.gc.ca/epb/sfish/maps/nf/nf.html.

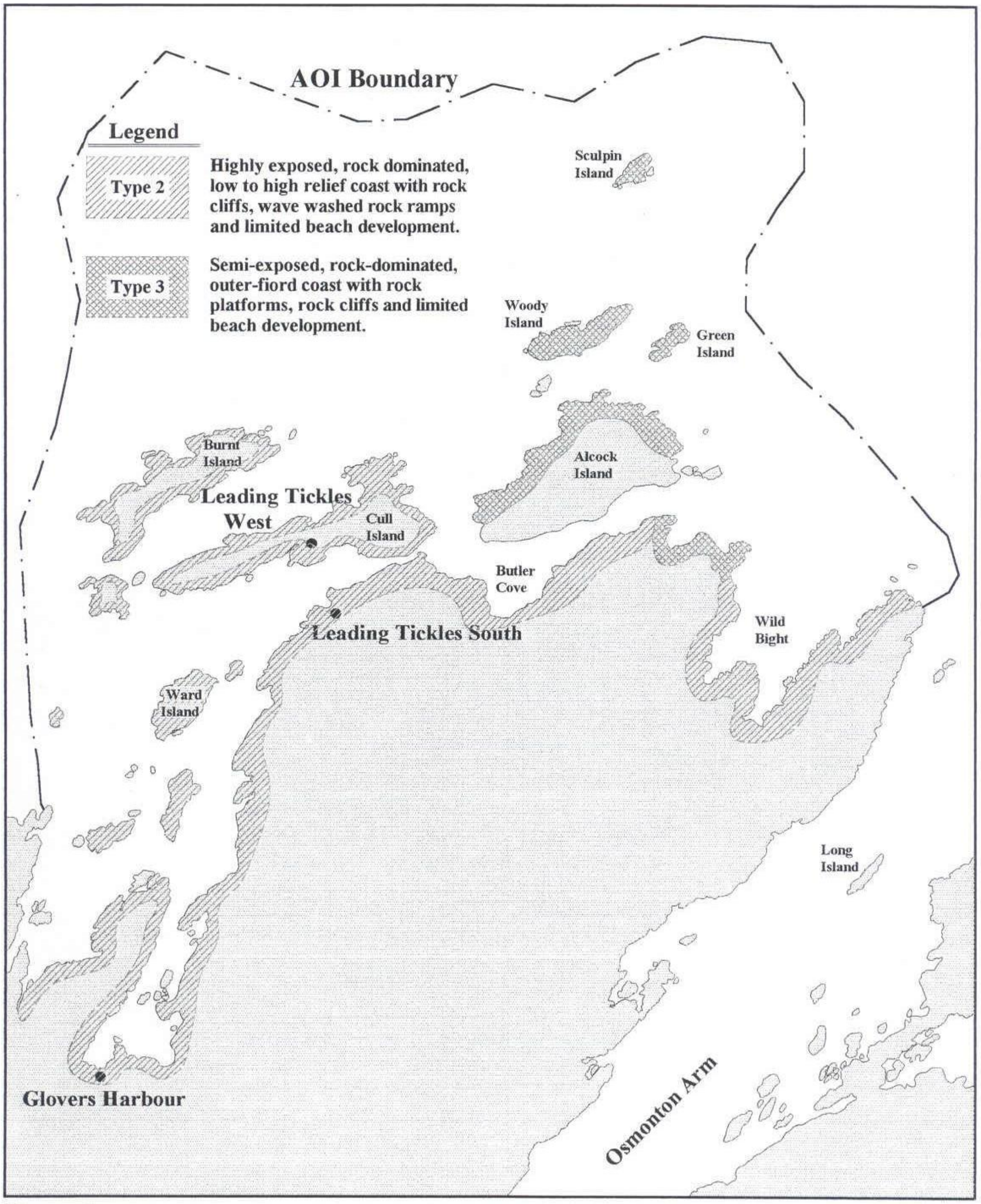


Figure 1.1. Leading Tickles study area showing coastal types.

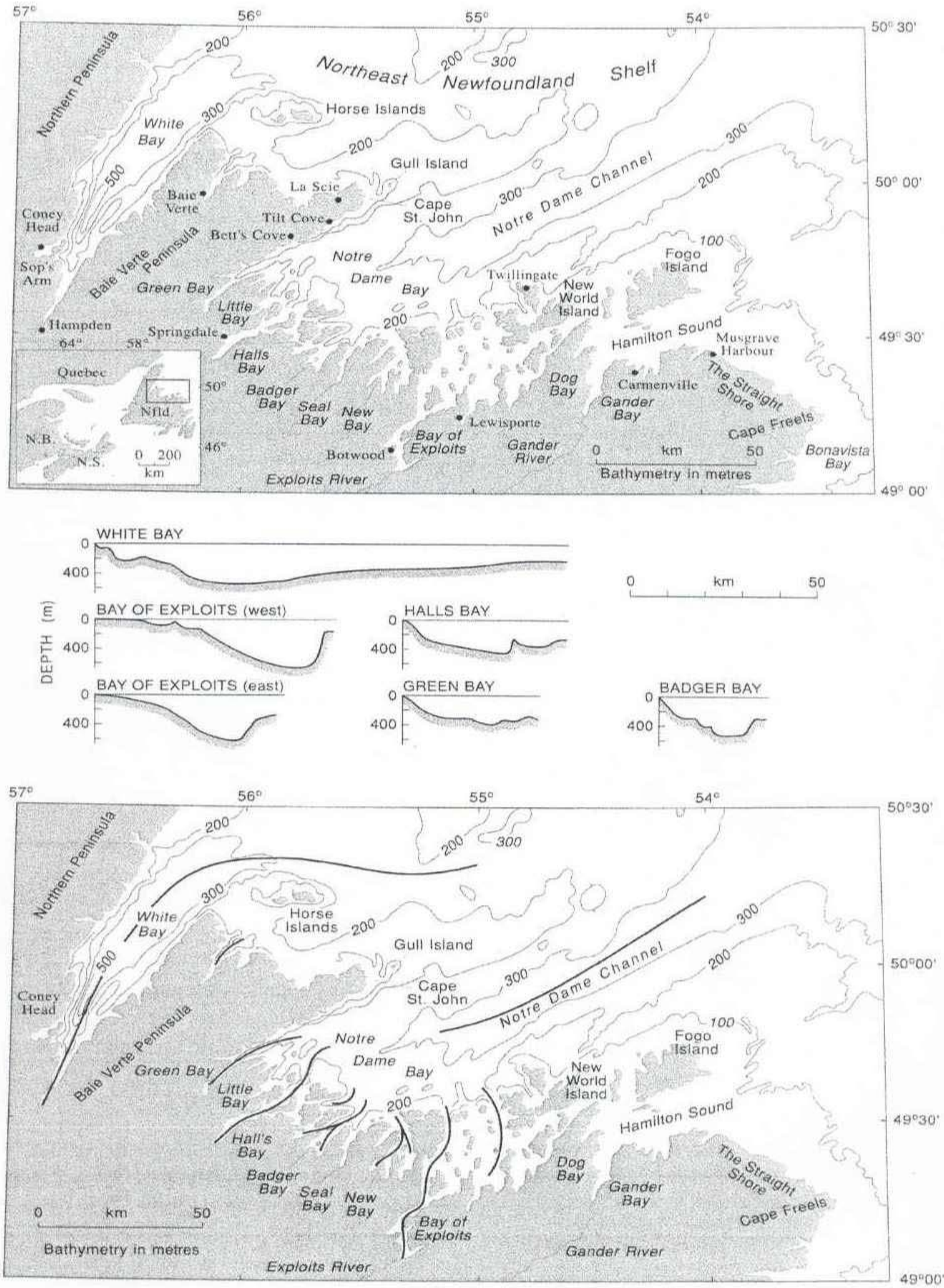


Figure 1.2. Northeast Newfoundland Shelf and bathymetry.

Seasonal closures for migratory bird hunting are available in the Migratory Birds Hunting Regulations published yearly by the Canadian Wildlife Service (CWS) of Environment Canada. There is no open season on Harlequin Ducks (known locally as Lords and Ladies, White-eyed Divers, or Squeakers). DFO regulates the annual seal hunt that has seasonal and area (e.g., near communities) closures. The reader should note closures are subject to change without notice and that DFO and Environment Canada should be contacted directly for the latest information on this issue.

The following sections are organized first by important physical components of the ecosystem, followed by important biological components that are described in an ecosystem context. This is followed by a brief section on the ecosystem as a whole, detailed species accounts and finally some recommendations for future research.

2.0 Physical Overview

The following sections briefly describe the body of knowledge of the physical environment of the study area, with reference to research work within the specific study area where possible. It should be noted that the physical environment of the NE Shelf of Newfoundland is complex and that many of the physical factors are highly inter-related. For example, climate and bathymetry affect water masses, currents and ice distribution, and vice versa; geological history and shoreline configuration affect water and sediment conditions, and degree of erosion. All of these factors in turn affect the distribution, abundance, biomass, and productivity of plants and animals.

2.1 Climate/Predominate Weather Conditions

There have been no climate or weather studies conducted in the Leading Tickles study area. The climate of the study area can be classified as temperate although relatively cool because of the influence of the cold Labrador Current. Weather and climate are closely linked to oceanographic conditions and they all affect marine organisms by affecting distribution, growth rates, reproductive timing and success, survival rates, and many other variables.

Environment Canada has been monitoring weather conditions (air temperature, precipitation, pressure, moisture, wind) at Comfort Cove, Notre Dame Bay for many years (see Environment Canada 1998a,b). These data are at least generally applicable to Leading Tickles.

Air temperature directly affects those marine organisms exposed to the air such as intertidal seaweeds and seabirds. It indirectly affects all marine organisms by influencing water temperature, particularly surface water temperature in the short term. Normal mean air temperatures in Comfort Cove range from –7.7ºC in February to 16.3ºC in July (1961-90 data; Table 2.1). Surface runoff from precipitation can affect salinities in the very nearshore, which in turn can affect the distribution of plants and animals. At Comfort Cove, mean precipitation ranges from 81.5 mm in June to 108.5 mm in October (Table 2.1).

Table 2.1. Comfort Cove, Notre Dame Bay, climate normals (1961-1990) and extremes (1967-1990) Environment Canada (1998a).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature													
Daily Maximum (°C)	-3.1	-3.3	0.3	5.0	11.2	17.2	21.8	20.3	15.5	9.5	4.5	-0.6	8.2
Daily Minimum (°C)	-11.7	-12.3	-8.4	-2.8	1.6	6.1	10.9	10.5	6.4	1.7	-2.1	-8.0	-0.7
Daily Mean (°C)	-7.3	-7.7	-4.0	1.2	6.4	11.6	16.3	15.5	11.0	5.6	1.3	-4.2	3.8
Extreme Maximum (°C)	12.4	12.5	15.6	22.0	28.2	32.0	33.3	33.3	27.5	23.9	20.0	15.0	
Date	986/28	981/12	979/25	986/23	979/20	988/16	975/19	976/22	982/14	972/01	967/04	969/05	
Extreme Minimum (°C)	-27.2	-32.2	-27.5	-14.0	-8.3	-2.5	0.6	3.9	-2.2	-6.2	-15.7	-26.1	
Date	971/14	975/04	986/10	984/05	972/02+	978/02	974/07	983/05+	972/29+	986/26	978/30	972/31	
Degree-Days													
Above 18 °C	0.0	0.0	0.0	0.0	0.1	5.7	28.6	19.1	0.6	0.0	0.0	0.0	54
Below 18 °C	787.9	729.0	684.5	506.5	358.6	196.6	80.0	98.0	210.5	383.3	503.4	692.2	5230
Above 5 °C	0.7	0.2	1.8	13.5	80.1	204.0	351.6	324.2	180.9	56.3	15.4	2.6	1231
Below 0 °C	235.5	227.0	144.2	29.7	0.9	0.0	0.0	0.0	0.0	2.0	31.8	150.7	822
Precipitation													
Rainfall (mm)	22.8	21.0	31.4	43.8	69.8	78.6	81.8	105.1	94.4	92.5	66.1	34.2	741.6
Snowfall (cm)	83.5	72.7	69.5	40.9	15.3	2.6	0.0	0.0	0.0	14.4	35.8	70.2	405.0
Precipitation (mm)	100.0	91.7	99.9	87.7	86.6	81.5	81.8	105.1	94.5	108.5	103.7	102.2	1143.1
Extreme Daily Rainfall (mm)	50.2	38.4	41.9	47.2	45.2	36.8	46.2	91.7	55.6	59.4	45.2	25.9	
Date	983/13	984/05	979/08	986/11	969/01	972/25	985/17	969/14	986/17	973/27	971/15	974/10	
Extreme Daily Snowfall (cm)	51.8	43.8	36.0	31.8	17.5	13.2	0.0	0.0	0.6	27.4	26.4	49.5	
Date	987/05	983/27	988/05	967/16	972/13	974/07	990/31+	990/31+	986/28	972/20	975/28	972/28	
Extreme Daily Pcpn. (mm)	52.8	45.8	43.4	47.2	50.0	36.8	46.2	91.7	55.6	61.5	57.7	43.2	
Date	987/05	983/27	969/08	986/11	969/01	972/25	985/17	969/14	986/17	973/27	971/15	972/28	
Month-end Snow Cover (cm)	39	56	33	5	0	0	0	0	0	0	6	23	
Days With													

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Maximum Temperature > 0°C	9	8	16	25	31	30	31	31	30	31	25	13	279
Measurable Rainfall	6	5	8	10	14	16	15	16	16	17	12	8	143
Measurable Snowfall	17	14	15	11	5	*	0	0	*	5	11	16	95
Measurable Precipitation	19	16	19	17	17	16	15	16	16	18	19	20	209
Station Pressure (kPa)	99.47	99.65	N	100.06	100.23	100.10	100.09	100.17	100.23	100.20	99.85	99.66	N
Moisture													
Vapour pressure (kPa)	0.33	0.32	0.40	0.55	0.75	1.05	1.42	1.41	1.09	0.79	0.59	0.42	0.76
Wind													
Speed (km/h)	21	20	20	19	18	17	16	16	17	19	21	21	19
Most Frequent Direction	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
Extreme Hourly Speed (km/h)	102	80	93	72	77	61	56	68	59	77	74	77	
Direction	E	NW	NW	S	NW	N	S	N	S	S	W	N	
Extreme Gust Speed (km/h)	113	116	129	109	114	90	93	90	90	117	113	130	
Direction	N	SE	NW	S	N	N	S	SW	N	S	S	S	

Location: 49°16-N 54°53-W/O
Elevation: 96m

Wind can cause upwelling of deep nutrient-rich water that may increase primary production by phytoplankton. For example, sustained strong offshore winds may induce upwelling in areas where deepwater occurs nearshore. Large and/or consistent increases in primary production can lead to increases in production of plankton, benthos, fish, seabirds and marine mammals. Prevailing winds at Comfort Cove are SW (DFO 1980).

The island of Newfoundland is well known for its fog, caused by warm air over cold water or vice versa. Fog frequency in NE Newfoundland is greatest in spring and there is a general trend of increasing fog with increasing distance offshore. Notre Dame Bay has significantly less fog than areas to the south of Cape Freels. In summer, Notre Dame Bay is relatively clear with less than 4% frequency of fog (LFA 1990). Fog affects the biological system in subtle ways by limiting the amount of light reaching the ocean and thus affecting primary productivity. It may also affect seabird behaviour and movements.

2.2 Geology, Geomorphology and Geographic Features

There have been no detailed geological studies conducted in the Leading Tickles Study Area. Some coastal typing and a small amount of relevant sediment information has been collected. Nonetheless, due to the broad scale nature of most geological processes, some of the considerable research done in Newfoundland in general is of relevance to the study area.

Substrate types (e.g., sand, gravel, rock, etc.), degree of exposure to wind and wave, shoreline and bottom topography are all important determinants of the makeup and productivity of marine communities, particularly intertidal and subtidal, bottom-dwelling ones. The irregular, rocky shoreline of the NE coast of Newfoundland is composed of resistant igneous and metamorphic rocks (Taylor et al. 1990). Weathering is slow and sandy beaches are rare. At Leading Tickles, coastal heights of land reach as high as 99 m (Alcock Island) (DFO 1980).

At least as of 1990, there have been no extensive beach surveys in the Leading Tickles study area. Aerial video surveys of the Newfoundland coast were conducted for Petro-Canada in the early 1980s (Owens and White 1982 *in* LFA 1990). The coastline is dominated by low bedrock cliffs with some higher rock faces in places, interspersed by pocket beaches composed of gravel, pebble and cobble (LFA 1990).

Boulder barricades, salt marshes and intertidal flats are all rare in the Leading Tickles study area (Woodward-Clyde 1980, Owens and White 1982 *in* LFA 1990). The majority of the salt marshes and intertidal flats on the NE Coast are at the heads of Notre Dame Bay and Bonavista Bay (Owens and White 1982 *in* LFA 1990). A relatively high percentage of the tidal flats and salt marshes on the NE coast occur in the area of Terra Nova National Park.

There have been no detailed geological studies conducted in the Leading Tickles study area of relevance to establishing a MPA. The Geological Survey of Canada started coastal surveys in Newfoundland in 1981 and established a series of 79 site-specific stations but none were located in (or immediately adjacent to) the study area (see Forbes 1984).

The geological history of central Notre Dame Bay has been mapped by Harris (1973). The main portion of the Leading Tickles study area is considered to fall within the Wild Bight Group (pillowed basalt, coarse agglomerate and tuff, chert, minor acid pyroclastics) with a small pocket of Leading Tickles Stock (gabbro, diabase, peridotite) immediately inland from Leading Tickles (Harris 1973). Most of the islands (Roswell, Burnt, Cull, and Alcock islands) were considered part of the Exploits Group (black and grey slates; minor sandstones, conglomerate, red and green slates and chert) whereas the offshore islands (Woody and Green islands), in the Lukes Arm Fault Zone, are Wild Bight and Exploits groups (Harris 1973).

Geologically, the island of Newfoundland is classified as part of the Southern Provinces of the Canadian Shield composed of rocks laid down during the different Precambrian eras, and rocks, mainly crystalline, that were produced or affected by the orogenies near the close of the Archean eon and of the Proterozoic eras (Douglas 1972). This area is known as the Appalachian Region of the Borderlands of the Canadian Shield that is bounded by the Atlantic Continental Shelf (Bostock 1972).

The Appalachian Orogen extends from Newfoundland 2,000 miles southwestward along the Atlantic seaboard to Alabama. The system was possibly once continuous with the Caledonian mountain chain on the eastern side of the North Atlantic in Ireland and Britain (Poole et al. 1972).

Most of the rocks of central Newfoundland were deformed in what is called the Acadian Orogeny that was caused by North America colliding with Europe or Africa (Hodych et al. 1989). The coastline along NE Newfoundland generally consists of rugged and broken cliffs with numerous capes jutting into the sea that were formed during the uplift, faulting and folding which occurred during the Appalachian Orogeny (LFA 1990).

In terms of tectonic zones, Leading Tickles is within the Dunnage Zone (Cambrian to Silurian marine clastic sedimentary rocks and/or island-arc volcanic and volcaniclastic rocks) (Hodych et al. 1989; WRD 1992). The Dunnage Zone is one of four northeast-trending tectonostratigraphic zones in the Newfoundland part of the Appalachians (Macpherson and Macpherson 1981) (Figure 2.1). The Dunnage Zone is believed to contain the vestiges of the Iapetus Ocean, an ancient ocean that disappeared when the tectonic plates collided. Most of the Leading Tickles area appears to be contained within a zone of mainly sedimentary rocks of middle Ordivician and earlier origin (Kean 1989).

Newfoundland is recognized worldwide as an important location for studying plate tectonics (i.e., continental movement) since the island was formed between 450 and 350 million years ago by the continental collision of Europe, Africa and North America (Macpherson and Macpherson 1981; King 1989) (Figure 2.2). Additional detail on the type of rock in the Leading Tickles area is contained in the geological map of O'Brien (1991).

Newfoundland was covered several times by continental ice sheets during the last two million years of the Pleistocene Epoch. Evidence of earlier glaciations was destroyed by the latest glaciation (Late Wisconsin) that ended about 10,000 years ago (Rogerson 1989).

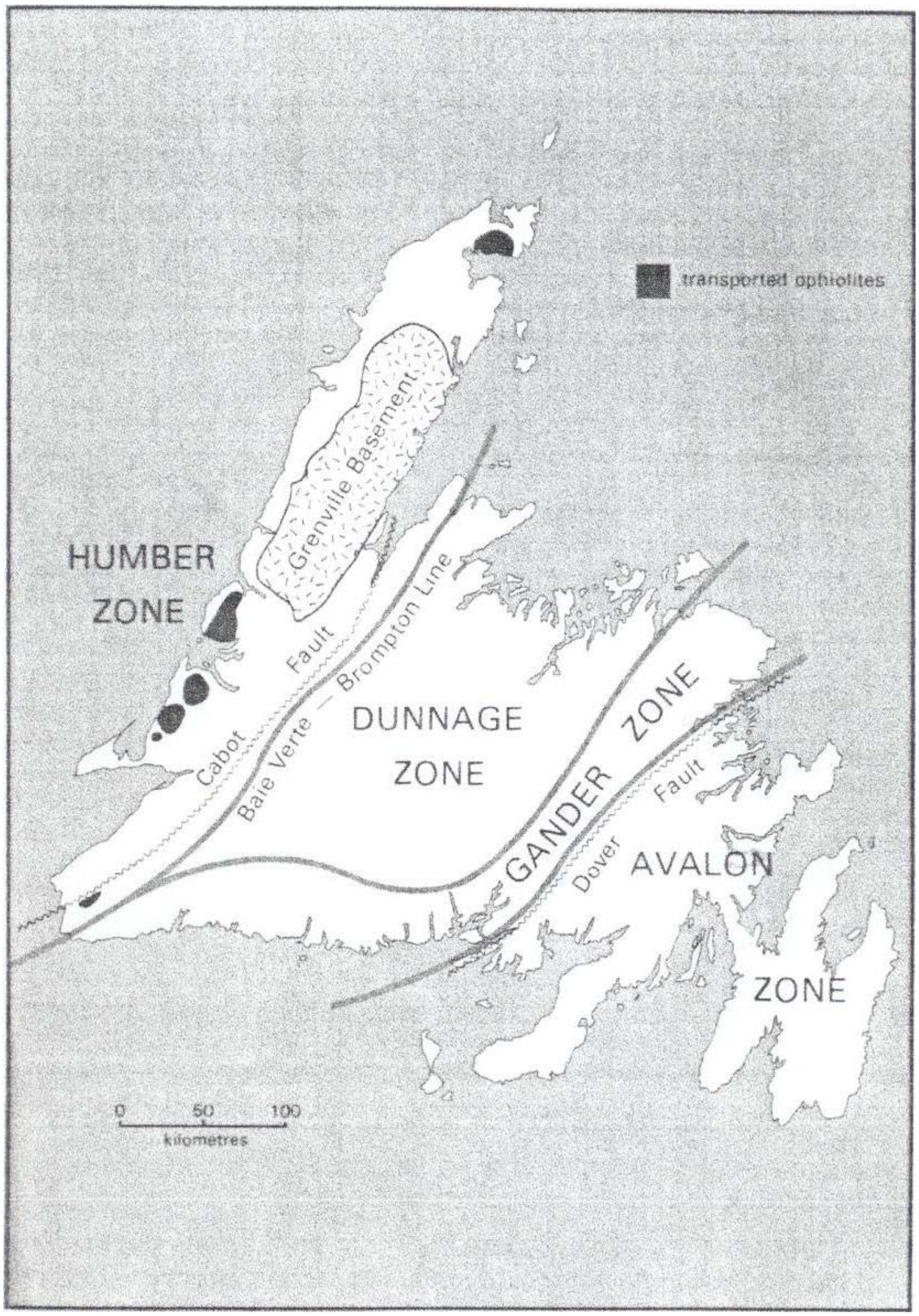


Figure 2.1. Tectonic zones of the Island of Newfoundland (after Williams 1979). From Macpherson and Macpherson (1981).

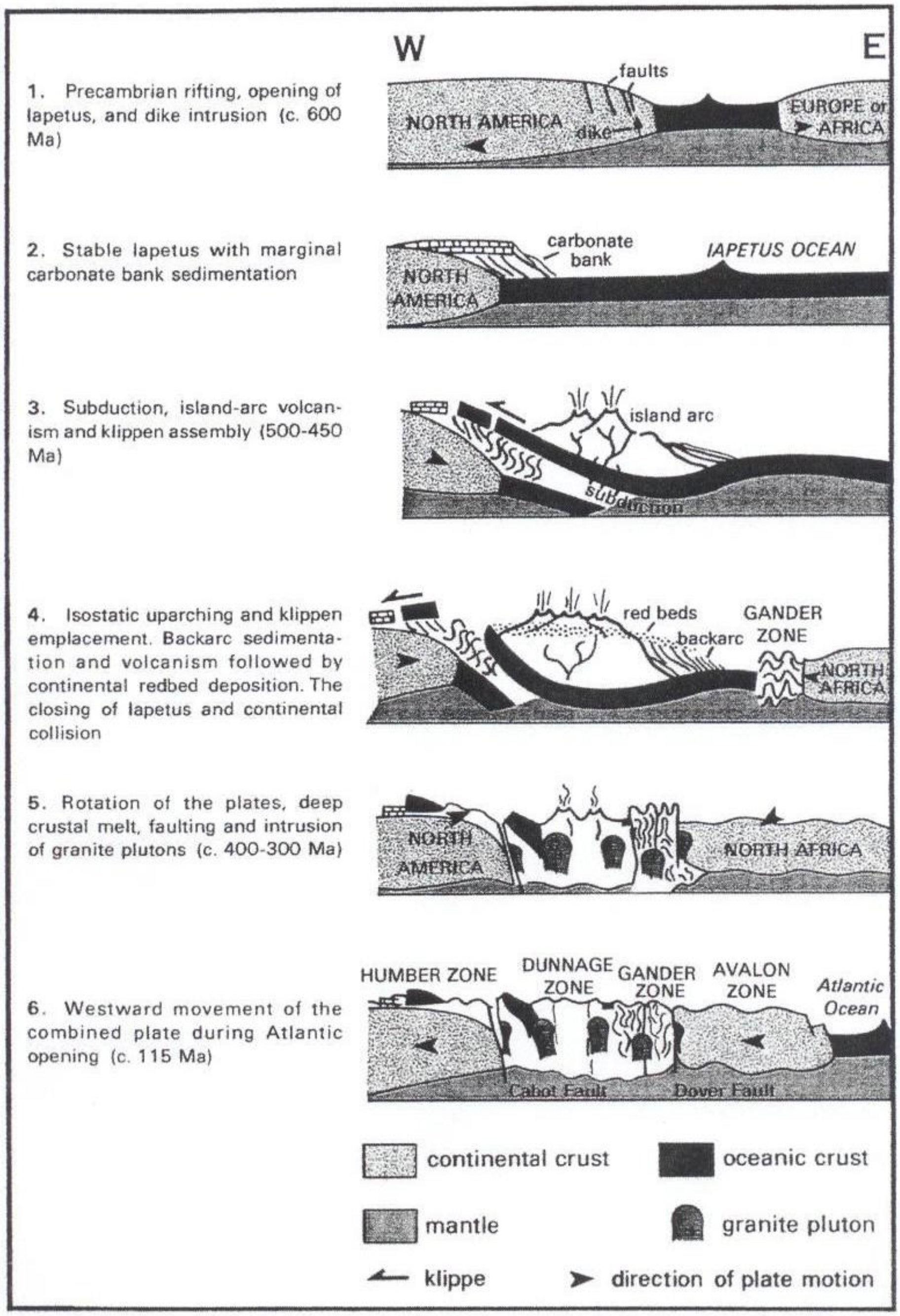


Figure 2.2. Tectonic evolution of the island from Precambrian times along an approximately W-E cross-section (much generalized from Hibbard 1979 and Strong 1977, 1980b). From Macpherson and Macpherson (1981).

Ice moved out from four or five centers on the island to the coasts (Macpherson and Macpherson 1981; Hodych et al. 1989) (Figure 2.3). Much of the soil was scoured onto the continental shelf. Glaciers left behind till which is a poorly sorted mixture of sediments containing grain sizes from clays to boulders. Erratic boulders and eskers (long sinuous deposits laid down by streams flowing within the ice) are common signs of glacial transportation. Many glacial streams built up deltas where they entered the sea or large lakes. Most coastlines are now found well above sea level due to the land rising after the ice load melted. The coast in the vicinity of Eastport rose on the order of 25 m whereas the coast in the region of Leading Tickles rose close to 75 m (Rogerson 1989; WRD 1992). Ice left the coasts about 12,500 to 11,000 years ago (Rogerson 1989).

Most sections of the Newfoundland coast, including the Leading Tickles study area, are sediment-starved except where abundant glacial deposits provide local sources (e.g., Eastport) (Hodych et al. 1989). Immediately offshore in and adjacent to the Leading Tickles study area, the textural character of surface sediments had not been studied, at least prior to 1990 (refer to geological mapping in oversize Figure 11.1B *in* Amos 1990). However, it is well known that the surficial sediments of northern shelves (including the NE Newfoundland Shelf) are highly influenced by iceberg scour and transport at depths less than 230 m (Barrie and Josenhaus 1990). Wind and waves would also influence the sediment characteristics of the NE Shelf perhaps more than the shelves to the north that are more sheltered by ice cover.

A major study of surficial sediments on the coast and inner shelf of NE Newfoundland, including the Leading Tickles study area has been conducted (Shaw et al. 1999). [However, only two ship tracks using *Huntec* seismic equipment were conducted on the outer and eastern border of the study area and one core sample from New Bay.] These authors used six coastal classification types (Table 2.2; see Figure 1.1).

Table 2.2. Coastal classification types used by Shaw et al. (1999).

Class	**Description**
Type 1	Exposed, rock dominated, low relief coast with extensive sandy beaches and dunes
Type 2	Highly exposed, rock dominated, low to high relief coast with rock cliffs, wave washed-rock ramps, and limited beach development
Type 3	Semiexposed, rock dominated, island and outer fiord coast with rock platforms, rock cliffs, and limited beach development
Type 4	Semiexposed to protected, rock dominated, fiord coast with limited development of mixed sand and gravel beaches
Type 5	Partly exposed to protected, rock dominated, low relief coast with extensive rock and boulder platforms, boulder flats, and locally extensive mixed sand and gravel beaches
Type 6	Protected, rock-dominated, low relief, shallow embayments with extensive boulder flats

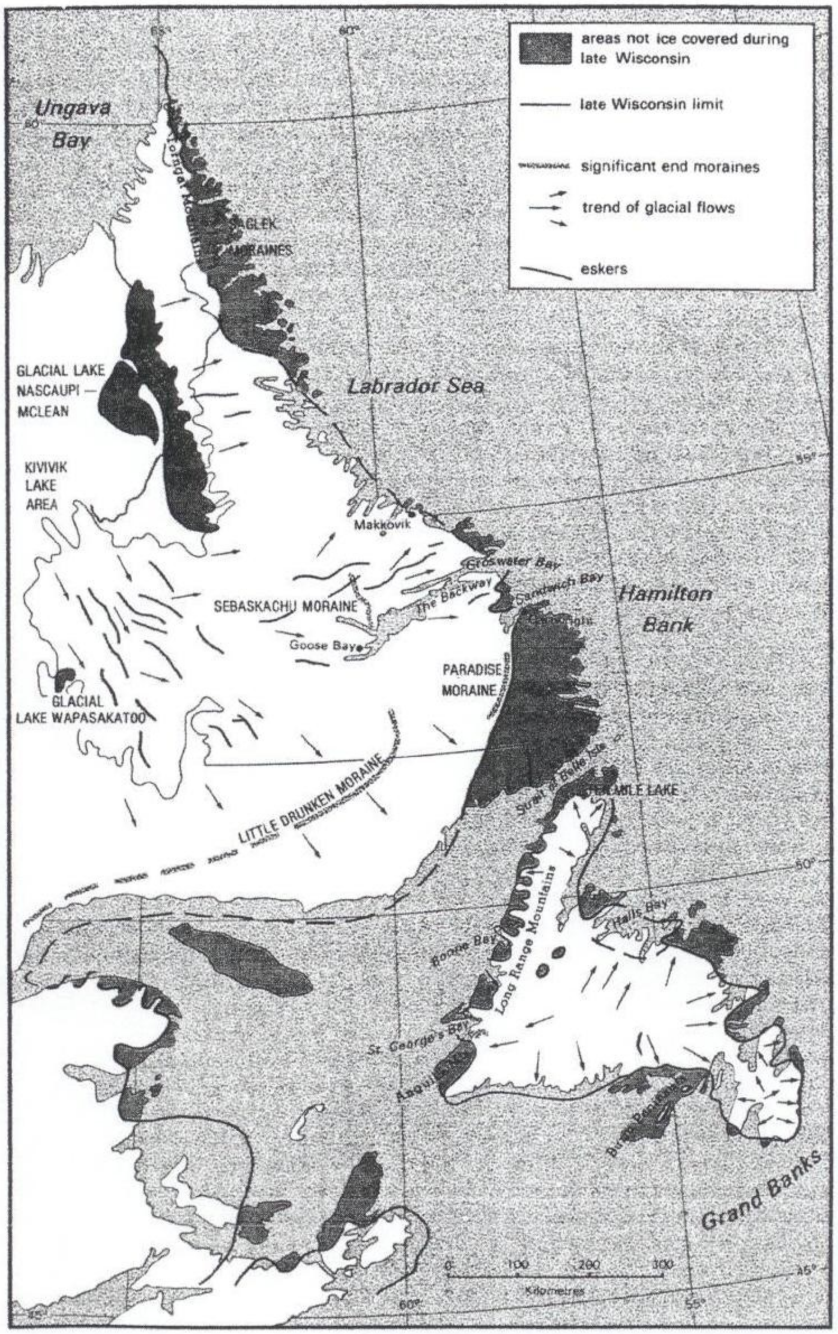


Figure 2.3. Speculative ice limits, patterns of ice flow and other glacial features for the late-Wisconsin glaciation (compiled from many sources). From Macpherson and Macpherson (1981).

Surficial sediment classifications are shown in the following table (Table 2.3).

Table 2.3. Surficial sediment classifications used by Shaw et al. (1999).

Class	Description
Unit 1	Bedrock predominate
Unit 2	Glacial diamicton
Unit 3	Glaciomarine mud
Unit 4	Postglacial mud
Unit 5	Postglacial sand and gravel

Within the Leading Tickles study area, coasts were classified as Type 2 on the exposed coasts of Alcock Island and the small offshore islands and Type 3 in the remainder of the study area (see Figure 1.1). Data on bottom surficial sediments in the Leading Tickles study area is very scarce but the bottom is characterized by Unit 1 (bedrock) shallower than about 200 m with post-glacial mud (Unit 4) dominating in deeper water just outside the study area (Shaw et al. 1999). Shaw et al. (1999) further confirmed the importance of icebergs on the surficial sediments of the NE Newfoundland Shelf (Figure 2.4).

The study area lies on the coastal margin of the NE Newfoundland Shelf, an elongate, relatively narrow shelf of about 120,000 km^2 in area (Keen and Piper 1990). At least as of 1990, the inshore areas of the study area had not been surveyed in detail for bathymetry. [Note, however, that DFO has sponsored some recent bathymetry surveys under the MPA program.] The Shelf is generally deeper (200-500 m) than the shelves to the south such as the Grand Banks and Scotian Shelf. There are no deep submarine valleys directly off the study area (Spenser 1903 *in* Keen and Piper 1990). Orphan Knoll, a submarine rise, far offshore from the study area may be an ancient continental land mass (Grant and McAlpine 1990).

2.3 Oceanography

The oceanography of the Leading Tickles study area is dominated by the southward flowing, cold Labrador Current that brings cold water and icebergs to the NE Coast and Shelf, particularly the cold inshore branch of the Current (Figure 2.5). The Labrador Current originates off Cape Chidley, Labrador from three main sources: (1) water flowing out of Hudson Strait, (2) water flowing south from Baffin Bay (Baffin Current), and (3) a branch of the West Greenland Current that is turned to the west and south by the Davis Strait Ridge (Dunbar 1951). This cold water flows through the Strait of Belle Isle, over the NE Newfoundland Shelf, and then over the Grand Banks to be mixed with and turned to the east by the warm Gulf Stream that flows north off the coast of North America. Under certain conditions (e.g., spinoff eddies), the Gulf Stream may introduce warm-water ‘exotic’ species to the Grand Banks but it is unlikely that these would reach the NE Shelf.

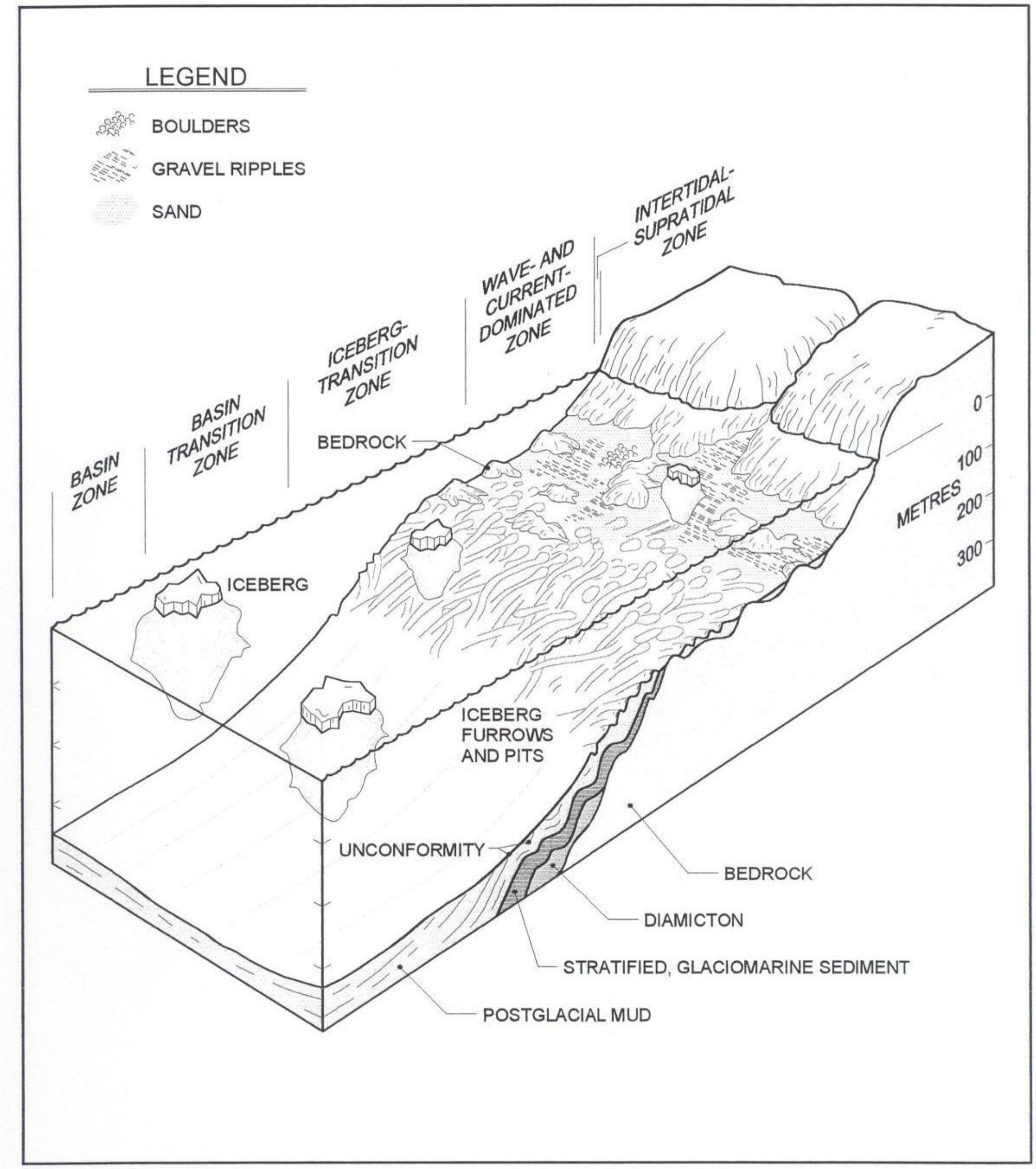


Figure 2.4. Conceptual model of modern sedimentary environments on the northeast Newfoundland inner shelf. From Shaw et al. (1999).

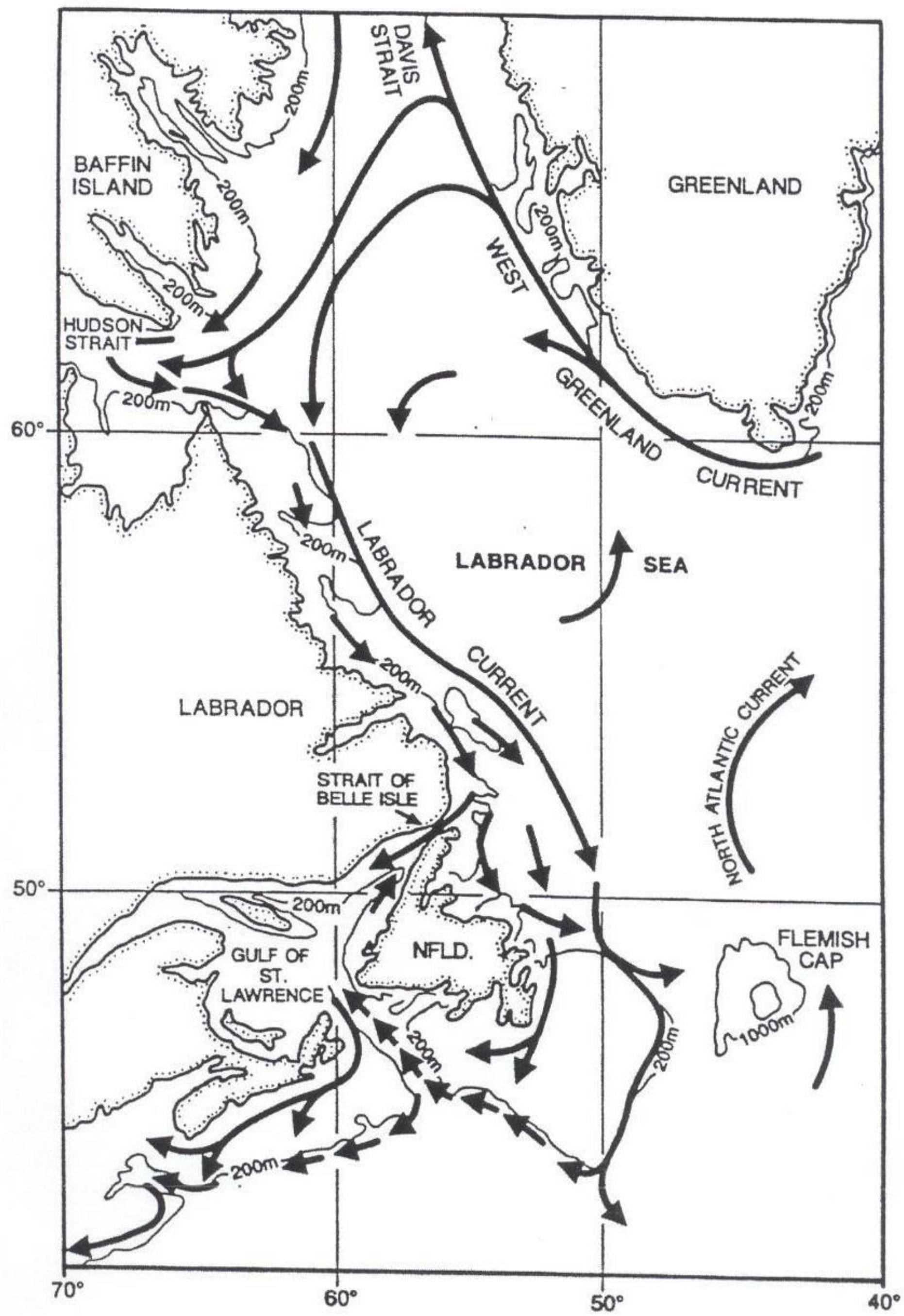


Figure 2.5. Labrador Current. From Petro-Canada (1995).

There are extensive oceanographic data sets for eastern Canadian waters (e.g., MEDS); however, most of these data were collected offshore because of relevance to such interests as large-scale oceanographic study, offshore oil development, offshore fisheries and so forth. Relatively few oceanographic studies have been conducted in near-shore Newfoundland waters and we are aware of none conducted in the Leading Tickles study area. Furthermore, near-shore currents and water mass characteristics are extremely variable and are governed by the complex and irregular shape of the coastline, bathymetry and other factors.

Of particular interest and relevance to the present study are some of the remote sensing products now available. For example, maps for sea surface temperature, chlorophyll a, and primary production are readily available on the Bedford Institute of Oceanography website (http://www.bio.gc.ca/welcome-e.html) (see Figures 2.6 to 2.8). These maps present data for the whole region including the specific areas of interest and thus allow researchers to place individual sites in perspective. In addition, remote sensing techniques allow data to be collected from broad geographic areas almost simultaneously, a feat that is impossible using conventional ship-based oceanographic techniques.

2.3.1 Temperature/Salinity

There are few temperature and salinity data specific to the Leading Tickles study area. DFO during their inshore-offshore surveys of plankton on Newfoundland and Labrador shelves sampled several stations for temperature and salinity in Notre Dame Bay, just to the east of the study area (Dalley and Anderson 1998). These authors found differences in surface and 50 m depth temperatures between years (1994-97 data) with some corresponding differences in zooplankton (planktonic invertebrates, fish eggs, and larvae) and nekton (selected species of large invertebrates and small fish capable of directed movements). Minimum water temperatures (-1.5ºC) were found at depths of 175 m. Temperatures rose to 0ºC in deep (300 m) trenches (Anderson and Dalley 2000).

Coastal conductivity (an indicator of salinity) and temperature by depth (CTD) data (1986-87, uninterpreted), including stations in or immediately adjacent to the study area are available from Schillinger et al. (2000). Seawater characteristic data for seven nearby potential mussel growing sites might also provide some relevant data, albeit outside the study area (see Dabinett and Clemens 1994).

The nearshore oceanography in the Leading Tickles study area is probably not affected to any large degree by freshwater inputs as there are no major rivers that enter the study area (WRD 1992).

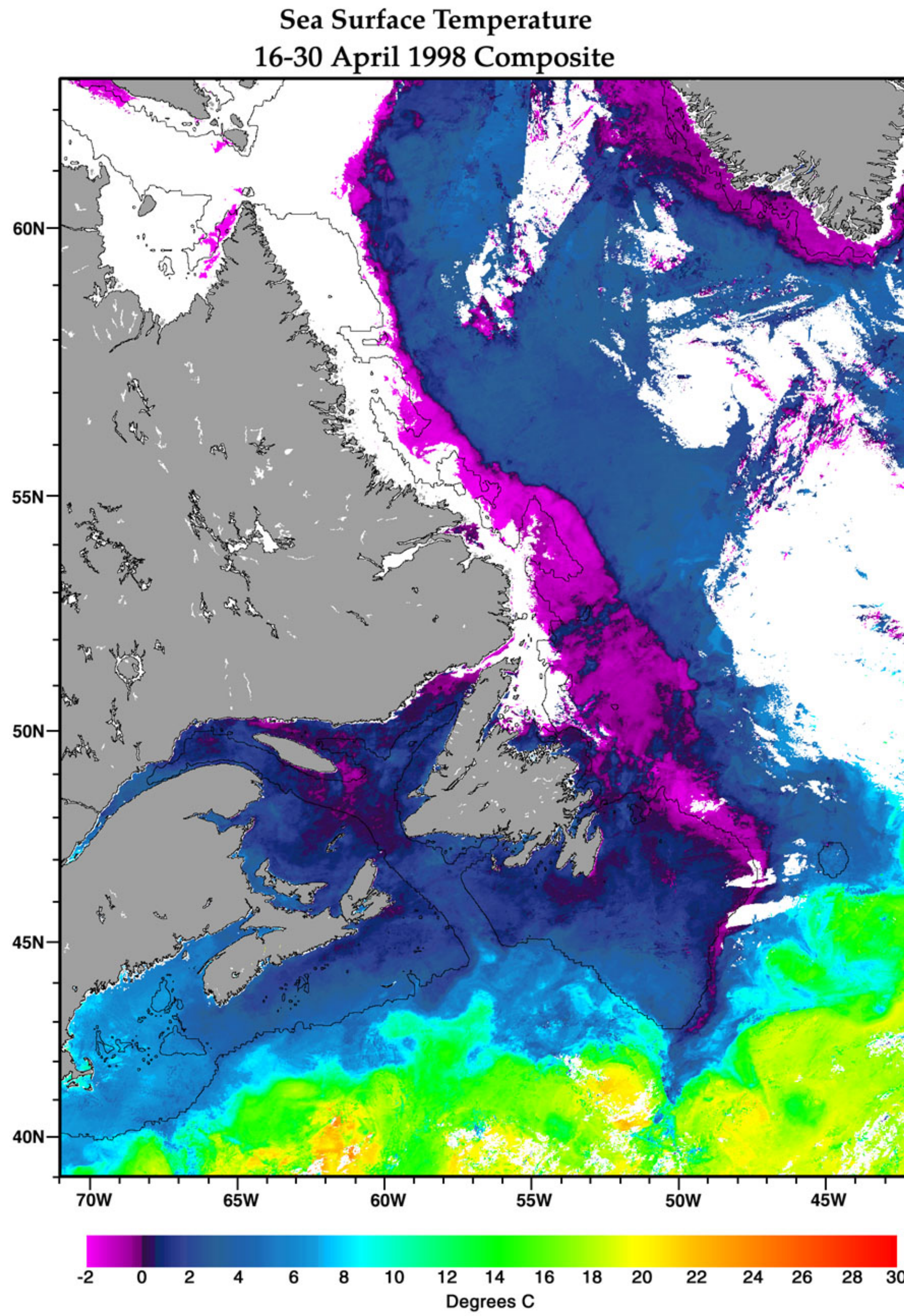


Figure 2.6. Sea surface temperature – 16-30 April 1998 Composite.

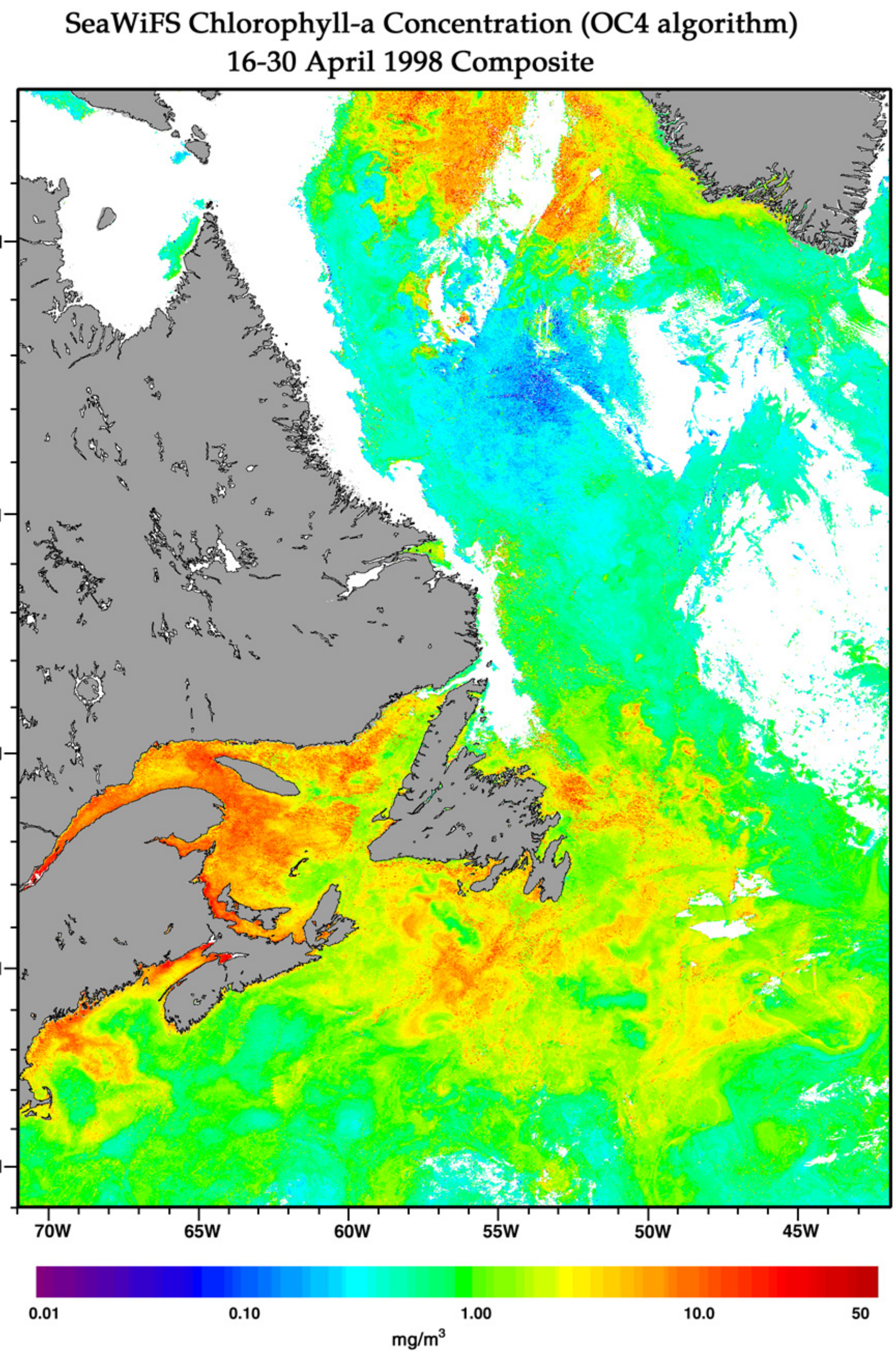


Figure 2.7. Sea WiFS chlorophyll-a concentration (OC4 algorithm) – 16-30 April 1998 Composite.

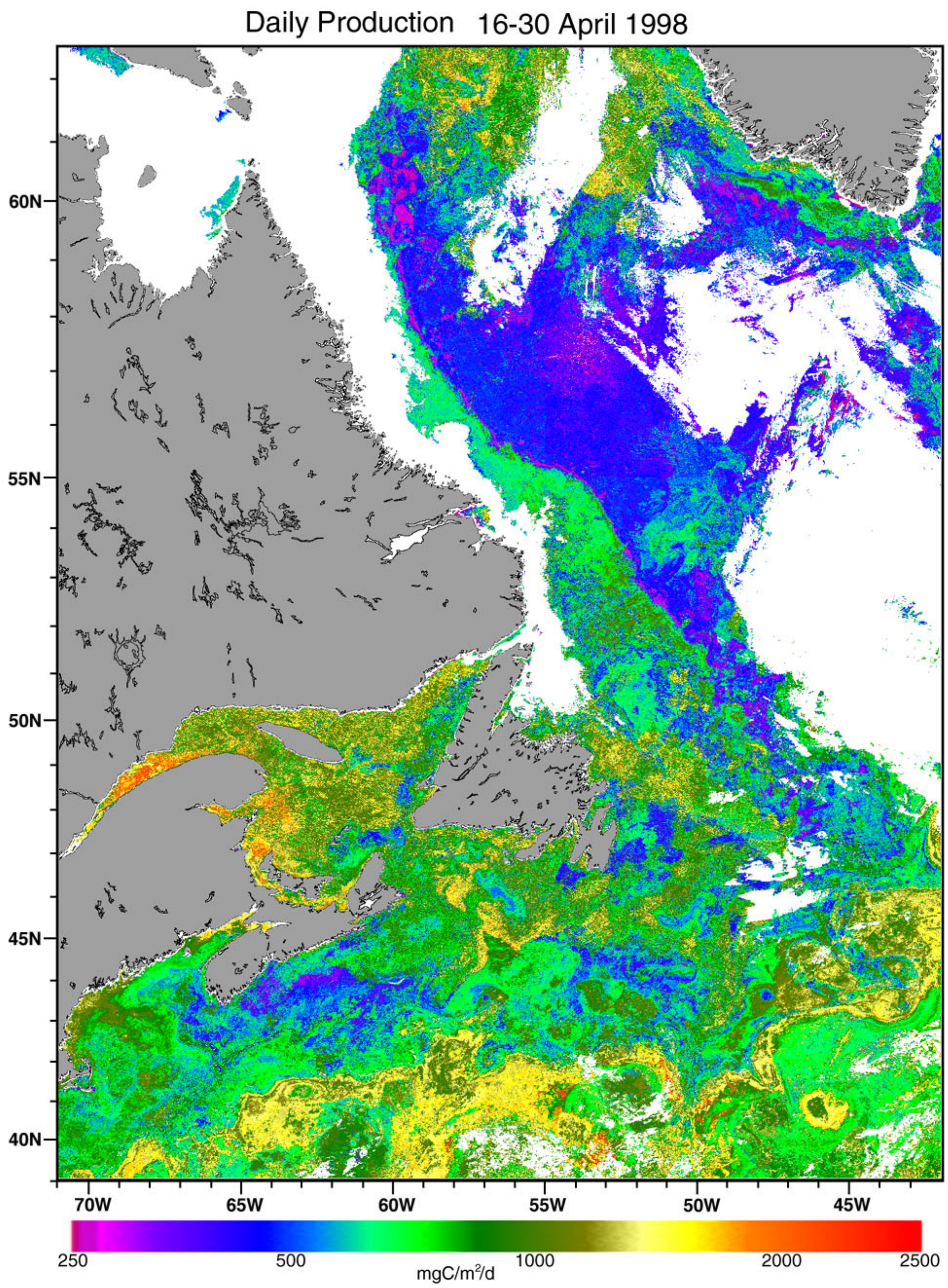


Figure 2.8. Daily production – 16-30 April 1988.

Temperature and salinity data have been collected since 1946 at Station 27, 10 km off St. John's (Figure 2.9); this station is considered typical for the inshore branch of the Labrador Current. DFO also routinely samples a temperature and salinity transect off Cape Bonavista (Figure 2.9) but in general there appears to be a lack of temperature and salinity data for the NE Newfoundland Shelf as well as the specific study area. The inshore branch of the Labrador Current is characterized by temperatures of <1ºC and salinities <33.5 ppt (Smith et al. 1937; Andersen 1968).

Additional shallow water temperature monitoring is conducted by DFO at Comfort Cove, Notre Dame Bay (DFO 2000a).

2.3.2 Nutrients

Nitrogen (nitrate + nitrite), phosphates and silicates are the main recognized nutrients for primary production in the ocean and those most studied by oceanographers. In northern marine waters such as those in the Leading Tickles study area, nitrogen is probably the limiting nutrient (Drinkwater and Harding 2001). Bottom waters are normally rich in nutrients and primary production is greatly enhanced in areas where bottom waters are upwelled to the surface where they are accessible to phytoplankton. Upwelling areas are usually important feeding areas for higher trophic levels such as fish, birds and marine mammals. Upwelling may occur at shelf breaks or along coastal areas, islands or shallow banks in the presence of strong winds. Strong offshore winds may cause upwelling in the summer in Newfoundland bays by pushing the warm water from the shallow inshore area to the offshore, to be replaced by deep (and nutrient-rich) cold water.

2.3.3 Tides

Tides affect nearshore currents that in turn influence the distribution of marine organisms. The long-term tide gauges that DFO uses to predict tides for Newfoundland are located in Port aux Basques, Argentia and St. John's (http://www.ec.gc.ca/climate/CCAF-FACC/Science/nat2002/ocean_e.htm#313).

Most tides in the Leading Tickles study area are semi-diurnal (two lows and highs per day) with a relatively small range; the difference between high and low water seldom exceeds 1.8 m (DFO 1980). In general, tidal currents are not strong in Newfoundland waters although they can achieve 7 km/h in very localized narrow channels between islands (Farmer 1981 *in* LFA 1990).

2.3.4 Waves

The degree of exposure to waves is an important factor that influences the distribution and productivity of marine organisms, particularly intertidal and shallow subtidal ones. The wave regime in the Leading Tickles study area is highly variable depending upon location, currents, bottom topography, water depth, degree of exposure, wind direction, ice conditions, and so forth. The 1-, 10-, and 100-year significant wave heights for eastern Newfoundland

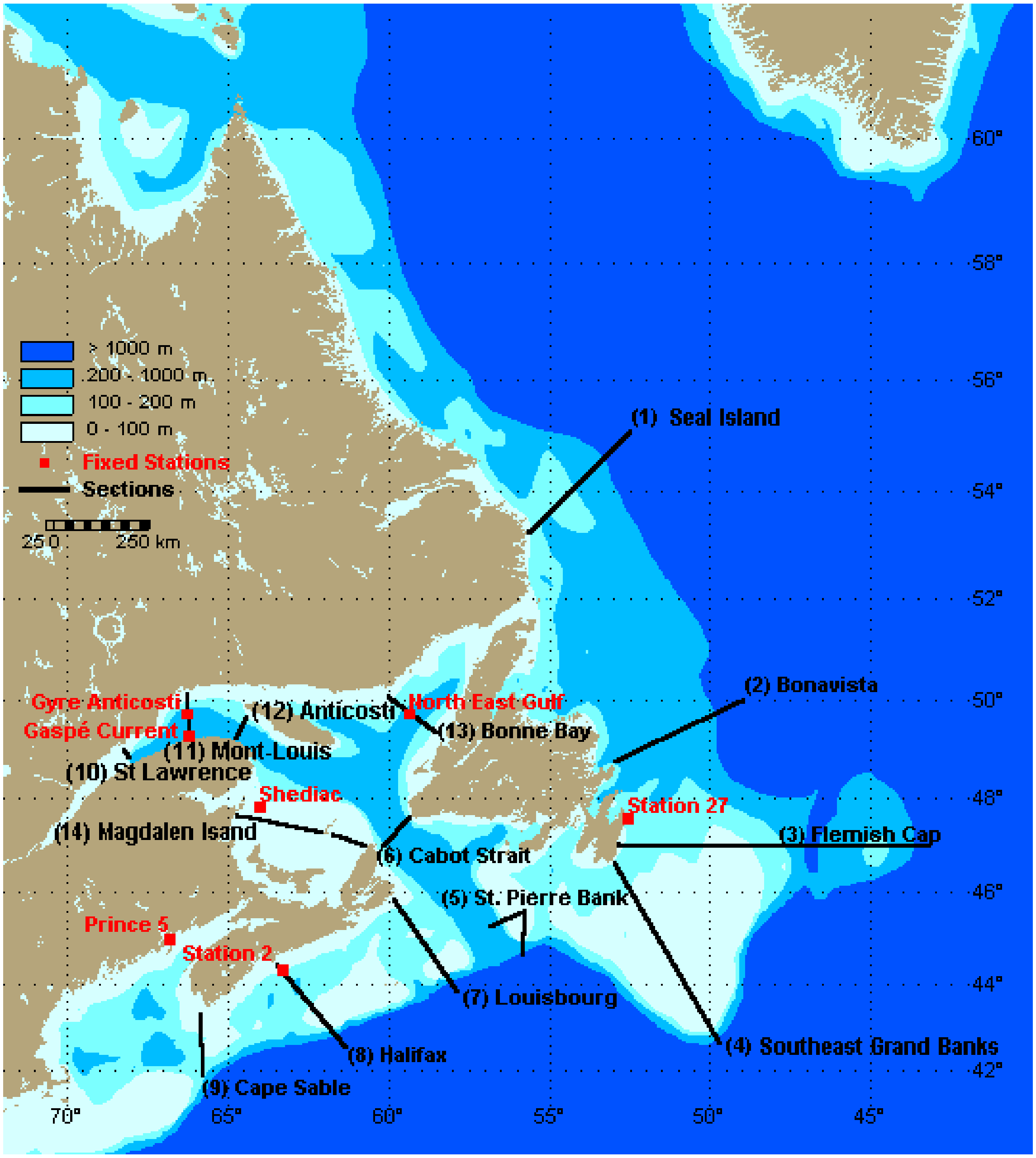


Figure 2.9 Location of DFO long-term temperature and salinity monitoring stations and transects.

are 8, 11, and 15 m, respectively (Neu 1982 *in* Forbes 1984). These significant wave heights can be expected to occur on the NE Shelf well below one percent of the time, and when they do occur would seldom (<10%) come from an easterly direction (MacLaren 1991). Presumably, large waves originating from an easterly or northeasterly direction would have the most impact on the exposed parts of the study area.

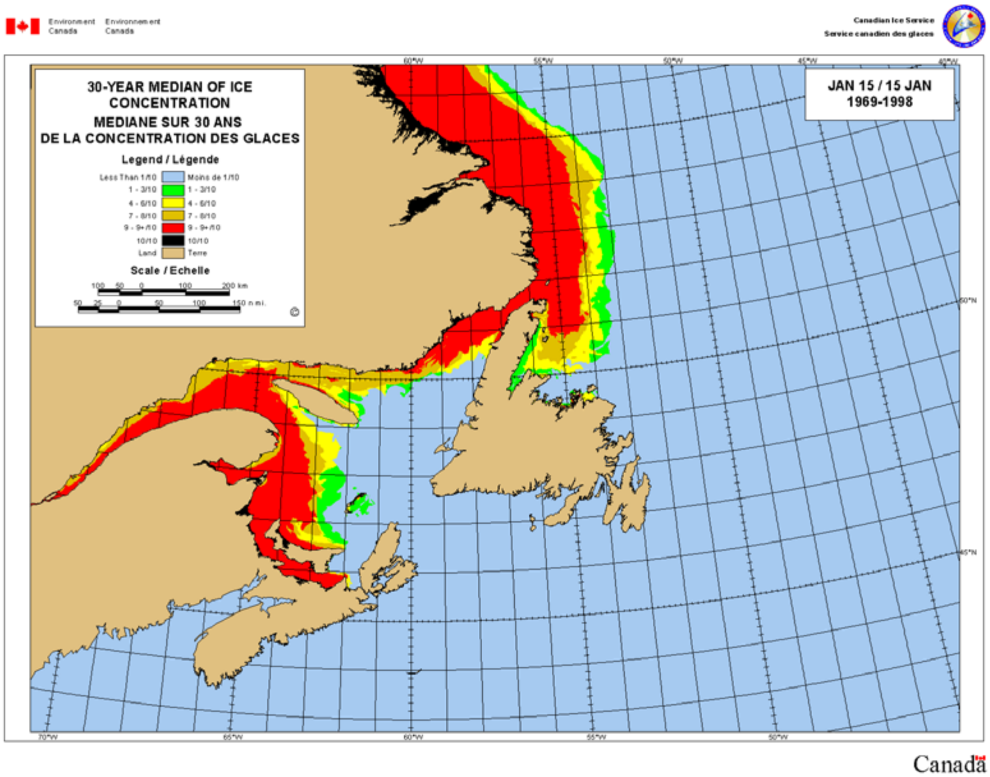
2.3.5 Ice

Ice is an important marine habitat variable in northern marine ecosystems for a number of reasons. Ice affects sea state, light penetration and water temperature, and ice edges may provide important upwelling and/or feeding habitat. The underside of the ice itself provides habitat for specialized phytoplankton and invertebrates, which in turn provide a food source for fish.

Sea ice begins to form on the coast of southern Labrador in mid-December and spreads south to Newfoundland waters in early January. It normally reaches Notre Dame Bay in late January (Figure 2.10), leaving Notre Dame Bay by mid June (DFO 1980). The timing and extent of ice coverage is highly dependent upon wind conditions, with strong, sustained easterly or northeasterly winds prolonging the ice season in this area. Sea ice, depending upon its origin can range from 0.8 to 1.2 m in thickness. Icebergs are common in the study area and may occur at any time of year with April, May and June being the peak months (DFO 1980). Landfast ice may form in sheltered embayments and last up to 14 weeks (Hiscock and Maloney *in* Forbes 1984.

Seaconsult (1985) analyzed 25 years (1959-84) of ice data and concluded that the earliest arrival date for Notre Dame Bay was December 18 and the latest departure date was July 2 (LFA 1990). Fast-ice persists in the small bays and inlets of Notre Dame Bay for most of the season. Open water leads do not normally occur until the fast-ice begins to deteriorate. A lead sometimes occurs along the SE coast of the bay (Seaconsult 1985 *in* LFA 1990).

Prinsenberg et al. (1997), using DFO's long term Bonavista transect and Station 27 oceanographic data and Environment Canada ice and weather data, concluded that interannual variability of sea ice extent was related to atmospheric circulation conditions as determined by the Icelandic Low. As this low deepens, northwesterly winds increase in the study area, bringing ice and low temperatures. Thickness of pack ice and landfast ice are determined by fall and winter air temperatures and by snow cover (Prinsenberg et al. 1997).



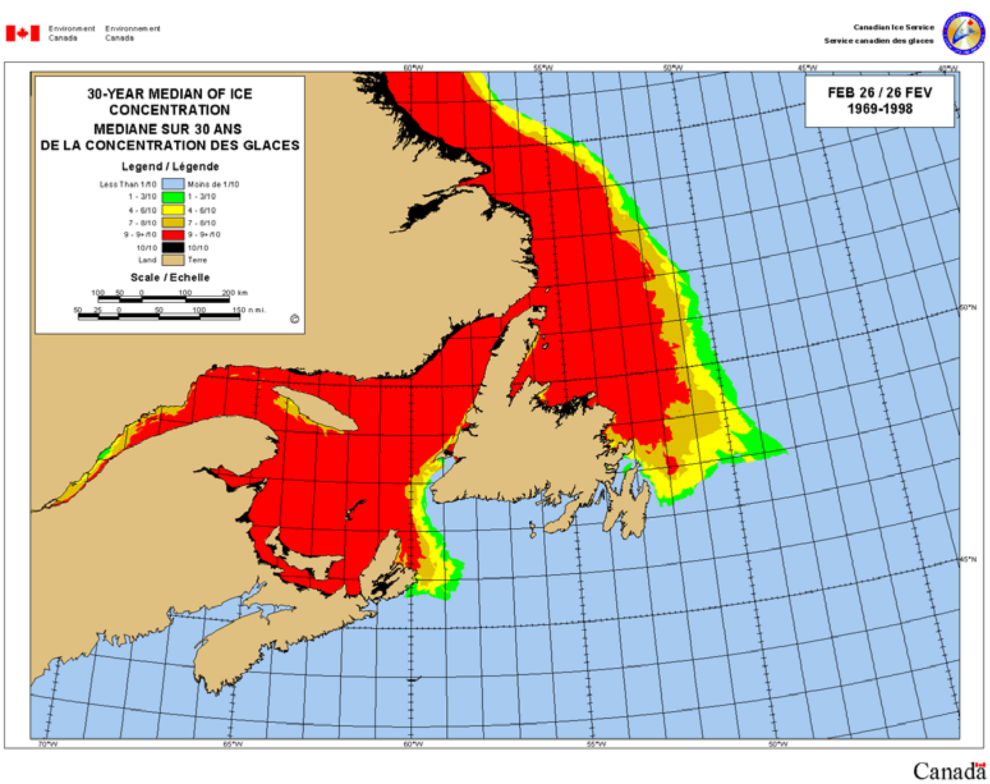
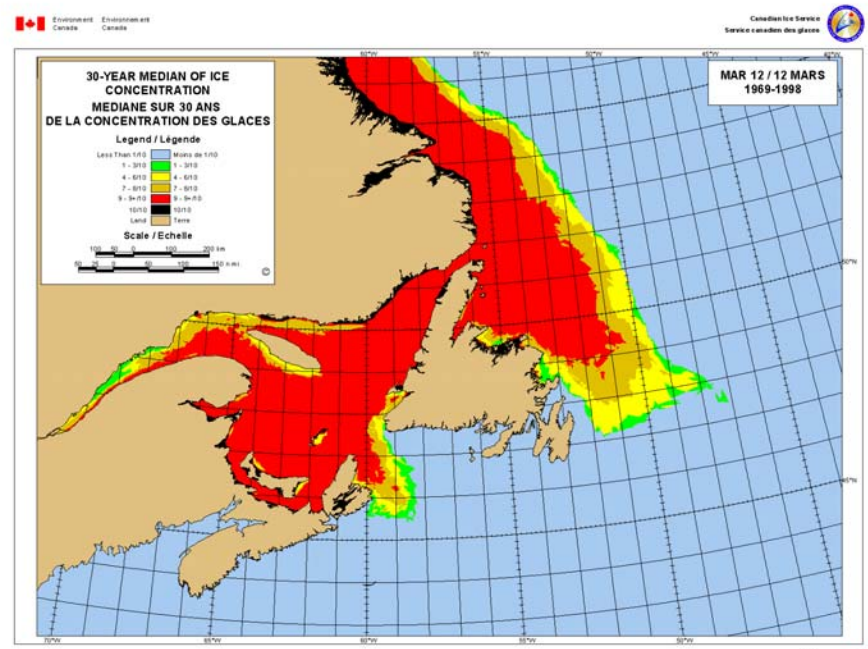


Figure 2.10 - Ice concentration on NE coast and Shelf, 1969-98.



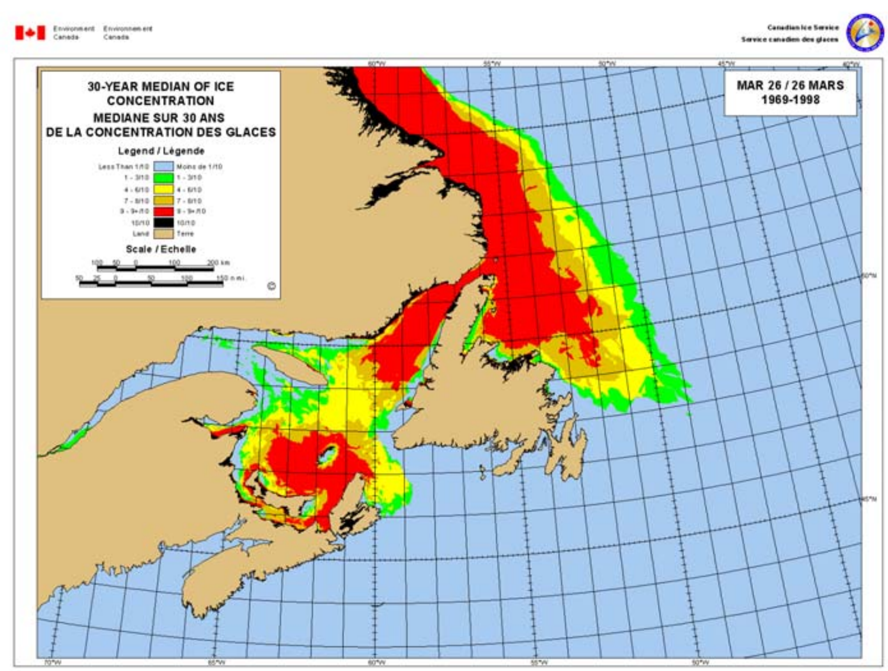
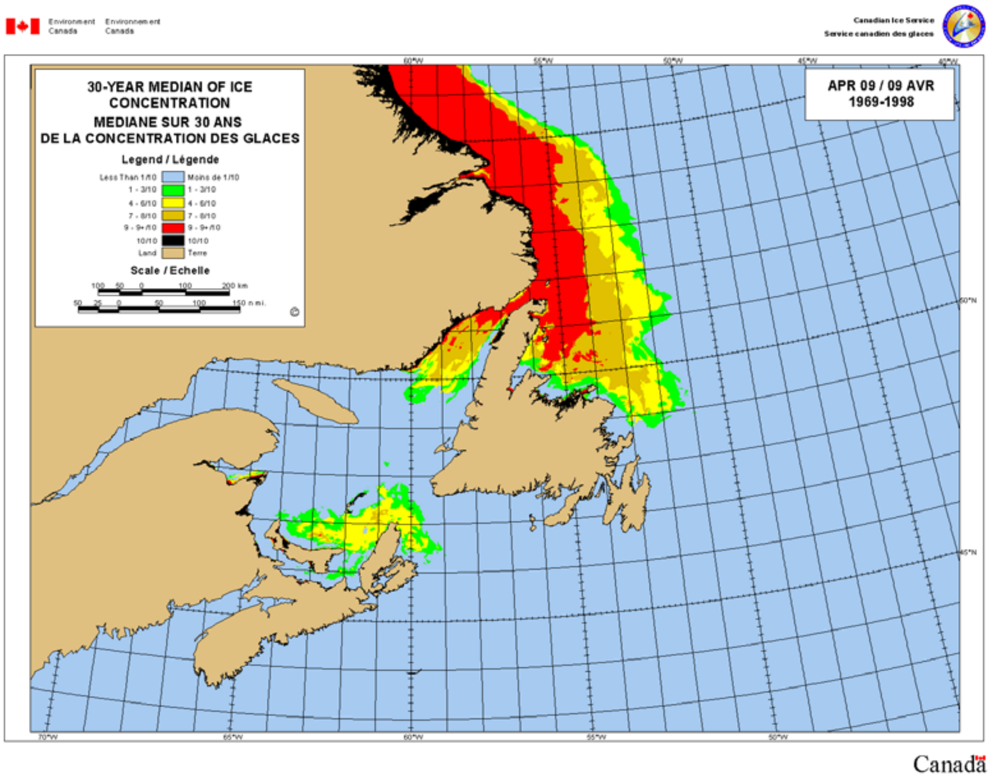


Figure 2.10 Cont'd - Ice concentration on NE coast and Shelf, 1969-98.



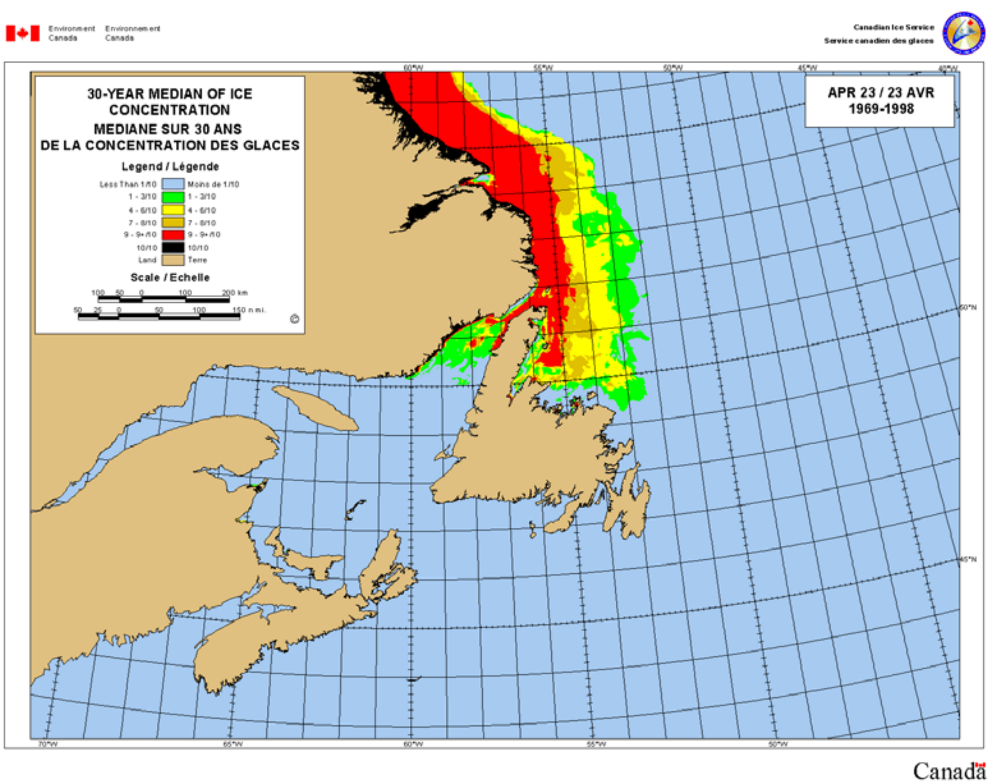
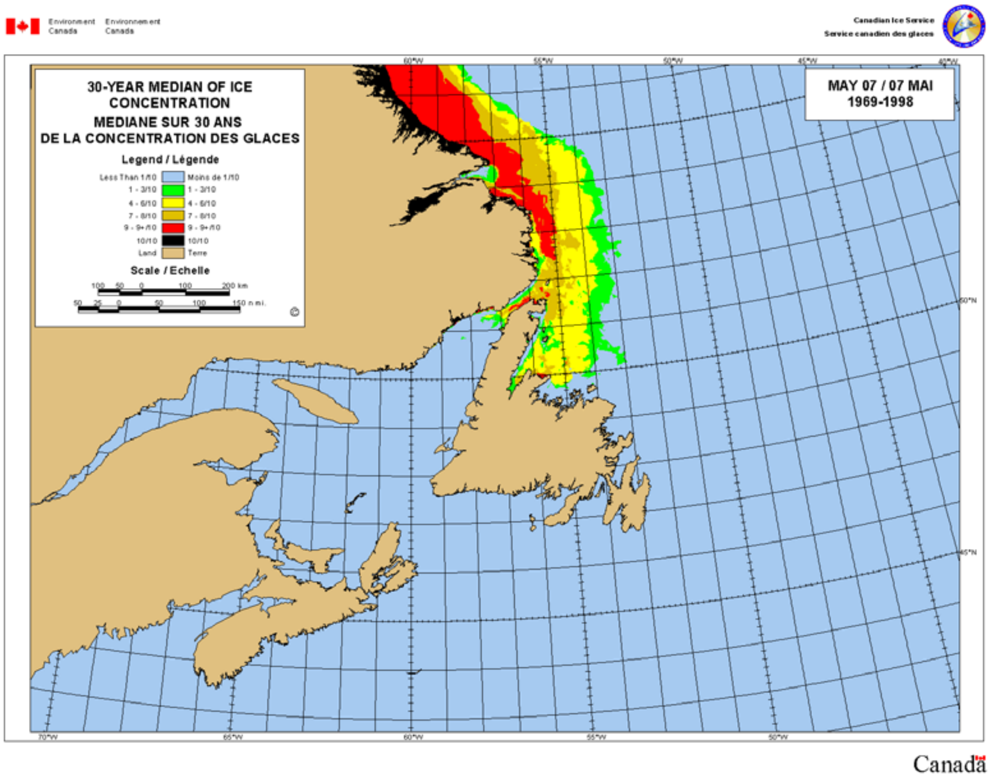


Figure 2.10 Cont'd - Ice concentration on NE coast and Shelf, 1969-98.



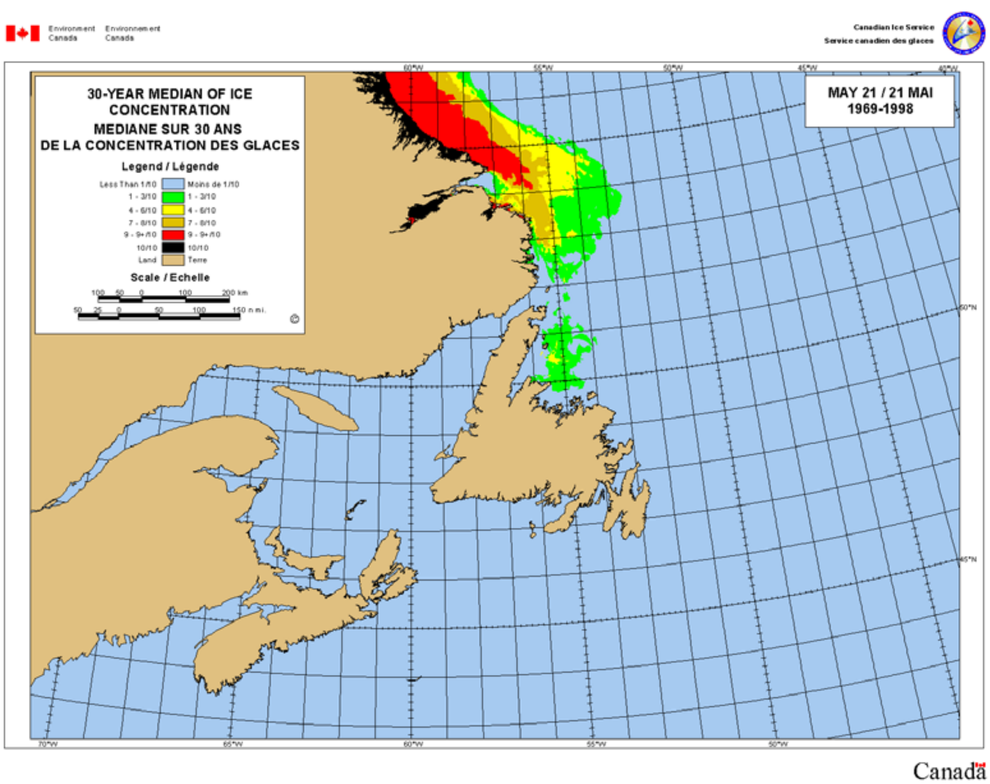


Figure 2.10 Cont'd - Ice concentration on NE coast and Shelf, 1969-98.

3.0 Environmental Changes

Changes in the NW Atlantic oceanographic conditions are evident based on extensive current meter, drift buoys, and CTD data and the long term transects (e.g., Bonavista) and Station 27 off St. John's (Colbourne et al. 1997). Since the late 1980s, the Northwest Atlantic has experienced severe meteorological, oceanographic and ice conditions. This is a direct consequence of the air mass relationship between the Icelandic low and the high pressure over the Azores. Station 27 data showed temperatures in the early 1990s from 0.25 to 0.75ºC below the 1950 to 1989 mean throughout the water column with some depths as much as 3.0ºC below normal. Bottom temperatures have been about 0.5 to 1.0ºC below normal since 1986, the longest time since measurements began in 1946. The salinity data (fresher in summer and winter; saltier in September and October) confirmed the delay in spring warming (Colbourne et al. 1997).

The Bonavista transect has been sampled since 1950. Data from this transect confirmed the cooling trend observed at Station 27 in the early 1990s in that the cold intermediate layer of the Labrador Current was colder, thicker and covered more area than normal (Colbourne et al. 1997). Over the whole NE Newfoundland Shelf, average bottom temperatures were colder than normal. However, in water depths greater than 200 m, bottom temperatures have been normal throughout the region.

In the current meter data, there was not a clear distinction between the inshore and offshore branches of the Labrador Current but rather a continuously increasing speed from 0.05 to 0.10 m/s nearshore to over 0.20 m/s at the shelf edge. Water transport along 150 km of the Bonavista transect represents about 15 to 20% of the total flow of the Labrador Current. There is some evidence that transport here was somewhat greater (but not statistically significant) than normal during the cold period (Colbourne et al. 1997).

The cooling trend on the Newfoundland Shelf reported by Colbourne et al. (1997) apparently reversed in the mid-1990s (DFO 1998a) with a noticeable warming in 1995 and subsequent years. In 1999, air temperatures were above normal, ice extent and duration was below normal, surface and bottom water temperatures were above normal, and the volume of subzero water was below normal and much below the cool period in the early 1990s (DFO 2000a).

In summary, physical environmental changes can affect fish stocks in a variety of complex, not always straightforward, ways. The physical environment may affect feeding, growth and maturation rates, migration patterns, egg hatching, larval settlement, predation rates and other variables. There appears to have been a recent shift in the species composition on the Grand Banks with a decrease in many species in addition to the northern cod, presumably due to environmental changes (Gomes 1993). If changes are occurring on a broad enough scale to affect the Grand Banks, then the Leading Tickles study area would likely be affected as well. On the other hand, in the case of capelin, a key species in the Leading Tickles study area, Carscadden et al. (2001) concluded that predation and not environmental factors was the critical element determining capelin stock size.

4.0 Marine Environmental Quality (MEQ)

The Leading Tickles study area, by North American standards, is a mostly pristine area with relatively few human impacts or inputs. Leading Tickles West is a small rural outport community. It has a land area of 26.1 km^2 and a small and declining population (from 564 in 1991 to 513 in 1996) (Statistics Canada 1996 Census). In 1995, it had a working population of 205, of which 105 were employed in resource-based industries (e.g., fishery, logging, etc.), 90 in service industries and only 10 in manufacturing and construction (Statistics Canada 1996 Census). Thus, it is clear that there is relatively little potential for industrial or other human activity that could create a large environmental impact on a large scale in the study area. Based on infrastructure data contained in the Community-based Coastal Resource Inventory (CCRI) prepared for DFO (EVTA CCRI 2001), potential impacts to the nearshore environment could occur from effluents or small spills of contaminants from the small community, the sawmill, three sewage outfalls, one fish plant, and two government wharves (Figure 4.1). See section 5.2 for a disclaimer regarding the use of CCRI data for biological resources.

The following is a description of the existing fish plant owned by Leading Tickles Seafoods (S. Hannon, Manager, pers. comm.).

The fish plant consists of two buildings: a processing facility 22 years old and a salting facility over 40 years in age. The buildings occupy about 25 x 300’ and are clad with blue vinyl siding. The wharf and plumbing are all new but there are no cold storage facilities. At peak production historically, the plant employed about 20 people processing about 80 to 90% cod with some mackerel and herring. At present, the focus of fishers is on lobster and capelin and these are trucked from the wharf and not processed at the plant.

Other than the sawmill that is located some distance from the ocean, all the major sources of human input identified in EVTA CCRI (2001) are concentrated in Leading Tickles West (i.e., Cull Island) and Leading Tickles South.

Marine water quality data are very scarce in and adjacent to the study area. Coastal conductivity (an indicator of salinity) and temperature by depth (CTD) data (1986-87, uninterpreted), including stations in or immediately adjacent to the study area are available from Schillinger et al. (2000). Seawater characteristic data for seven nearby potential mussel growing sites might also provide some relevant data (see Dabinett and Clemens 1994), albeit outside the study area. There are no registered aquaculture sites within the Leading Tickles study area (DFA Aquaculture Database). However, there is a development license for blue mussels issued for Lockport Harbour, Seal Bay just to the west and a blue mussel commercial license for Budgell’s Harbour, Osmonton Arm, just east of the study area. Information on aquaculture siting can be obtained from colintaylor@gov.nl.ca and on water quality from dave.curtis@ec.gc.ca.

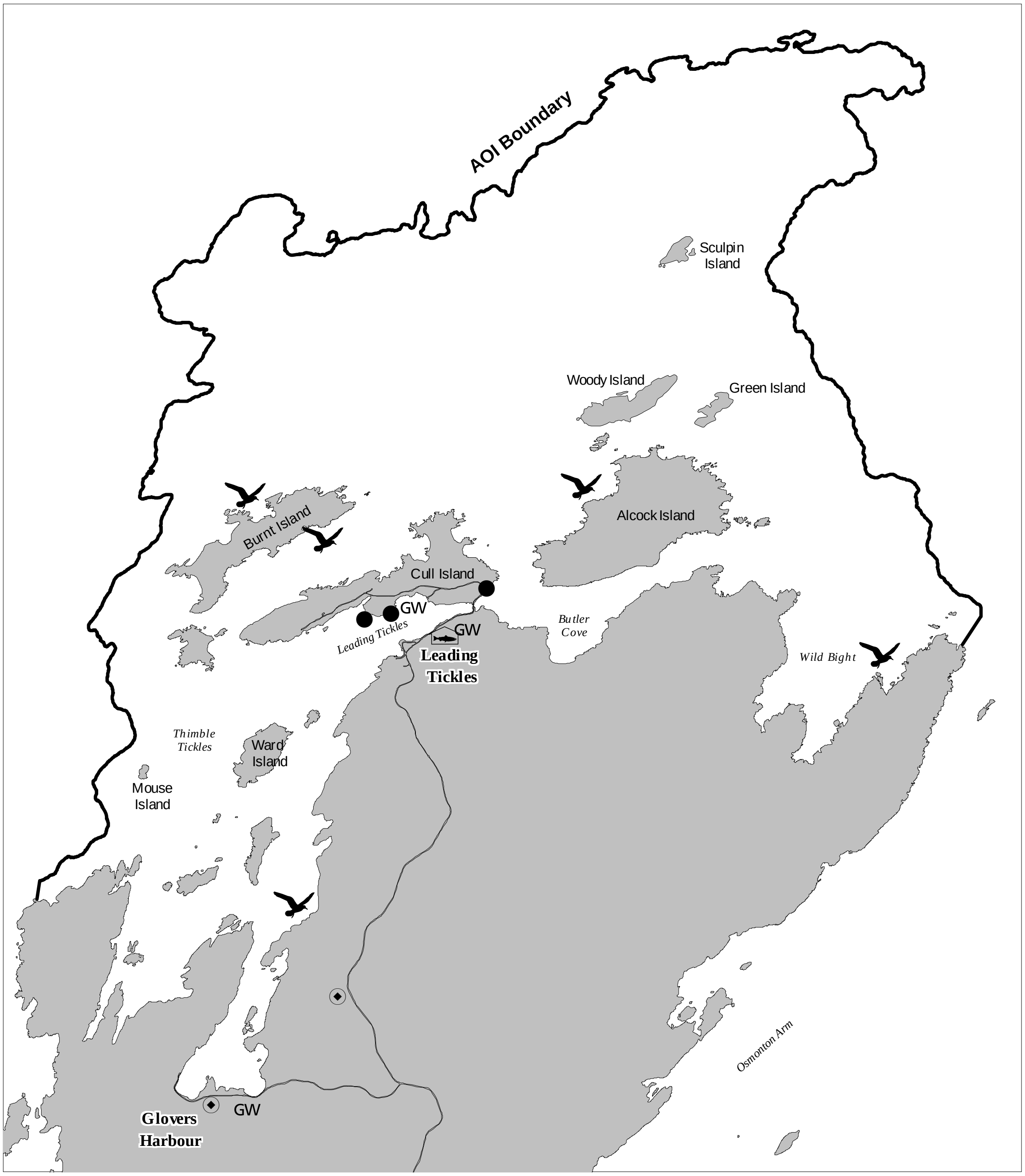


Figure 4.1 Seabird colonies and effluents in Leading Tickles study area. From EVTA CCRI (Feb. 2001).

As stated above, the Leading Tickles study area is flanked by waters approved for blue mussel harvesting. These approvals can be considered an indication of good water quality because blue mussels tend to concentrate contaminants and as such make good sentinels of marine environmental quality (see Christian and Buchanan 1998). There are, however, waters within Notre Dame Bay that are closed to shellfish harvesting because of water quality or paralytic shellfish poisoning (PSP) problems. There is no comprehensive map of these sites whose locations may change from time to time in any event. Some indication of the locations can be obtained from the site-specific maps on the Internet at www.ns.ec.gc.ca/epb/sfish/maps/nf/area6.html with the warning that the nearest DFO office should be contacted for the most up-to-date information on closures.

5.0 Biological Overview

5.1 Surrounding Ecosystem

An ecosystem can be defined as an inter-related complex of chemical, physical and biological components that together form a whole functioning unit in nature. The complexity is demonstrated by the food web depicted in Figure 5.1. 'Ecosystem' is imprecise terminology in terms of scale because the unit is often defined by the user depending upon what they are trying to illustrate. For example, marine scientists may use geographic definitions at differing scales such as nearshore or offshore ecosystem, bay ecosystem, Grand Banks ecosystem, NW Atlantic ecosystem or even an oceanic ecosystem. Some scientists refer to separate ecosystems based on function or location in the water column (e.g., planktonic or benthic ecosystem).

The study area can be considered to fall within the NE Shelf Ecosystem (see Figures 1.1 and 1.2). This section describes the characteristics of important components of this ecosystem such as nutrients, phytoplankton, zooplankton (invertebrates, fish eggs and larvae), nekton (jellyfish, juvenile fish, squid), fish, benthos, marine birds and mammals. Discussion is also included on the ecosystem context of the various components.

In simple terms, the NE Newfoundland Shelf ecosystem is structured in similar fashion to other marine ecosystems in that primary production by plants (phytoplankton and seaweeds), nurtured by nutrients (various forms of nitrogen, phosphorus, and silicate) and sunlight, under suitable conditions of temperature, salinity, currents, substrates, and so forth, form the base of the system. Herbivorous animals (e.g., planktonic copepods and benthic sea urchins) are consumed by first level predators represented by a vast diversity of organisms ranging from small worms to large whales, which in turn are preyed on by other predators. Waste products and dead material are processed by bacteria and a huge variety of scavengers, ultimately to be rendered back to basic elements and nutrients.

The NE Newfoundland Shelf ecosystem can be considered unique due to its unique oceanographic conditions as influenced by its location, bathymetry, Labrador Current, ice conditions, and other environmental factors. All of these physical factors affect the biology of the ecosystem, of which the Leading Tickles study area is an integral part.

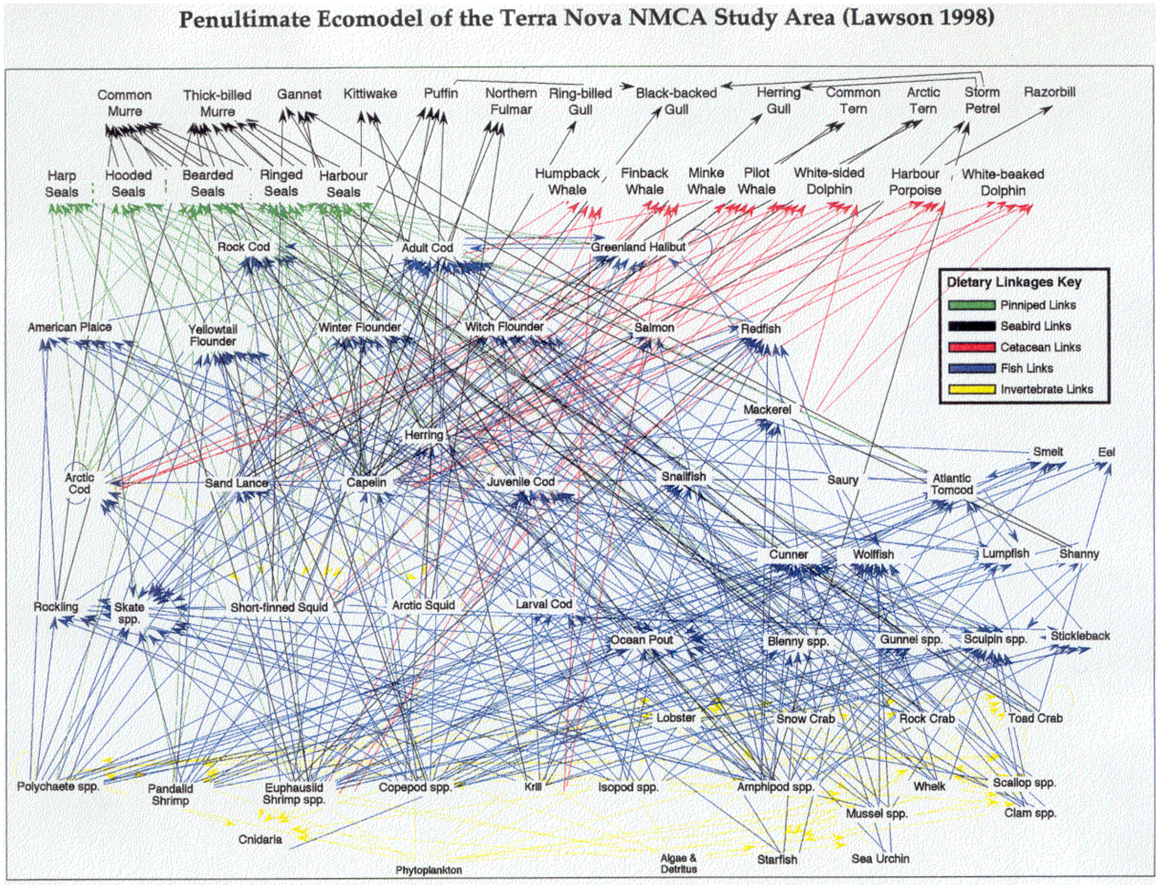


Figure 5.1 Proposed food web for Terra Nova area. From Lawson (1998).

5.2 Important Species in the Study Area

Based on the EVTA CCRI (2001) maps and other sources, a number of important species are known to occur, at least occasionally, in the Leading Tickles study area (Table 5.1). However, it should be noted that other than the CCRI there is little documentation describing the specific biological resources of the study area.

Table 5.1. Summary list of important species known to occur in the Leading Tickles study area. Note that the bird and mammal lists should be considered tentative because they have not been documented.

Common Name	**Scientific Name (s)**
Seaweeds	
Eelgrass	*Zostera marina*
Irish moss	*Chondrus crispus*
Kelp (winged, finger, cabbage kelp)	*Alaria esculenta, Laminaria digitata, Laminaria longicirrus*
Rockweed	*Ascophyllum nodosum*
Invertebrates	
Mussel (blue)	*Mytilus edulis*
Clam (soft shell)	*Mya arenaria*
Periwinkle (Snail)	*Littorina spp.*
Whelk	*Buccinum undatum*
Giant scallop	*Placopecten magellanicus*
Toad crab	*Hyas spp.*
Rock crab	*Cancer irroratus*
Snow crab	*Chionoecetes opilio*
Lobster (American)	*Homarus americanus*
Sea urchin (green)	*Strongylocentrotus droebachiensis*
Squid	*Illex illecebrosus*
Fish	
American plaice	*Hippoglossoides platessoides*
Atlantic cod	*Gadus morhua*
Lumpfish	*Cyclopterus lumpus*
Skate	*Raja radiata*
Turbot	*Rheinhardtius hippoglossoides*
Winter flounder	*Pleuronectes americanus*
Witch flounder	*Glyptocephalus cygnoglossus*
Redfish	*Sebastes spp.*
Sea-run brook trout	*Salvelinus fontinalis*
Capelin	*Mallotus villosus*
Eel (American)	*Anguilla rostrata*
Herring (Atlantic)	*Clupea harengus*
Mackerel (Atlantic)	*Scomber scombrus*
Salmon (Atlantic)	*Salmo salar*

Common Name	**Scientific Name (s)**
Smelt (rainbow)	*Osmerus mordax*
Shark (spiny dogfish)	*Squalus acanthias*
Seabirds	
Cormorant	*Phalarocorax spp.*
Gulls	*Larus spp.*
Terns	*Sterna spp.*
Black Guillemot	*Cepphus grylle*
Bald Eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*
Northern Gannet	*Morus bassanus*
Greater Shearwater	*Puffinus gravis*
Sooty Shearwater	*Puffinus griseus*
Northern Fulmar	*Fulmarus glacialis*
Leach's Storm-Petrel	*Oceanodroma leucorhoa*
Turr (Common Murre, Thick-billed Murre)	*Uria aalge, Uria lomvia*
Marine Mammals	
Humpback whale	*Megoptera novaeangliae*
Minke whale	*Balaenoptera acutorostrata*
White-beaked dolphin	*Lagenorhynchus albirostris*
Harbour porpoise	*Phocoena phocoena*
Grey seal	*Halichoerus grypus*
Harp seal	*Phoca groenlandica*
Hooded seal	*Cystophora cristata*
Harbour seal	*Phoca vitulina*

The following sections describe the importance, distribution, reproduction and habitat of these important species that are known to occur in the study area. Additional species that probably occur in the area are mentioned in the text where appropriate. Major sources of information were the reviews conducted by LGL Limited for DFO (e.g., DFO Fact Sheets; Christian 2001; Grant 2001a), EVTA CCRI (2001), and a number of other university, government and consultant reports. The CCRI is a major source of information but the reader should note it is based on interview information with local residents and as such is somewhat anecdotal. Furthermore, not all of the information in the CCRI has been verified by DFO and thus it should be used with some caution. Nonetheless, it is the opinion of the authors that the CCRI data for Leading Tickles appear to be an accurate reflection of the biological resources of the area. A brief list and description of plant and animal species commonly encountered in Notre Dame Bay is contained in Burry (1991).

5.3 Plankton

Plankton refers to those plants and animals that more or less drift with water currents. Plankton includes bacteria, fungi, phytoplankton (algae), juvenile and adult invertebrates, and many species of fish eggs and larvae (ichthyoplankton). Some plankton is capable of vertical migration within the water column in response to light and other environmental factors such as water temperature. Their distribution and abundance is determined by oceanographic conditions and season. In the North Atlantic, plankton abundance typically peaks in the spring, often with a lesser peak in the fall. Plankton may occur in aggregations caused by oceanographic conditions such as upwelling, vertical or horizontal fronts or behaviours that create 'swarms.' These aggregations are often exploited by feeding fish, sea birds, seals and whales and other predators.

On the NE Shelf, the conversion of water and carbon dioxide into organic matter using sunlight (primary production) is accomplished mostly by phytoplankton and macrophytes (seaweed) in the upper 50 m or so of the water column. Important nutrients used by the plants during this process include various forms of nitrogen, silicon and phosphorous. Nutrients are recycled into the upper water column by upwelling of near-bottom water, microbial activity, and animal excretion. The resulting biomass forms the base of the food web that supports higher life forms. Lawson (1998) studied the energy flow in the greatest proportion of the estimated biomass near the study area during summer, followed by shrimp (*Pandalus*), Arctic cod and rock cod. Seals and whales accounted for relatively little biomass. During the summer, jellyfish and ctenophores (comb jellies) may be the most important predators in the study area, followed by capelin, and to a lesser degree herring, shrimp and common murre (turres) in terms of biomass flow (Lawson 1998). Potentially important energy pathways on the NE Shelf are illustrated in Appendix A.

Zooplankton plays a key role in the NE Shelf ecosystem as elsewhere in the world's oceans. Herbivorous species such as certain copepods (a group of small crustaceans) feed on phytoplankton and in turn, are fed upon by predacious invertebrates, fish, birds and marine mammals. Their grazing on phytoplankton provides a critical pathway for nutrient regeneration, and it influences phytoplankton species composition and biomass. Further up the food chain, invertebrate zooplankton such as young copepods can increase fish abundance because copepods are an important food source for young fish. Calanoid copepods are generally believed to be the most important zooplankton group in the NW Atlantic, at least in terms of biomass. The copepod *Calanus finmarchicus* typically represents the greatest biomass of copepods in the spring (Campbell and Head 2000). The eggs and nauplii of copepods are important prey items for many species of fish larvae, including the key species capelin (Campbell and Head 2000). A complete list of copepods (>150 species) that could occur in the study area is contained in Tremblay and Anderson (1984). The degree of recruitment success of young fish may be linked to the availability and abundance of prey at critical times (Cushing 1975 *in* Campbell and Head 2000). Many other species may also influence the planktonic community; for example, predacious zooplankton species such as jellyfish can decrease the abundance of fish by predation upon fish eggs and larvae.

Many species of fish have planktonic eggs and/or larvae; some examples include cod, capelin, haddock, flounders, redfish, sand lance and others.

Plankton in Newfoundland nearshore waters, including the Leading Tickles study area, has not been extensively studied. Labrador Shelf research on temperature, salinity, nutrients, phytoplankton, zooplankton and icthyoplankton includes Buchanan and Foy (1980a,b), Buchanan and Browne (1981), and Drinkwater and Harding (2001). Studies of the inner branch of the Labrador Current are of some relevance to the NE Newfoundland Shelf and the Leading Tickles study area.

DFO has been sampling plankton and nekton over a broad geographic area including several stations in or immediately adjacent to the study area, at least from 1994 to 1997 (Dalley and Anderson 1998). In general, these authors found zooplankton biomass to be greatest in the north, in some cases in or adjacent to the Leading Tickles study area, depending upon the size ranges analyzed.

5.4 Benthos and Benthic Habitat

Benthos refers to plants and animals that live at the seabed. The group has very diverse lifestyles and includes attached micro- and macro-algae and invertebrates (e.g., barnacles, mussels, anemones, etc.), mobile members such as crabs and sea stars, as well as animals that live in the sediment (e.g., polychaete worms, molluscs, crustaceans, and others). Commercially important benthos includes some species of seaweeds, urchins, clams, scallops, lobster, shrimp and crab. Some species of fish are closely associated with the benthos and may use the bottom substrate for cover, feeding and egg-laying. Some fish (e.g., herring, lumpfish, sandlance) attach their eggs to the substrate (i.e., demersal eggs). The composition of the benthic community is highly related to substrate type and water conditions and depth.

Benthic animals have a variety of feeding behaviours, including filtering, scraping, boring, scavenging, engulfing and seizing. Some have the ability to absorb nourishment from dissolved organic material. They form an important food resource for many species of fish, including flatfish and cod.

In the development of a general marine coastal habitat classification scheme for Newfoundland and Labrador, Hooper (1997) attempted to simplify extremely complex ecosystems by using a very pragmatic scheme. Based on thirty years of direct observation during more than 5,000 scientific SCUBA dives, Hooper (1997) proposed thirteen different habitat types. For each of these habitat types, he highlighted biological (key flora and fauna) and physical parameters (e.g., substrata, salinity, water temperature, currents, exposure to wave energy, degree of ice scour) that he felt were most important in the characterization process. The habitats discussed are located in the intertidal and shallow subtidal zones.

The coastline in the Leading Tickles area is dominated by bedrock cliffs interspersed by pocket beaches composed of gravel, pebble and cobble. Based only on this predominant geology of the area (hard, stable substrata), benthic community types occurring in the

Leading Tickles study area are most probably described by the biotic groupings associated with the following nine habitat types presented by Hooper (1997). There is considerable variability in the physical characteristics attributed to each habitat type.

1. Periwinkle/Rockweed

   These very high primary production areas tend to be relatively sheltered from wave energy and protected from major ice scour.

   Key benthic fauna typically includes the common periwinkle (*Littorina littorea*), the smooth periwinkle (*Littorina obtusata*), and hydroids (*Dynamena* spp. and *Clava* spp.). The benthic flora includes various rockweed species (*Ascophyllum nodosum* and *Fucus* spp.) and possibly Irish moss (*Chondrus crispus*). Another animal typically associated with this habitat is the snailfish.

2. Kelp Beds

   These extremely productive habitats are more exposed to wave energy than are the 'rockweed' habitats but are also relatively protected from ice scour.

   Key benthic fauna normally include epiphytic hydroids (*Obelia* spp.), epiphytic bryozoans, snails (*Lacuna*, *Margarites*), and various polychaete species. Depending on the degree of wave exposure, the kelp beds could be dominated by any of the following algae: *Alaria* spp., *Laminaria* spp., *Agarum* spp. Other animals often associated with this habitat include amphipods, lobster, scallop and juvenile cod.

3. Sea Urchin Barrens

   Compared to the 'rockweed' and 'kelp' habitats, this habitat type is relatively unproductive. It generally exhibits moderate to full exposure to wave energy and can withstand major ice scour.

   Key benthic fauna includes green sea urchins (*Strongylocentrotus droebachiensis*), limpets (*Tectura* sp.), sea anemones (*Metridium* sp. and *Tealia* sp.) and various sea stars (*Leptasterias* sp., *Asterias* sp., and *Solaster* sp.). The flora is dominated by coralline algal species (*Lithothamnion* sp., *Clathromorphum* sp., *Phymatolithon* sp.). Other animal species sometimes associated with this habitat include flounders, wolffish and cod.

4. Coralline Algal Beds

   The high biomass and diversity of benthic invertebrates make coralline algal beds important feeding habitat. This habitat type typically has moderate to full exposure to wave and current energy.

Benthic fauna typically includes chitons (*Tonicella* sp.), brittle stars (*Ophiopholis* sp.), horse mussels (*Modiolus modiolus*), and truncate clams (*Mya truncata*). Key benthic flora would be predominated by the coralline algal species *Lithothamnion glaciale*. Other animal species often associated with this habitat might include winter flounder, yellowtail flounder, ocean pout, wolffish and juvenile cod.

5. Lobster Grounds

   As the name implies, these areas are locally very valuable as grounds for lobster fisheries. This habitat displays wide ranges of current strength and exposure to wave energy.

   Lobster (*Homarus americanus*), green sea urchins (*Strongylocentrotus droebachiensis*), mussels (*Modiolus modiolus* and *Mytilus* sp.), brittle stars, and crabs (*Cancer* sp. and *Hyas* sp.) comprise the key benthic animal species on this type of habitat. The predominant flora include coralline algae, *Desmarestia* sp. (filamentous brown alga), and sometimes kelp species. Other animals typically associated with this benthos include winter flounder and eel pout.

6. Ice Scoured Shores

   This habitat type is normally very productive in spring and summer due to the high mortality of herbivores caused by ice scour. The resultant microherbivores are ideal food for small fish such as juvenile cod.

   The key benthic fauna and flora typically associated with this habitat type include snails (*Lacuna* sp. and *Margarites* sp.) and numerous ephemeral algal species such as *Urospora* sp., *Spongomorpha* sp., *Chordaria* sp., *Dictyosiphon* sp., *Alaria* sp., *Pilayella* sp., *Polysiphonia* sp., and *Porphyra* sp. Other animals often associated with this benthos include amphipods, copepods, snailfish and juvenile cod.

Based on information from EVTA CCRI (2001), there are other commercially important benthic species occurring in the Leading Tickles study area that are not typically associated with the hard, stable substrata habitats discussed above. These include the giant (sea) scallop (*Placopecten magellanicus),* clams (*Mya* sp., *Ensis* sp. *Cyrtodaria* sp.), snow crab (*Chionoecetes opilio*), waved whelk (*Buccinum undatum*) and eelgrass (*Zostera marina*).

Referring once again to Hooper's (1997) marine coastal habitat classification scheme, the other habitat types that are associated with these species are 'seagrass beds', 'clam beds', and 'scallop beds'.

7. Seagrass Beds

These sheltered sand/fine gravel areas with minimal erosion are very productive and serve as important feeding areas for the juveniles of many fish species. Herring often spawn in this type of habitat.

Key benthic floral and faunal species in this habitat include seagrasses (*Zostera marina* and sometimes *Ruppia* sp.), and polychaetes (*Nereis* sp., *Saccoglossus* sp., *Arenicola* sp.). Other animal species often associated with seagrass bed areas include sand shrimp (*Crangon* sp.), sticklebacks (*Gasterosteus* sp.) and American eels (*Anguilla* sp.).

8. Clam Beds

There are numerous types of clam beds with different current and temperature regimes and different degrees of exposure to wave energy. However, most have sand/fine gravel substrata and full salinity.

Key benthic faunal and floral species typically associated with this habitat include soft shell clams (*Mya* sp.), razor clams (*Ensis* sp.), propeller clams (*Cyrtodaria* sp.), ocean quahogs (*Arctica* sp.), cockles, moon snails (*Lunatia* sp.), sand dollars (*Echinarhachnius* sp.), polychaetes (*Nephthys* sp.), and numerous microscopic algae (e.g., diatoms, chrysophytes). Other animals often utilizing these habitat types include numerous flatfish species and sand lance.

9. Giant Scallop Beds

Giant scallop beds are most abundant in shallow sheltered sand/fine gravel locations with warm summer water temperatures. Key fauna and flora typically associated with this habitat include giant scallops (*Placopecten magellanicus*), toad crabs (*Hyas* sp.), rock crabs (*Cancer* sp.), hermit crabs (*Pagarus* sp.), polychaetes (e.g., *Myxicola* sp.), sand dollars (*Echinarhachnius* sp.), chitons (*Tonicella* sp.), and fleshy algal species, such as kelp.

Snow crabs are deeper water benthic animals, normally occurring at depths of 50 m or more. The larger snow crabs tend to be distributed in deeper water than the smaller ones and often occur on much harder substratum.

Waved whelks exhibit broad habitat preferences and may occur on both hard and soft substrata. The distribution of this gastropod is very widespread in Newfoundland and Labrador waters.

It is likely that most, if not all, of the communities described above occur within the Leading Tickles study area. However, the distribution and relative importance of these communities is not known for the study area.

5.5 Marine Plants and Algae

Marine plant and algae research in the Newfoundland environment by LGL Limited has shown plant species and biomass distributions to be closely related to the physical environment (e.g., LGL 2001). Marine plant and algae species distributions are strongly correlated with coastal exposure in that sheltered intertidal areas tend to be dominated by rockweeds *Ascophyllum* sp. and *Fucus* sp. while more exposed subtidal areas tend to be dominated by kelps *Laminaria* sp. and *Alaria* sp. (Lee et al. 1998; LGL 2001). Areas with sand and fine gravel substrates may be devoid of plants and algae in exposed locations (newly settled plants are constantly removed by wave and/or ice action and a lack of adults reduces the dispersion of germlings and new plants). In a sheltered location, sand and fine gravel substrates can sustain less vigorous rockweed and kelp populations; however, these tend to be tenuous and easily damaged/ removed by wave or ice action (Lee et al. 1998; LGL 2001). Bedrock, boulders, and coarse gravel/ cobble substrates can support long-term and relatively stable rockweed and kelp beds. Given a suitable substrate, marine plant and algae distribution is usually determined by depth. Rockweeds are typically encountered within the upper and intertidal zones (commonly exposed to air at low tides) with the subtidal region dominated by the kelps (Lee et al. 1998; LGL 2001). Eelgrass was the predominant species encountered at estuarine or brackish locations that typically exhibited a sand and/or fine gravel substrate (Lee et al. 1998).

Marine environmental quality can affect the distribution of marine plants and algae. Sewage outflow, industrial effluents, agriculture runoff, aquaculture inputs, and atmospheric deposition have been demonstrated to reduce the biomass, plant quality, and extent of rockweed beds (Rueness 1973; DFO 1999).

Shoreline plant and algae beds are important habitat for a number of fish and invertebrate species (LGL 2001). Gastropods, blue mussel (*Mytilus edulis*) spat and juveniles, and polychaetes (*Spirobis* sp.) are most common and may be present in sufficient numbers to completely cover the branches and stalks of *Ascophyllum* sp. within a bed. Amphipods and isopods (both on the substrate and free-swimming within branches) are also commonly encountered in high numbers. Rock crab (*Cancer* sp.), shore shrimp (*Palaemonetes* sp.), winter flounder, and juvenile Atlantic cod have also been observed to utilize marine plant and algae habitat (LGL 2001). Rockweed investigations conducted in the Maritimes have identified 31 fish species and over 100 invertebrate species that are commonly associated with rockweed (DFO 1999). A range of waterfowl have also been found in association with marine plant beds including purple sandpipers, kingfisher, common tern, Bonaparte's gull, common loon, double-crested cormorant, osprey, and common eider (DFO 1999). Eider ducklings are particularly dependent upon rockweed habitat for food (invertebrates within beds) and predator shelter at a stage when their ability to dive is poorly developed (Mann 1992). Bonaparte's gull is very rare in Newfoundland and thus probably does not occur in Leading Tickles (B. Mactavish, pers. comm.). It is not known if eiders reproduce in the Leading Tickles area.

Over the past decade, the Newfoundland seaweed industry has created employment opportunities for harvesters and processors that were displaced by the 1992-93 cod moratorium. Commercial/ experimental harvesting and processing operations have been established at Isle aux Morts, Ramea, and Lamaline. As a recent 'fishery', the marine plant and algae industry has the potential to produce long-term employment opportunities in rural Newfoundland. Harvesting efforts to date have mostly concentrated on the rockweeds (*Ascophyllum* sp., *Fucus* sp.) and less so on the kelps (*Laminaria* sp., *Alaria* sp. etc.). Seaweeds are harvested by hand, sun-dried and ground into powdered form for use as fertilizers and food additives.

Rockweed is known to occur along the entire rocky shoreline of the Leading Tickles study area (EVTA CCRI 2001). Eelgrass is restricted in the study area but is known to occur at the head of Glover's Harbour. Many other species of marine plants and algae also likely occur in the study area. The major ones are described below.

5.5.1 Eel Grass

Eelgrass, *Zostera marina*, is a green flowering plant (Anthophyta) with a limited distribution within the Leading Tickles study area (Figure 5.2).

Importance

Historically, eelgrass (has been used for various uses such as stuffing mattresses and packing material (DFO Coastal Zone Species Profile Series No. 18). It no longer has direct commercial value but has great ecological importance as habitat for juvenile fishes (Grant and Brown 1998a,b).

Distribution

Eelgrass is found on both sides of the Atlantic. In the NW Atlantic, it occurs from northern Labrador to South Carolina and in the east it occurs along the coast of Western Europe. It also is found in the North Pacific (DFO Coastal Zone Species Profile Series No. 18).

Reproduction

Eelgrass has a typical flowering plant life cycle. It is a perennial that reproduces by underwater flowers that are fertilized by waterborne pollen in waterproof packets (DFO Coastal Zone Species Profile Series No. 18). It also spreads through a system of roots and rhizomes (creeping runners). Eelgrass flowers in late spring to early summer producing shoots bearing fruits that house rows of rice-sized seeds. The shoots detach, float to the surface, and are transported by currents.

The majority will germinate in the spring, producing the new eelgrass when the risk of desiccation (drying) and freezing is low.

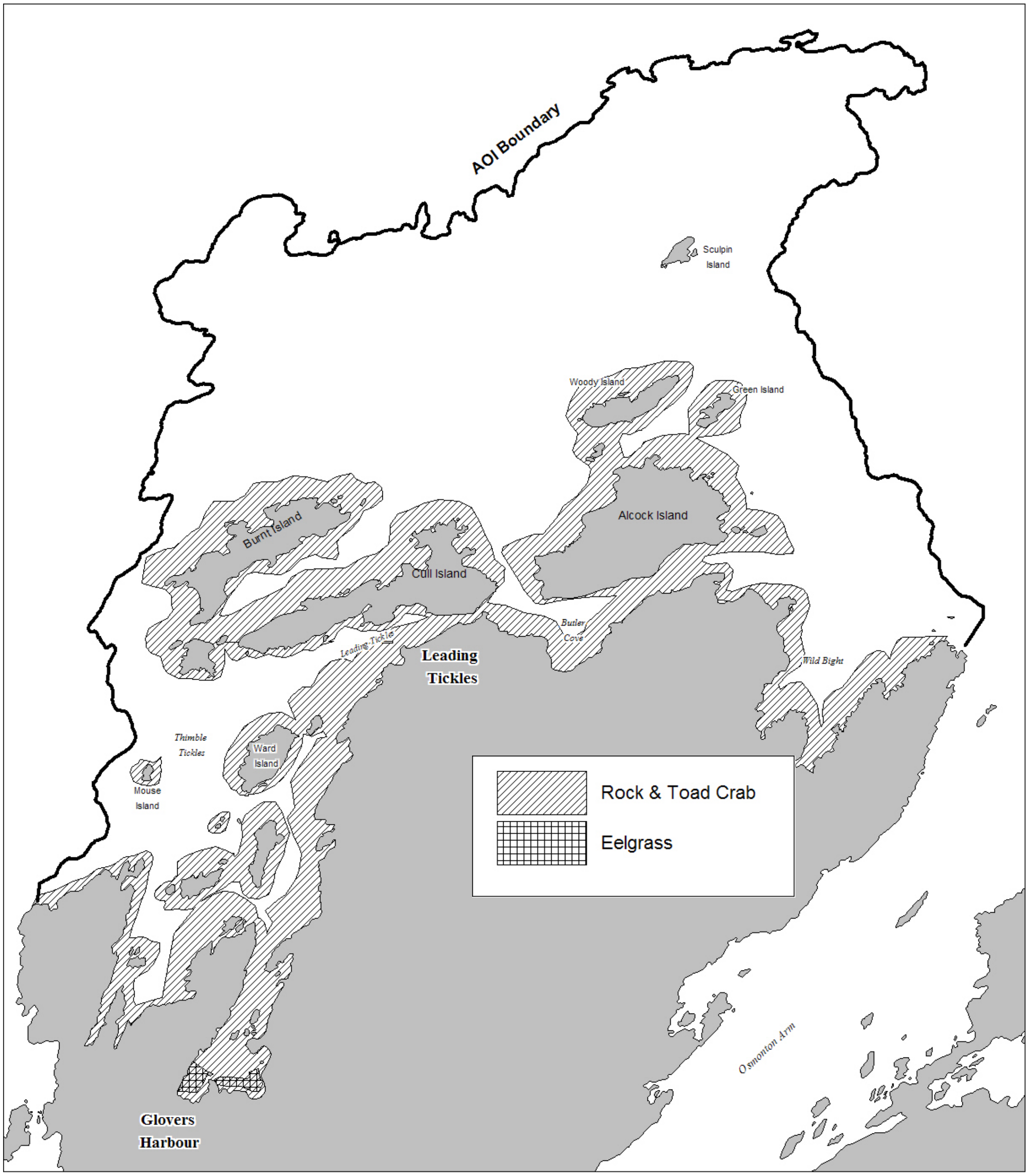


Figure 5.2 General toad and rock crab grounds and eelgrass beds in the Leading Tickles study area. From EVTA CCRI (Feb. 2001).

Habitat

Eelgrass grows on mud, firm sand or gravel mixed with coarse sand (DFO Coastal Zone Species Profile Series No. 18). It is mostly subtidal but can be found in the intertidal zone. It is tolerant of a wide range of salinities. Eelgrass beds tend to stabilize the substrate and trap additional sediment thus providing habitat and food for a variety of animals including fish and waterfowl.

5.5.2 Irish Moss

Irish moss, *Chondrus crispus*, is a red seaweed (Rhodphyta).

Importance

Irish moss is used in various food products and thickeners (DFO Coastal Zone Species Profile Series No. 17). The species also has indirect commercial importance in that it provides food for urchins and important habitat for juvenile fish and lobsters.

Distribution

It is found on both sides of the Atlantic; in the west from northern Newfoundland south to Long Island Sound, New York and in the east it is common on the west coast of Europe.

Reproduction

Irish moss reproduces both asexually (spores) in late summer or fall in Newfoundland and sexually in early summer.

Habitat

Irish moss is found from the lower edge of the intertidal zone to a depth of 18 m along the Atlantic coast. In Newfoundland it is found as under story below the rockweed (*Fucus*) zone and may occur at least as deep as 20 m (DFO Coastal Zone Species Profile Series No. 17).

Irish moss grows attached to hard substrates as rocks, shells, or wood. It is often the dominant species in wave-exposed, stable rock environments.

5.5.3 Kelp

The winged kelp (*Alaria esculenta*), finger kelp (*Laminaria digitata*) and cabbage kelp (*Laminaria longicruris*) are three common brown seaweeds (Phaeophyta) in Newfoundland that often dominate the seaweed biomass at rocky, wave-exposed locations (DFO Coastal Zone Species Profile Series Nos. 13-15).

Importance

Kelps have a wide variety of commercial applications from food additives and supplements to fertilizers and other uses.

Distribution

Winged kelp occurs from the Arctic south to Long Island Sound but is rare north of Labrador and south of Cape Cod. It also occurs along northwestern Europe. The cabbage kelp has a similar distribution. The finger kelp is also found from the Arctic to Long Island Sound and in Western Europe.

Reproduction

Kelps have an unusual life cycle, quite different from terrestrial flowering plants. The large kelp plants are only the asexually reproducing half of the life cycle. The haploid spores (having a single set of genes and chromosomes), released from the sporophylls, swim until they find a suitable habitat within which to settle. They then grow into independent, microscopic filaments that are responsible for sexual reproduction. New kelp blades subsequently develop. The winged kelp produce microscopic filaments most abundantly in the winter, spring, and early summer in Newfoundland, and through the entire summer and fall in Labrador. Finger kelp are reproductively active in the spring in Newfoundland and early summer in Labrador. The cabbage kelp are reproductively active all year long except in mid-summer in the southern part of Newfoundland and May to October in the northeastern part of Newfoundland and Labrador.

Habitat

The kelps grow attached to rocks, shells or other hard substrates in exposed locations. The cabbage kelp is the most tolerant of the three species in terms of high temperature and low salinities. The winged kelp is the least tolerant of high temperature. The winged kelp out competes the finger kelp in ice-scoured areas. The kelps are common in the low intertidal to subtidal at least to 10 m depth.

5.5.4 Rockweed

Rockweed or knotted wrack (*Ascophyllum nodosum*) is a very common brown seaweed (Phaeophyta) in Newfoundland. It is known to occur along the entire shoreline of the Leading Tickles study area (EVTA CCRI 2001).

Importance

Rockweed has a wide variety of commercial uses as food additives, thickeners, supplements, fertilizers and animal feed (DFO Coastal Zone Species Profile Series No. 16). It is used to produce alginate, which is used in making many products including specialty papers, dyes, welding rod coatings and others. Its gelling properties are useful in air fresheners and explosives.

Distribution

Rockweed occurs on both sides of the North Atlantic from the Arctic to Long Island Sound and in Western Europe (DFO Coastal Zone Species Profile Series No. 16). Rockweed is very common throughout Newfoundland.

Reproduction

The knotted wrack has a life cycle that uses sexual reproduction. The parent male or female plant produces sperm and eggs. A zygote (a cell formed from the union of an egg and a sperm cell) develops directly into new plants. In the winter/early spring, mature knotted wrack form short, contrastingly yellow (male) and yellow-green (female) receptacles that grow out sideways (laterally) from the main shoots of the knotted wrack. These receptacles are shed after the egg and sperm cells have been released, usually in July in Newfoundland (rarely in June) and in August in Labrador or during cold summers in Newfoundland (DFO Coastal Zone Species Profile Series No. 16).

Habitat

Knotted wrack is found in the mid to low intertidal zone, especially in bays that are relatively free from ice scour. Free-living sterile mats or ecads (*A. nodosum* ecad *mackaii*) can be found in the upper intertidal, and anchored non-floating forms in the subtidal. The anchored forms tend to densely cover rocks, and with other rockweeds form a distinct zone of aquatic plants with the knotted wrack closest to the water's edge at neap tide (a tide with a minimum range occurring the first and third quarters of the moon) (DFO Coastal Zone Species Profile Series No. 16).

Knotted wracks require rocky substrates for attachment in the intertidal zone and co-occur with other rockweeds. Growth of the knotted wrack is inhibited by water temperatures >20^{o}C. Further, unseasonably warm water temperatures can initiate early growing seasons. Knotted wracks are also limited to habitats of little to no ice scour. In areas of frequent ice scour, other rockweeds tend to dominate (DFO Coastal Zone Species Profile Series No. 16).

5.6 Invertebrates

In the Leading Tickles study area, periwinkles, mussels, urchins, lobster, rock and toad crab are common invertebrates and are harvested in shallow water along most of the coast of the study area (Figures 5.2 to 5.4). Lobsters are taken from one to five fathoms in pots. Rock crabs are trapped at about five fathoms and toad crabs are caught in snail pots set a bit deeper at 5 to 15 fathoms. Snow crabs are harvested in deep water throughout the study area at 50 to 150 fathoms (EVTA CCRI 2001). Divers pursue scallops in a few locations and squid may be present at certain locations and times. Clams are probably occasionally taken by hand or shovel.

The following sections provide a briefing on key distributional, reproductive, and feeding aspects of the important invertebrate species in the study area.

5.6.1 Giant Scallop

Giant scallop (*Placopecten magellanicus*) occur in a number of 'pockets' throughout the Leading Tickles near shore part of the study area (Figure 5.3).

Fishery

Important Canadian commercial sea scallop fisheries occur on Georges Bank, the Bay of Fundy, various banks on the Scotian Shelf, in the Gulf of St. Lawrence and on St. Pierre Bank. Inshore harvesting in Newfoundland occurs mainly along the south coast (Placentia Bay, Fortune Bay, and St. Mary's Bay), and on the west coast in Port-au-Port Bay. A recreational fishery (SCUBA divers) also occurs around the coast of insular Newfoundland. Depending on location, scallops attain size for exploitation by ages 4 to 7.

Distribution

Sea scallops are found in the NW Atlantic from Labrador to Cape Hatteras, North Carolina. In the northern part of their distribution range, they tend to occur in shallower water at depths of less than 20 m while in the southern portion of their range, sea scallops are normally found in water deeper than 55 m. In Newfoundland and Labrador, they are generally distributed throughout the shallow coastal region of insular Newfoundland occurring most often on sand-gravel or gravel-pebble substrates (reviewed *in* Christian. 2001).

Spawning

Sea scallop spawning times vary from July to early October, depending on location (Beninger 1987). Spawning time tends to be later as one moves north within the distribution range. In Newfoundland, sea scallop spawning typically occurs in September and October, specific timing being dependent on latitude and environmental conditions.

Observed bottom water temperatures during spawning and durations of spawning range from 4 to 14°C, and one to five weeks, respectively. Sea scallops are highly fecund, with large females capable of producing well over one hundred million eggs and males several billion sperm (Couturier et al. 1995). There is a strong positive association between female size and fecundity. Fertilization of sea scallop eggs is external, occurring in the water column immediately above the scallop bed.

The pink and brown fertilized eggs are approximately 64 μ in diameter and are planktonic. At 15°C and 32 ppt salinity, the embryos develop to hatching larvae within two to three days. Planktonic sea scallop larvae may be transported out of the spawning area by currents. Therefore, many of the scallop populations are not self populated by their own larvae and spat. At settlement, the spat tend to attach themselves to the underside of shell fragments and other solid materials on the bottom, perhaps as a way to counter predation. The larvae are able to delay metamorphosis to juvenile/adult form for approximately one month while they search for suitable substrate. After settlement, the post-larval scallops are found on various substrate types but seem to prefer firm gravel and cobble areas with good water exchange to

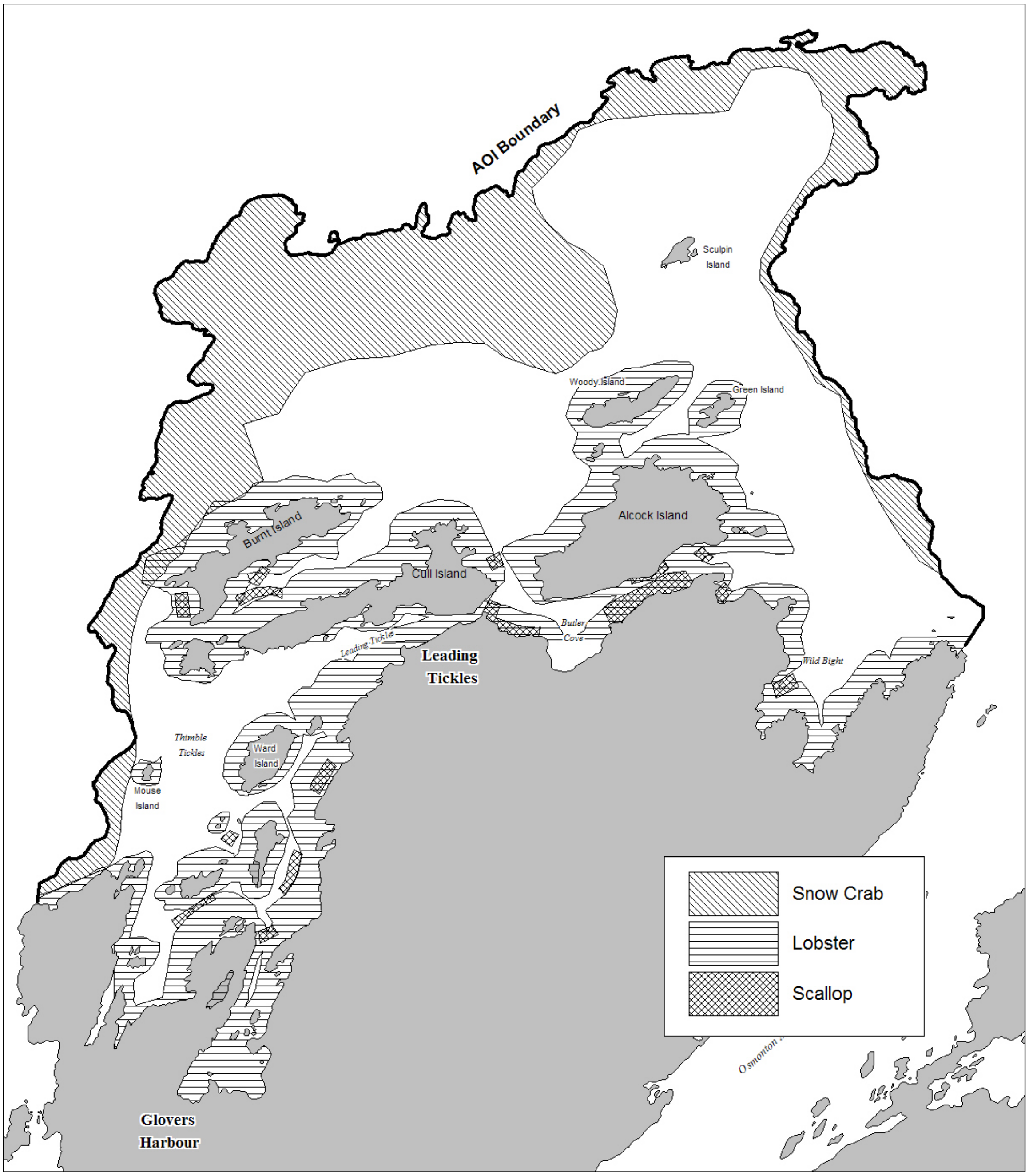


Figure 5.3 General lobster, scallop and snow crab grounds in the Leading Tickles study area. From EVTA CCRI (Feb. 2001).

maximize food and oxygen availability (Hawkins 1996).

The eggs and larvae require uncontaminated seawater within a particular temperature range and the larvae also require an adequate planktonic food supply. Under laboratory conditions, larvae grow well at a water temperature of 15°C but show high mortality at 19°C. They appear to be tolerant of a range of salinities, surviving at salinities as low as 10.5 ppt (Hawkins 1996).

Generally, sea scallops are in juvenile stage (i.e., sexually immature and benthic) for approximately one year. By the onset of their first winter, sea scallops are approximately 5 mm in diameter. Byssal attachments disappear as the scallops grow larger after which time the scallops commence to lie on the bottom. As juveniles and young adults, sea scallops are relatively efficient swimmers and respond with this behaviour to disturbances such as predation and commercial dredging. Sexual maturity is normally reached by age one to two but again, time to maturity varies between locations.

Habitat

A preference for gravel substrate by juveniles has been reported for Nova Scotia inshore habitats although there was some evidence of juvenile scallop seasonal movement between areas of differing substrate and depth (i.e., silty area in early summer and gravel area in the fall) (Kenchington et al. 1991).

Large adult scallops (about 9 cm long) are recessed in the sediment and do not usually move unless physically disturbed. Sea scallops older than 20 years are frequently observed in areas of low exploitation.

Where conditions are favourable, scallops frequently occur in dense local populations known as ‘beds’ (DFO 1989a). Occurrence of a ‘bed’ in a specific area depends on the chance of larval settlement in that area and the subsequent survival rate of a large number of spat. Environmental conditions, including predator presence, dictate both factors.

The sea scallop has been identified as a key organism of the biota assemblage associated with ‘scallop bed’ habitat type characterized by Hooper (1997) as one classification of marine coastal habitat for Newfoundland and Labrador. This scallop is often associated with kelps and other fleshy seaweeds. The geology of this habitat type generally includes sand or fine gravel and other physical characteristics typically include warm summer water temperatures and minimal exposure to wave energy. In Newfoundland, sea scallop beds are most abundant in shallow sheltered sandy locations such as Port au Port, Salmonier Arm, Long Harbour and western Placentia Bay.

Newfoundland shallow water areas (6 to 10 m) may be more favourable for shell growth, somatic growth and gonad production than the deepwater areas (>30 m) (MacDonald and Thompson (1985a,b; 1986). It is not known if this is applicable to the scallop populations in the Leading Tickles area.

Feeding

Sea scallop larvae and adults filter-feed on phytoplankton. Adult scallops filter feed on plankton and detritus. The presence of inorganic suspended solids can adversely affect sea scallops by interfering with normal feeding.

5.6.2 Lobster

The American lobster (*Homarus americanus*) is an important commercial species and occurs throughout the Leading Tickles study area (see Figure 5.3). It is harvested using lobster pots at 1-10 fathoms (EVTA CCRI 2001).

Fishery

The inshore lobster fishery in Newfoundland is carried out with traps in depths generally less than 15 to 20 m during spring to early summer (April to July). Specific season dates vary between locations. Landing statistics for the Newfoundland fishery began in 1874. In 1990, landings peaked but later during the 1990s, landings in Newfoundland declined, more severely in some areas than others. Overfishing is believed to be the major cause of the population decline. In the Lobster Management Plan 1998-2001, DFO stipulated an increase in the minimum carapace length for legally caught lobsters in Newfoundland to 82.5 mm. This measure was intended to increase egg production by 56%. Other fishery conservation practices being instituted in Newfoundland include 'no-take reserves' and V-notching ovigerous female lobsters that exclude those females from the legal fishery. V-notching is the process of cutting a shallow notch mark into the tail of an ovigerous female. When a V-notched female is caught during the commercial fishery, she must be released, thereby protecting confirmed sexually mature lobsters for several more years. A V-notch is retained for up to two molts (Rowe 2000).

Distribution

The American lobster ranges from southern Labrador (Strait of Belle Isle) to Cape Hatteras in North Carolina. Offshore populations occur along the outer edge of the Continental Shelf and upper slope (110 to 145 m) from the southern Scotian Shelf off Nova Scotia southwards to Virginia (DFO 1996a). Generally, lobsters are continuously distributed around the island of Newfoundland and along the Strait of Belle Island portion of the Labrador coast, occupying a narrow band of rocky bottom in a depth range of 2 to 40 m (Ennis 1984).

American lobsters in Newfoundland waters do not exhibit large-scale seasonal inshore-offshore migration behaviour because the preferred habitat is only a narrow belt around parts of the island. However, Newfoundland lobsters do tend to move to slightly deeper water (20 to 40 m) in mid to late fall in order to spend the winter in more stable water temperatures and less perturbed conditions. In spring, they will move back into shallower areas (< 20 m) where water temperatures are higher. It is in this shallower area that fishers set their traps.

Spawning

Mating between male and female American lobsters usually occurs immediately following the female's shedding of her old shell (molting) during the summer months. The hormonal regulation of molting is sensitive to cues such as temperature, light, salinity and food availability (Aiken and Waddy 1980).

Sperm is usually stored by the female in a receptacle on the underside of her body and carried until fertilization occurs. Spawning of nearshore lobsters is normally regulated by seasonal seawater temperature but photoperiod can assume a regulatory role if the winter seawater temperature remains abnormally high (Nelson et al. 1988). During summer and autumn months, the eggs are pushed from the ovaries and fertilized as they pass through the sperm receptacle. The pine-green, 1 mm diameter fertilized eggs are extruded and attached to long hairs on the female's pleopods. Lobster fecundity increases exponentially with female size, ranging from a few thousand to several tens of thousands of eggs.

Development of the fertilized egg (embryonic development) is strongly influenced by water temperature. In Maine lobster, development stops or is barely discernible once water temperatures fall to about 6ºC (Perkins 1972). Bottom temperatures normally remain this low during November to May period but if water temperatures remain low for a longer time, then hatching will be delayed.

The female carries the embryos until the following summer when the pre-larvae hatch and remain attached until they molt into the first larval stage within 24 hours of hatching (Charmantier et al. 1991). Hatching can occur over a wide range of temperatures during the May to July period on the Atlantic coast of North America (Ennis 1995). Hatching generally begins around 10 to 15ºC and is most intense at 20ºC (Hughes and Matthiessen 1962). The female then releases the first stage larvae by fanning her pleopods. Ennis (1975) reported that American lobster larval release occurs most frequently at night, usually shortly after darkness although batches of larvae are often released at different times of the day as well. The larvae may be released over a period of time from a few days to a few weeks. There is normally a two-year period between mating and pre-larval hatch (i.e., a two year reproductive cycle) (Ennis 1995).

The three distinct larval stages are planktonic, generally found in the upper two to three m of the water column during a two to eight week period (Hudon et al. 1986). Field studies have suggested that the maximum depth of decapod larval vertical migration is related to the depth of the thermocline (Harding et al. 1987). During this time, lobster larvae are passive drifters so their gross movements are largely controlled by the direction of the wind and water currents. Both are generally onshore during the regular time of larval release.

The Stage 1 lobster larvae measure about 6 mm in length. These larvae are typically concentrated at or near the water surface during the night, and depending on the light intensity, may be at surface or at greater depth during the day. This diel vertical migration by Stage 1 lobster larvae can range from 15 to 30 m and maintains the larvae in the presence of other planktonic animals and plants. Thus Stage 1 larvae remain in a rich food supply. It is believed that lobster larvae display raptorial (adapted for snatching) feeding behaviour. Stage 2 lobster larvae are about twice as long as the Stage 1 larvae (8 mm) and are more physically developed. Behaviourally, they are similar to the Stage 1 larvae. Third stage larvae are larger again (~ 10 mm) and more physically developed. However, Stage 3 lobster larvae are less light sensitive and are therefore found more often in the near-surface waters (Ennis 1995).

Metamorphosis to the postlarval stage occurs at the fourth molt. Time of development from the onset of Stage 1 to the postlarval stage depends on water temperatures. At 22ºC, development time can be as short as 11 days but at 10ºC, it might take almost eight weeks for larval development (Ennis 1995). Salinity also modifies larval development time. At temperatures of 15 to 17.5ºC, a salinity range of 21 to 32 ppt does not appear to have any effect on development time and survival of the larvae, but salinities outside of this range do have a negative effect. It has been estimated that an average of nearly 99% mortality occurs between the first larval stage and the first postlarval stage. The metamorphic postlarvae look like miniature adult lobster, are also light seeking like the Stage 3 larvae and are commonly found in the upper 1 m of the water column (Hudon et al. 1986). Despite their increased swimming ability, these postlarvae still use winds and currents as their primary mode of transport. As the molt into fifth stage approaches, light becomes repellant and the metamorphic postlarvae begin to seek shelter in the benthic (bottom) environment. The postlarvae are strong swimmers and it is thought that they are able to make excursions to the sea bottom in order to detect suitable settlement substrate (Incze et al. 2000). Upon recognizing appropriate substrate, the postlarvae settle and become benthic juvenile lobster. Laboratory experiments have indicated that the postlarvae are capable of delaying the molt into fifth stage for a period of time until suitable settlement substrate is found. The extent to which postlarval settlement originates with eggs produced in the same area is unknown.

Habitat

As larvae, lobsters prefer uncontaminated water above critical temperature (about 10ºC) and salinity (about 20 ppt). Settling postlarval lobster prefer inshore habitat with gravel/cobble substrate (Palma et al. 1999) and kelp cover.

The early benthic lobsters prefer warm water but are more tolerant of lower salinity than the planktonic stages. The early benthic lobsters will find refuge in the smallest crevasses and in kelp beds. As the lobster grows, its sheltering requirements and thus the substrate particle size preference also change (Wahle and Steneck 1991, 1992).

Settling postlarvae quickly find refuge in the substrate and remain essentially hidden for the first year of their benthic lives. The transition from planktonic to benthic realms is the most dangerous period in the life cycle of the lobster. They are extremely vulnerable to predation during the move from surface to bottom. The smallest lobsters observed outside of their shelters during laboratory studies were about 20 mm carapace length.

Adulthood is reached within five to eight years, depending largely on the water temperatures in the area they lived (Lawton and Lavalli 1995). Larger juvenile and adult lobsters prefer substrates consisting of a combination of coarser-sized particles (large cobble and boulder) and finer substrate that permits burrowing. Kelp beds are also beneficial to large juvenile and adult lobsters. Christian (1995) surveyed 1.2 hectares of substrate at Broad Cove, Newfoundland and identified more than 200 lobster shelters that occurred primarily in areas of the study area with boulder/bedrock substrate (>70%) and substantial kelp cover. Only twenty-two shelters were identified in areas with a sand substrate component. Adult lobster life is similar to that of adolescents except for the array of physiological, ecological and behavioural events that are related to reproduction.

The American lobster has been described by Hooper (1997) as a key animal species of the biota assemblage associated with 'lobster grounds' habitat type that he characterized as representing one of the marine coastal habitats in Newfoundland. Physical characteristics often associated with this habitat type include mixed substrata with suitable rocks for burrows, generally full salinity, a wide range of affecting currents, areas with relatively warm summer water temperatures, and a full range of exposure to wave energy. This characterization should be applicable to the Leading Tickles study area.

Upon settlement, their main predators are bottom-feeding fish including cunner, sculpin and white hake, depending on the geographical area (Hanson and Lanteigne 2000). While most lobsters eaten by fish are less than 50 mm long, larger ones have been found in larger fish. Published studies attempting to detect consumption of American lobsters by fishes in the natural habitat are rare and reports of consumption by fish species such as Atlantic cod and flatfish are anecdotal at best.

Large juvenile and adult lobsters are primarily nocturnal. Activity levels in lobsters are related to water temperatures (Christian 1995).

Lobsters around Newfoundland do not tend to display any large-scale migration behaviour. They do exhibit small-scale movements to slightly deeper waters in the fall/winter and back to shallower regions in spring/summer, probably in response to storm episodes and increased turbidity, and the seasonal changes in water temperature (Ennis 1983b, 1984). It appears that individual lobsters exhibit a relatively high degree of fidelity to an area, even to the scale of shelter use (Christian 1995).

Feeding

Lobster larvae commence feeding immediately upon release from the female (Ennis 1995). Food availability (phytoplankton and zooplankton) is a very important factor, particularly to Stage 1 larvae.

Laboratory observations have found that the early benthic lobsters (<20 mm) use a combination of raptorial techniques carried over from larval stages and suspension feeding techniques to capture the plankton from the water (Lavalli and Barshaw 1989). These small lobsters appear to generate currents through their shelters by pleopod fanning. This plankton diet supplemented by feeding on in-shelter organisms such as worms and amphipods allow these vulnerable-sized lobsters to remain sheltered during the first year of their benthic life.

As the juveniles grow, they are found outside of shelters more often, foraging for food and exploring the territory. The natural diets of immature lobsters (12 to 73 mm carapace length) during June to November in Newfoundland were investigated by Carter and Steele (1982). The most frequently occurring prey were sea urchins, mussels, rock crabs, polychaetes and brittlestars. Rock crabs, brittlestars and mussels were the dominant food item.

Large juvenile and adult lobsters feed primarily on bottom invertebrates including crabs, sea urchins (Himmelman and Steele 1971), mussels, polychaetes, periwinkles and sea stars (Ennis 1973; Reddin 1973; Elner and Campbell 1987). Being opportunistic feeders, they will also scavenge fish carcasses (e.g., capelin) when they are available. There may be a shift to a more calcium-rich diet during molting season (July to September) (Ennis 1973). During this time, the proportions of sea stars, sea urchins and mussels in the diet increased. Crabs remained the primary prey item throughout the year.

5.6.3 Mussels

The blue mussel (*Mytilus edulis*) is harvested in several locations in the Leading Tickles study area (see Figure 5.4). Its distribution is undoubtedly wider in the shallows of the study area than suggested by the map in Figure 5.4.

Fishery

As early as 1968, blue mussel beds in Newfoundland were assessed for harvesting potential (Scaplen 1970). In 2000, almost 100 licenses were issued in Newfoundland for blue mussel aquaculture. In 1997, almost 800,000 kg of mussels were produced by Newfoundland aquaculture, much of them from Notre Dame Bay (DFA 1998). There are no mussel farms in the Leading Tickles study area although there is a development license just to the west of the study area and a commercial license just to the east in Osmonton Arm (see also MEQ section).

Over the years, adult blue mussels have been used as a bioindicator species for marine environmental quality in many areas, including inshore Newfoundland (Christian and Buchanan 1998). Being a stationary filter feeder makes this species an ideal candidate as a bioindicator.

Distribution

The blue mussel has a circumpolar distribution in boreal and temperate waters. In the NW Atlantic Ocean, its distribution extends from the Arctic to South Carolina. This bivalve can be found in habitats ranging from slightly brackish shallow estuaries to highly saline deep offshore environments. In Newfoundland, blue mussels are most commonly found in the intertidal and shallow subtidal zones (< 20 m) (DFO 1996b) but they occur along Newfoundland and Labrador coasts over a depth range of 1 to 62 m (Barrie 1979). A population on the SE Shoal of the Grand Banks is one of the world's few deep subtidal populations and the one furthest from shore (Carscadden et al. 1989).

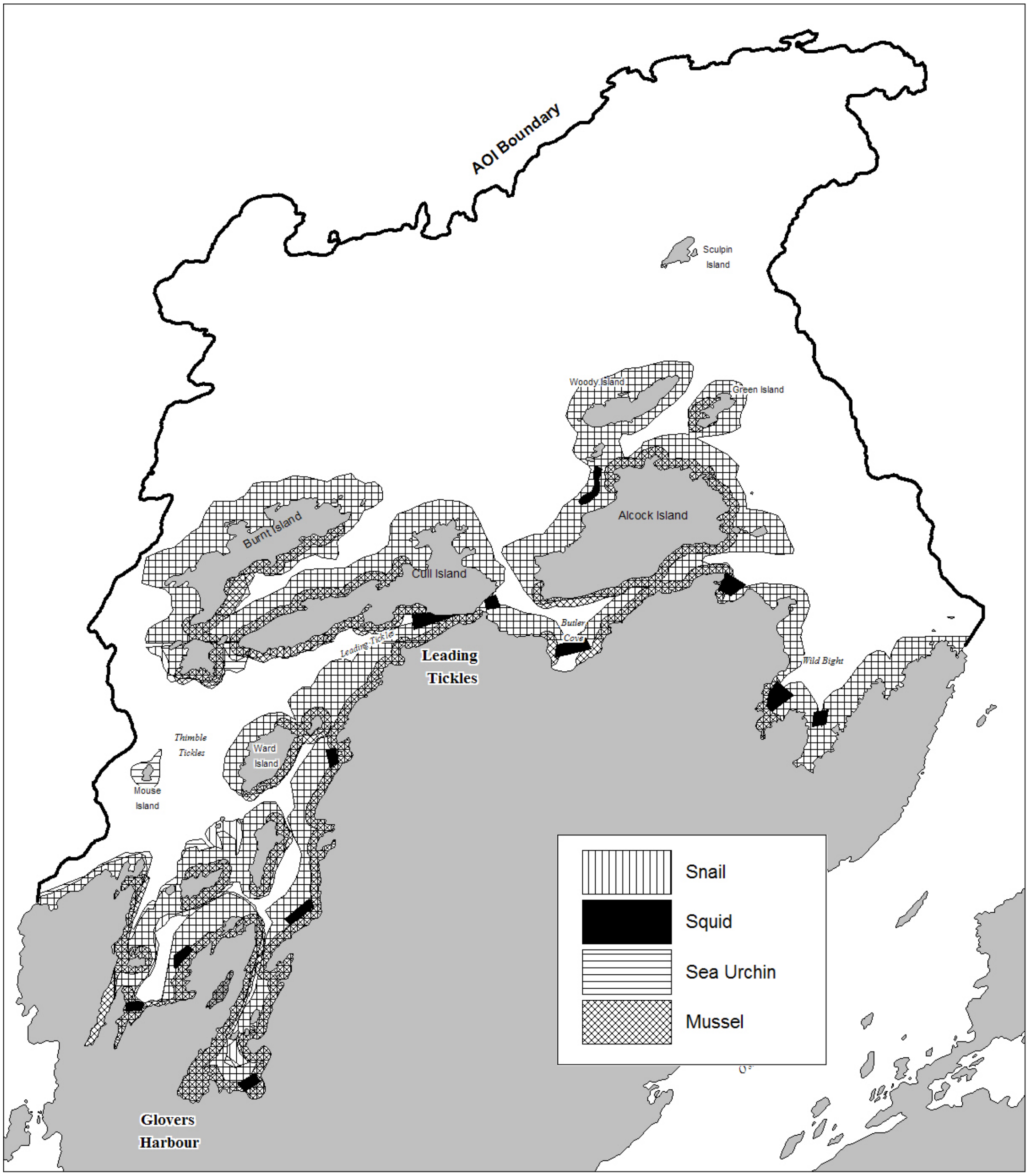


Figure 5.4 General squid, urchin, mussel and snail grounds in the Leading Tickles study area. From CRIA (Feb. 2001).

Spawning

Spawning generally occurs during the May to August period, peaking between mid-May and late-June (possibly mid-July at some Newfoundland locations as recorded by Pryor et al. 1999). Spawning appears to occur in response to environmental triggers including sufficiently high water temperatures (10 to 12˚C), suitable planktonic food supply, water movement during spring tides, and sudden physical disturbance during storms. Salinity should be at least 15 ppt to ensure successful fertilization (Bayne 1976). There is some evidence for phytoplankton-sourced chemical stimuli that trigger the spawning process (Starr et al. 1990). Female blue mussels can release between 3 and 20 million eggs (Mallet and Myrand 1995).

Fertilized eggs of the blue mussel are benthic and require temperatures of at least 5ºC for proper development. Food availability is especially important upon larval hatch. The free-swimming larvae remain planktonic for three to four weeks before settling. The duration of the planktonic life stage is primarily dependent on water temperature, salinity and food level. Although capable of vertical migration, blue mussel larvae are essentially at the mercy of currents and may be carried considerable distances from the spawning area. In Atlantic Canada, settlement can occur at any time from mid-June to late September, generally peaking during the mid-June to late-August period.

Habitat

The sessile spat prefer stable, hard substrates (i.e., bedrock/boulder) for attachment. The location of attachment must also have sufficient water movement to allow movement of food, nutrients and waste. Kelp harvesting can impact mussel larval settlement by reducing the amount of substrate for attachment. The juvenile mussels can easily detach themselves and change locations, either by using their foot to actively crawl or by floating passively in the water column. Movement becomes increasingly limited as the mussels become heavier (Mallet and Myrand 1995).

The blue mussel is a key species of the biotic assemblage generally associated with what Hooper (1997) calls ‘lobster grounds’ habitat type found in coastal marine areas of Newfoundland (including such areas as Leading Tickles). Physical characteristics of this habitat type include mixed substrata with suitable rocks for burrows, generally full salinity, a wide range of affecting currents, areas with relatively warm summer water temperatures, and a full range of exposure to wave energy.

Sea-ice may also play a role in mussel distribution by clearing settlement areas. The blue mussel occurs on the intertidal flats at the boulder barricade and associated tide pools near the outer edge of the flats area near Nain, Labrador (Gilbert et al. 1984). Blue mussels may be found in the lower intertidal zone of three types of intertidal/subtidal regions in the northern Gulf of St. Lawrence: (1) moderately exposed, medium-sloped bottom, (2) exposed, gently sloping bedrock platform, and (3) rocky faces (Himmelman 1991).

In summer, Bergeron and Bouget (1986) found low abundances of organisms associated with the smooth regular surfaces whereas there were high abundances of organisms, including blue mussels, in the cracks and crevices of the substratum, sheltered from ice scour. The blue mussels tended to occupy the lowest region of the crevices while barnacles and rockweed occurred immediately above the mussels.

The ability of mussels to grow and reproduce under a wide range of environmental conditions is largely responsible for their worldwide distribution (Seed 1969). Juvenile and adult blue mussels can tolerate a salinity range of 0 to 31 ppt although growth rates are severely affected at each extreme of the range. Optimal growth occurs around a salinity of 26 ppt (Mallet and Mynard 1995). Little growth occurs below and above water temperatures of 0 and 2ºC, respectively. Bourget (1983) reported that juvenile blue mussels in the St. Lawrence estuary showed less cold tolerance (–8 to –12ºC) than the adult mussels (-12 to –20ºC). The median lethal temperatures varied seasonally due to the variability of water salinity. Loomis (1995) reported that this bivalve is able to withstand temperatures far below zero and that its freezing tolerance is increased if it is acclimated to high salinity.

Feeding

Blue mussel veligers (planktonic larval stage), juveniles and adults all filter-feed on plankton and detritus.

5.6.4 Clams

Both surf clam and soft-shell clam may occur in the Leading Tickles study area although it is not prime clam habitat. The surf clam occurs primarily offshore on the continental shelf. The coastal species (soft-shell clam, *Mya arenaria*) is reviewed here.

Fishery

Commercial fisheries for soft-shell clam are very limited in the study area and Newfoundland in general compared to other areas of eastern North America. The soft-shell clam has been considered as a new candidate bivalve species for aquaculture in the Canadian Atlantic provinces and northeastern U.S.

Distribution

The soft-shell clam is widely distributed in both North American and European coastal waters. In the NW Atlantic Ocean, this bivalve occurs primarily from Labrador south to Cape Hatteras, with lower abundances as far south as Florida. Adults have an aggregated distribution and are normally limited to intertidal and shallow subtidal zones in soft-bottom estuarine areas. However, they have been known to occur as deep as 200 m (Newell and Hidu 1986). The soft-shell clam occurs in small, localized beds around Newfoundland (DFO 1989a; DFO 1996c). Examples of soft-shell clam bed locations in Newfoundland include Burgeo, Piccadilly in Port au Port Bay, St. Paul's Harbour, Stephenville Crossing in St. George's Bay, and Salmonier (Hooper 1997). Barrie (1979) found the soft-shell clam in sandy substrata at various Labrador locations and in Conception Bay, Newfoundland over a depth range of 3 to 60 m. A few small beds are found in the Leading Tickles study area according to the EVTA CCRI.

Spawning

Sexual maturation of the soft-shell clam depends upon the size of the individual rather than its age. Clams with shell length exceeding 20 mm (two or three years old) are generally capable of spawning. Gametogenesis (development of eggs and sperm) commences in late winter/early spring (Newell and Hidu 1986).

Depending on water temperature and food availability, the soft-shell clam spawns sometime during the June to September period, usually peaking around July when water temperatures reach approximately 20ºC. Initiation of spawning occurs once water temperatures are approximately 10 to 12ºC (Caddy et al. 1977). In some cases (south of Cape Cod), an additional spawning may occur in early to late fall (Brousseau 1978).

Males generally spawn before the females. Fertilization is external after gamete release through the excurrent siphon (DFO 1993). Female fecundity increases with size. Females of shell length 63 mm are capable of releasing as many as three million eggs per year but there is considerable variation.

The gelatinous fertilized eggs (about 66 µ in diameter) are benthic and persist for up to 12 hours before hatching occurs. Hatched larvae (trochophore and veliger stages) remain planktonic for two to three weeks prior to settlement and can be carried substantial distances from hatching location. The optimal water temperature range for larval development is about 17 to 23ºC although slow development can occur at temperatures as low as 10ºC. The larvae are less tolerant to salinity fluctuation than the adults and appear to prefer a range of 16 to 32 ppt (Stickney 1964).

Habitat

The soft-shell clam has been identified as a key species of the biotic assemblage associated with ‘clam bed’ habitat type characterized by Hooper (1997) as one classification of marine coastal habitat for Newfoundland and Labrador. General physical characteristics typically associated with this type of habitat in Newfoundland and Labrador include fine to coarse sand/fine gravel substratum, full salinity, and low to high exposure to wave energy.

Spat may remain in a floating/crawling mode for two to five weeks, attaching to the substrate (eelgrass, filamentous algae, abiotic substrate) with byssal threads. As they grow larger, the spat commence to burrow into the soft sediment, burrow depth increasing with age. Once these animals reach a diameter of approximately 5 mm, they are coined ‘seed clams’. Juvenile seed clams may migrate shoreward as far as several hundred meters. Soft-shell clams typically attain sexual maturity by a diameter of 20 mm. Densities of seed clams tend to be highest in eddies, along the sides of sand bars or islands, at mouths of rivers/streams emptying into shallow estuaries, and in slack water adjacent to swift current.

Although growth is slowest in the upper intertidal zone, survival is highest here. Optimal growth occurs in fine sediments (sand or sandy mud) in the lower intertidal zone where food availability is greatest. Faster water currents tend to support greater population densities. They have been found as deep as 200 m. Since the adults live in permanent burrows, shifting sand habitat is not appropriate because of the potential of suffocation. Green algal mats may also smother this clam by acting as a barrier to siphon extension (Thiel et al. 1998).

Overall, soft-shell clams have wide tolerances to fluctuations of salinity and water temperature, respectively. Preferred salinity levels appear to decrease moving south through the distribution area. The lowest tolerable salinity level observed for this species is about 5 ppt. but they seem to do best at 25 to 35 ppt. Salinity tolerance of soft-shell clam appears to be linked to water temperature. Generally, the preferred temperature range of this clam is six to 14ºC but it can withstand freezing for up to seven weeks (Caddy et al. 1977).

Feeding

The filter feeding soft shell clams ingest flagellates, diatoms, bacteria, organic detritus and dissolved organic molecules. Since these clams burrow as deep as 30 cm, they use a siphon to pump seawater from above the substrate in order to feed and respire. Soft-shell clams are most vulnerable to predation during larval, spat and early juvenile stages.

5.6.5 Sea Urchin

The green sea urchin (*Strongylocentrotus droebachiensis*) is very common in shallow water on rocky subtidal shores in the Leading Tickles study area (see Figure 5.4).

Fishery

In Newfoundland, green sea urchins are typically harvested from shallow subtidal areas by SCUBA divers. The timing of the harvest is critical since the targeted roe must be at a certain stage of development. In Newfoundland, the harvest usually occurs in late winter or early spring, prior to peak spawning time. Commercial harvesting of this species has been conducted primarily in Trinity Bay and Conception Bay, with lesser efforts occurring in Placentia Bay, Fortune Bay, and elsewhere (DFO 2001).

Distribution

The green sea urchin has a circumpolar distribution and is present on both coasts of North America. On the east coast of North America, it is a common inshore species (maximum depth of 40 to 60 m) from Baffin Island south to New Jersey wherever the salinity is greater than 15 ppt. Green sea urchins are generally most abundant immediately below the subtidal algal fringe at a depth range of 5 to 10 m (Hawkins 2000). In Newfoundland, this urchin species is a common component of shallow subtidal communities in rocky stable substrate areas with at least medium energy exposure (DFO 1996d).

Spawning

The green sea urchin generally spawns during the spring to early summer period once conditions such as water temperature and food availability (phytoplankton) are favourable for fertilization and subsequent embryonic and larval development. Some summer and fall spawning may occur in Newfoundland waters (Keats et al. 1987).

Spawning is a rapid event in this species. The variable time period between gonadal maturity and spawning may indicate that the spawning is triggered externally. There is substantial variability in water temperature at time of spawning (from < 3.0ºC to 8.0ºC), suggesting that temperature alone does not stimulate spawning in the green sea urchin (Himmelman 1977). There appears to be a stronger relationship between spawning and the spring phytoplankton bloom (Starr et al. 1990). Female urchins may release between 100,000 to 2,000,000 eggs into the water column where external fertilization occurs. Since urchin sperm has a life span of only 20 to 30 minutes, successful fertilization in the water column depends on the synchronization of gamete release by individuals in the same aggregation.

Fertilized eggs initially sink to the bottom but rise to the surface waters within one to three days for larval hatching. Eggs undergo normal development within a –1 to 11ºC temperature range (Himmelman 1977). The free-swimming larvae hatch and can remain planktonic for two to five months. The upper water temperature limit for larval development is around 10ºC (Stephens 1972). Eventually they settle to the ocean bottom and metamorphose to the initial postlarval urchin stage (juvenile) within hours. Larval sea urchins require uncontaminated seawater of suitable temperature and salinity, and a sufficient supply of phytoplankton as a food source. The larvae use cilia to feed. Sea urchin larvae are vulnerable to predation by certain zooplankton and surface feeding fish species.

Habitat

Survival of postlarval sea urchins is highest on kelp-covered rock substrate in relatively shallow water. Temperature, intolerance to low salinity levels, lack of food, and shelter availability are some of the factors responsible for the wide variability in juvenile growth and survival. Low salinity levels are particularly harmful to smaller juveniles of five to 10 mm test diameter (Himmelman et al. 1984).

Adult sea urchins are able to live in a diverse range of habitats due to their generalist diet but tend to be most fit in areas of stable substrate (bedrock/boulder) with substantial kelp growth (Moore et al. 1986). Adult urchins are quite sensitive to reduced salinity levels (i.e., < 20 ppt) (Himmelman et al. 1984). Work by Drouin et al. (1985) in the northern Gulf of St. Lawrence suggested that salinity fluctuations have an important impact on echinoderm populations probably due to the high permeability of their outer surfaces. Sea urchin abundance was lower in water shallower than 4 m at the location with substantial salinity flux (6 to 30 ppt) compared to the other site where salinity was more stable (24 to 30 ppt). The sea urchins that were present in shallow water at the polyhaline site tended to be large.

The green sea urchin has been identified as a key organism of the biota assemblage associated with the 'sea urchin barren' habitat type characterized by Hooper (1997) as one classification of marine coastal habitat for Newfoundland and Labrador. The geology of this habitat type generally includes bedrock and/or boulders. Other physical characteristics typically include full salinity, some current effect, moderate to full exposure to wave energy, and the ability to withstand major ice scour (Hooper 1997).

Primary predators of sea urchins around the Newfoundland coast include lobsters, crabs, seastars, flatfish, wolffish, sculpins, ocean pout, and sea birds (Himmelman and Steele 1971; Keats 1991). Common eiders *Somateria mollissima* feed on green sea urchins over barrens and *Agarum* beds in the Gulf of St. Lawrence (Guillemette et al. 1992). Disease can also be a major cause of sea urchin mortality.

Growth and mortality rates of mature green sea urchins can be obtained through a tagging study. In Maine, over 500 individuals from tidepools were tagged during 1994 and of the 458 urchins caught in 1995, 262 were tagged (Russell et al. 1998). They concluded that the study urchins were slow growing and long lived, the age of the largest urchins being estimated at over 50 years. They found the maximum growth rate occurring in sea urchins with test diameters of 18 to 25 mm (three to 12 years of age).

Off the Atlantic coast of Nova Scotia, destructive grazing of kelp by the green sea urchin is a recurrent phenomenon (Scheibling et al. 1994). This destructive grazing results in less productive, coralline algal-dominated assemblages known as 'barrens'. Considering the large numbers of fish and invertebrates that utilize kelp beds as habitat, large-scale shifts in community state occur when the urchins overgraze (Scheibling et al. 1999).

Feeding

After settlement, prey preference broadens considerably to include dead organic material. Common food sources include thick macrophytes (*Laminaria spp.* and *Alaria spp.)*, detritus and various marine organisms.

Despite the urchin's preference for macroalgae, they will scavenge on dead animals, drifting algae and even prey on other animals. In barren areas, sea urchins have been known to graze on diatoms on rocks and ingest sand to remove diatoms, radiolarians and other protozoa. Various studies, although none in the Leading Tickles study area, have been conducted on diet of the green sea urchin (reviewed *in* Christian 2001).

5.6.6 Snow Crab

Snow crab (*Chionoecetes opilio*) are harvested with pots in deep water (up to 150 fathoms) of the Leading Tickles study area with the bulk of the harvest probably occurring offshore of the study area in water up to 220 fathoms (EVTA CCRI 2001) (see Figure 5.3).

Fishery

After the collapse of the cod fishery, most fishers in Newfoundland obtained snow crab licenses. At present, it is the most important fishery in the province in terms of total value although it is not a large component of catches in the Leading Tickles study area *per se*. The fishery is pursued by a variety of boat sizes employing circular-shaped metal pots.

Distribution

The snow crab occupies a broad depth range in the NW Atlantic Ocean from Greenland to the Gulf of Maine (DFO 2000b). The species typically occurs on soft bottoms at depths of 60 to 400 m where water temperatures remain primarily between –1 and 4ºC.

Spawning

Prior to copulation, the male retains the female in a precopulatory embrace and drives away intruding males for the period leading up to the female's molt. Once the female has molted with assistance from the male, copulation occurs. Bright orange fertilized eggs are extruded onto the female's pleopods within 24 hours of copulation. The female can also extrude subsequent clutches of eggs fertilized by spermatophores stored in her ventral spermathecae. Snow crab can extrude up to approximately 128,000 eggs.

Large numbers of sexually paired snow crabs have been observed in relatively shallow water (10 to 40 m) during late April/early May at Bonne Bay, Newfoundland (Ennis et al. 1990). The pairs were found in algal covered boulder slopes less than one km away from areas of depth > 100 m. Level sand or mud substrates supported lower densities of paired snow crab but were the main sites where feeding was observed. In Newfoundland waters, the fecundities of females may range from 8,500 to over 103,000, averaging just below 45,000 per female (Taylor 1996). Individual fecundity is correlated with size.

The larvae, initially known as zoea I Stage, spend 12 to 20 weeks as plankton and molt through two more stages (zoea II and megalopae) (Conan et al. 1996) before settling to the bottom. Neuston net sampling at the water's surface on the Scotian Shelf in the 1970s took snow crab larvae up to 230 km from shore at temperatures ranging from 5.6 to 18.6ºC, and salinities ranging from 30 to 32.4 ppt. (Roff et al. 1984). Ocean currents can transport the larvae considerable distances from their hatching location before settlement occurs during the fall. The larvae are vulnerable to predation by larger planktivores.

Nearshore (<20 m from shore) plankton sampling was conducted at St. Chads, Bonavista Bay, Newfoundland from May to September at different depths (less than nine m) and distances from shore (Ennis 1983a; Squires et al. 1997). Some Stage 1 snow crab larvae were taken primarily at surface during onshore wind conditions. No adult female snow crab were found suggesting that the larvae moved inshore with the onshore winds. Occurrences of the snow crab Stage I zoea showed two peaks; one in mid-June and the other in early to mid-July.

Habitat

Commercial size snow crab (males >95 mm CW) in Newfoundland and Labrador are most common on mud or mud/sand bottom while smaller crabs are common on harder substrates. Substrate type may be more important than depth in determining abundance (Robichaud et al. 1989).
In Conception Bay, Newfoundland, baited traps were set a various depths (20 to 210 m depth range) during a continuous 13-month period (Miller and O'Keefe 1981). Snow crab depth distribution was generally deeper than 90 m and individual size increased with depth and changed seasonally. At 90 m, snow crab were largest between September and February. Bottom temperatures at stations of 90 m and deeper ranged from –1.1 to 1.1ºC during the 13-month period.

In a Bonne Bay study, relative abundance of early benthic to commercial-size individuals suggested that small immature crabs migrate from shallow rocky areas to deep muddy bottom areas (Comeau et al. 1998). The patchy spatial distribution observed for the snow crab in Bonne Bay appeared to be determined more by substrate and intraspecific factors than by depth. Seasonal movements to shallow waters by larger crabs were related to density- and temperature-dependent factors associated with the reproductive and growth cycle.

Feeding

The most favoured natural prey types of the snow crab in Bonne Bay during April and May were polychaetes, ophiuroids and bivalves although the most frequently eaten food was fish used as lobster bait (Hooper 1986).

5.6.7 Toad Crab

Toad crab (*Hyas* spp.) are harvested in shallow water in and adjacent to the Leading Tickles study area (EVTA CCRI 2001).

Fishery

Considerations have been given in the past towards the potential commercial value of meat from larger toad crabs (DFO 1989b). At present, it is not an important commercial species.

Distribution

The toad crab is found on both sides of the North Atlantic, from shallow subtidal areas to depths exceeding 500 m. This species' NW Atlantic Ocean range extends from Labrador to Rhode Island. Toad crabs are very common near most of the coastline of Newfoundland and Labrador, and also occur on the continental slopes from Labrador to the Grand Banks. These crab occur predominantly at intermediate depths, essentially overlapping the conventional inshore rock crab and offshore snow crab areas (DFO 1996e,f). *H. araneus* tend to be found in slightly shallower water than *H. coarctatus* (Miller and O'Keefe 1981).

Spawning

Larvae typically hatch during the warmer summer months and remain in the upper water column plankton for one to several months as they molt through three stages (two zoeas and one megalopa). Field studies have suggested that the maximum depth of decapod larval vertical migration might be determined by the depth of the thermocline (Harding et al. 1987).

Plankton sampling was conducted in Bonavista Bay, Newfoundland from May to September at different depths and distances from shore (Ennis 1983a; Squires et al. 1997). Stages 1 and 2 toad crab larvae were taken in large numbers (400+) during only one sampling time in July when the water temperature was 8.3ºC throughout the water column. They were much more abundant at surface than at depths from three to nine m, and were more abundant with onshore winds than with offshore winds. Eighty percent of the toad crab larvae were collected about four m from shore.

Densities as high as 50,000 larvae/1,000 m^3 seawater have been sampled (Hudon and Fradette 1993). As with most zooplankton, dispersion of toad crab larvae is dependent primarily on oceanic currents/water movements considering the limited swimming ability of the larvae. Roff et al. (1984) reported the capture of *Hyas* larvae up to 310 km from the Nova Scotian shore at temperatures of 0 to 20ºC and salinities of 29 to 33 ppt. After molting through the three stages, settlement to the benthic habitat occurs.

Habitat

Toad crab appear to prefer gravel, sand or mud substrates. Gilbert et al. (1984) reported the presence of toad crab in the subtidal zone (15 to 45 m) below an intertidal flat area near Nain, Labrador. The area with toad crab had a cobble/pebble substratum and strong currents. Barrie (1979) reported toad crab at three Labrador locations with sandy substrata over a depth range of 1 to 36 m.

In Conception Bay, Newfoundland, baited traps were set a various depths (20 to 210 m depth range) during a continuous 13-month period (Miller and O'Keefe 1981). Toad crab depth distribution was generally in the 20 to 55 m depth range and individual size was relatively constant with depth and time of year. Bottom temperatures at stations located in this distribution area ranged from –1.1 to 13.0ºC over the 13-month period.

Feeding

The toad crab larvae are planktivorous and, in turn, are subject to predation by other zooplankton and planktivorous fish. Adult toad crab diet includes amphipods, polychaetes, bivalves, ophiuroids, gastropods, chitons, sea urchins, small crab and scavenged fish. In the northern Gulf of St. Lawrence, *H. araneus* was found to be the major predator of juvenile sea scallops (Arsenault and Himmelmann 1996).

5.6.8 Rock Crab

Rock crab (*Cancer irroratus*) are commonly harvested throughout the Leading Tickles study area in shallow water (EVTA CCRI 2001).

Fishery

This crab species generally occurs as a by-catch in the lobster fishery and is subsequently used as bait. Commercial fishing of the rock crab in Atlantic Canada has been limited over the years.

Despite its limited commercial value, the rock crab is very important ecologically especially as it pertains to lobster. The rock crab is a principal prey species for lobster which continues to be a principal commercial species in Atlantic Canada.

Distribution

The rock crab is found in the NW Atlantic from Labrador south to Florida at depths ranging from the low water mark to 750 m. This crab species is most common in shallow water, especially in bays on open sand or sand/mud bottoms (DFO 1997a). In the northern part of its range, the rock crab is generally found in five to 20 m of water while to the south, it occurs primarily in deeper water (DFO 1996f).

Spawning

The number of eggs carried by the female rock crab is dependent on the size of the female. For example, a 60 mm CW female can carry approximately 125,000 fertilized eggs while a 90 mm CW female may carry as many as 500,000 (Tremblay and Reeves 2000). Rock crabs carry the fertilized eggs for approximately four months. Egg extrusion typically occurs during mid to late fall (late October).

Larval hatch generally occurs during the warmer late spring/summer months. The free-swimming larvae immediately join the near-surface plankton and remain there for up to three months. Hudon and Fradette (1993) described the wind-induced advection of larval decapods, including rock crab, into a bay of the Magdalen Islands in the southern Gulf of St. Lawrence. They discussed the chance factor of sporadic wind events coinciding with times of peak larval abundance. Rock crab larvae are initially positively phototactic (attracted by light) but change abruptly to positive geotaxis (attracted to the bottom) in preparation for settlement. Field studies have suggested that the maximum depth of decapod larval vertical migration could be determined by the depth of the thermocline (Harding et al. 1987). The rock crab larvae molt through six stages (five zoeas and one megalopa) before settlement to the seabed (Hudon and Fradette 1993). Settlement resulting in highest survival most often occurs inshore on gravel/cobble substrate with kelp cover.

Plankton sampling was conducted in Bonavista Bay, Newfoundland from May to September at different depths and distances from shore (Ennis 1983a; Squires et al. 1997). With onshore wind conditions, rock crab larvae were generally most abundant at surface but also occurred in substantial numbers at three m and less so at six and nine m. From mid-June to early August, water temperatures ranged from 7.6 to 15.2ºC, but little vertical stratification was evident during any one sampling time. The highest abundances of rock crab larvae occurred in samples collected during the first two weeks of July (water temperature range of

7.8 to 10.0ºC). Within the surface layer, the concentration of larvae varied with distance from shore (<2 to 20 m) but not in any consistent pattern. Stages 1, 3 and 4 zoeas and megalopae were all included in the sampled larvae.

During a study to compare zooplankton samplers, rock crab larvae were far more abundant in the upper 40 m of the water column at the head of Conception Bay than at the mouth of Conception Bay (Pepin and Shears 1997). Mean catches of rock crab larvae (per thousand m^3) at the head of the bay during late July and early August ranged from 5,420 to 25,000. Mean catches at the mouth of the bay during the same period ranged from 66 to 3,650. Rock crab larvae have been found in densities as high as 50,000 1,000 m^{-3} water, comparable to toad crab but substantially greater than American lobster (Hudon and Fradette 1993).

Habitat

Rock crabs in the Gulf of Maine showed considerably less discrimination among habitat types and environmental conditions during settlement than did lobsters (Palma et al. 1999). By virtue of their high fecundity, rock crabs have high rates of settlement and suffer high levels of post-settlement mortality relative to lobsters. Newly settled rock crabs were found in wider ranges of substratum and depth, and in considerably lower salinities in estuarine habitat.

After settlement, the rock crab grows through a juvenile stage and reaches sexual maturity within three to six years. As the crab grows through juvenile and adult stage, their sheltering needs change and preference shifts to coarser substrates (i.e., large cobble, boulder) mixed with patches of finer substrate suitable for burrowing.

Rock crab in the northern Gulf of St. Lawrence show broad habitat preferences, occurring on both rocky and sediment bottoms (Himmelman 1991). The rock crab is one of the major predators in the northern subtidal communities.

Feeding

Rock crab larvae are omnivorous planktivores. They in turn are prey to larger zooplankton and planktivorous fish. Juvenile and adult rock crab diet includes juvenile sea scallops (Barbeau et al. 1996), juvenile Iceland scallops (Arsenault and Himmelman 1996), mussels, snails, green sea urchins (Himmelman and Steele 1971), brittlestars, amphipods and polychaetes. Large rock crab have been known to take small lobster (Hudon and Lamarche 1989), a species with which they often share habitat.

5.6.9 Whelk

Whelk (*Buccinum undatum*) are apparently not harvested in the Leading Tickles study area but probably occur there.

Fishery

In the Gulf of St. Lawrence, waved whelks are harvested in a coastal fishery using pyramid-shaped traps deployed from small craft. Due to its sedentary life style, the waved whelk is quite vulnerable to overharvesting. Commercial catches of whelk around Newfoundland have been relatively poor in the past (Flight 1988).

Distribution

The waved whelk occurs in the NW Atlantic from Labrador south to New Jersey, including the Gulf of St. Lawrence. This gastropod is very common in cold water from tidal level to depths of 180 m (DFO 1997b; Kenchington and Glass 1998) and attains its greatest densities in Labrador, eastern Newfoundland and the northern shore of the Gulf of St. Lawrence (Himmelman and Hamel 1993). Barrie (1979) found waved whelks at Nain, Labrador over a four to 90 m depth range.

According to Golikov and Scarlato (1973), the summer and winter temperatures for the northern boundary of its distributional area are 5 and <0ºC, respectively, and the summer and winter temperatures for the southern boundary of its distributional area are 16 and 6ºC, respectively. The ranges of optimum temperatures of inhabitancy and spawning have been reported as 5 to 6ºC, and 0 to 5ºC, respectively.

Spawning

Copulation occurs between May and July on the north shore of the Gulf of St. Lawrence. There is often shoreward migration by this species prior to copulation (Martel et al. 1986). A female may mate with more than one male and is able to store sperm for up to eight weeks. Fertilization is internal in whelk and the female extrudes the fertilized eggs two to three weeks after copulation.

Egg deposition may extend to the end of August. The eggs are enclosed in benthic masses that may contain as many as 340,000 developing embryos. Preferred egg laying areas are the irregular surfaces and faces of boulders and the stalks of kelp. While attached to a substrate, the egg masses are vulnerable to predation by sea urchins and to loss through detachment due to storm activity. There is not a planktonic larval stage in this species, thereby limiting the whelk's ability to disperse widely. In the northern Gulf, juveniles hatch after five to eight months of development, generally during the late autumn to late winter period. Usually there is successful hatching from only about 1% of the eggs. At hatching, the juvenile whelks measure approximately three mm in shell length (Martel et al. 1986).

Habitat

In the northern Gulf of St. Lawrence, as whelks grow from recruitment size (<1 cm) to immature adult size (3-7 cm), they move from deeper sand-mud substratum to shallower, coarser substratum (Jalbert and Himmelmann 1989). Once they attain sexual maturity, they return to the gravel/sand/mud in the deeper areas (16 to 20 m). This distributional shift could be due to the distributions of the various sized prey of waved whelks.

Juvenile and adult waved whelks spend much of their time lying immobile, half buried in the sediment or on the substrate surface when not feeding or mating (Himmelman 1988). However, they will exhibit substantial mobility in response to food and predators. Himmelman (unpublished) has observed this whelk to move 50 m in two days.

Waved whelks in the northern Gulf of St. Lawrence show broad habitat preferences, occurring on both rocky and sediment bottoms (Himmelman 1991). The waved whelk is one of the major predators in the more northern subtidal communities whereas fish and decapod crustaceans are the predominant predators in more southern communities. *Buccinum undatum* was one of the most abundant predators in the northern Gulf subtidal communities, generally occurring in the 0 to 5 m depth range.

The lower lethal salinity limit for whelk is around 18 ppt (Staaland 1972). Whelk do not like large fluctuations in salinity (Drouin et al. 1985).

Feeding

Whelks are both predacious (live prey) and necrophagous (scavenge on dead animal tissue) carnivores, feeding primarily on molluscs and other invertebrates (Himmelman 1988). Himmelman and Hamel (1993) identified this mollusc as one of the primary subtidal predators exploiting the bivalve and sand dollar resource in the northern Gulf. December collections revealed that the proportion of whelks sampled on sand habitat with stomach contents was significantly greater than those with stomach contents on rock, gravel and mud habitats, suggesting that more food resources were available for whelks on sandy bottoms. Urchins, polychaetes and amphipods were the most frequent prey items found in whelk stomachs from sandy areas. In whelks from rocky habitat, pieces of decapod crustaceans and fish eggs were the most common prey. Stomach contents from whelks collected in mud and gravel areas were essentially unidentifiable.

5.6.10 Periwinkle (Snail)

Periwinkle (*Littorina* spp.) are common in the rocky shallow water in the Leading Tickles study area and are harvested there (EVTA CCRI 2001) (see Figure 5.4).

Fishery

There is a limited periwinkle fishery in eastern Canada. Hand gathering of periwinkles is an open fishery not requiring a license. The common periwinkle is a popular food item in Europe (Caddy et al. 1974; DFO 1998b).

Distribution

The common periwinkle (*L. littorea*) is widely distributed throughout the North Atlantic. In the NW Atlantic Ocean, this gastropod occurs from Labrador to New Jersey, from the high water mark to depths of 40 m on diverse substrata ranging from rock to sand (DFO 1998b).

This species is very characteristic of the intertidal zone and is generally the most dominant molluscan species in the mid-intertidal zone.

The smooth periwinkle (*L. obtusata*) is also distributed on both sides of the Atlantic. In the NW Atlantic Ocean, it occurs from the Arctic to New Jersey and is commonly found among rockweeds (Gosner 1979). Its local distribution is limited by the need for rockweed, sheltered rocky coasts and clear water.

Barrie (1979) found another species of the same genus, *L. saxitalis*, during his benthic community surveys in Labrador. This periwinkle was found at depths ranging from 1 to 7 m.

Spawning

While the fertilized eggs of the common periwinkle are released into the plankton during the April to July period (Hayes 1929), the fertilized eggs of the smooth periwinkle are laid on the fronds of rockweed species (*Fucus* spp.) (Barkman 1955).

An accelerated temperature increase caused peak spawning to occur three weeks earlier than normal and shortened spawning duration from 21 to 14 weeks (Chase and Thomas 1995). At a New Brunswick study site they found that gonad maturation occurred from January to April and copulation occurred in late April/early May while water temperatures were approximately 5 to 6ºC. Maximum spawning occurred when water temperatures approached 10ºC.

L. littorea

Fecundity of the female common periwinkle is positively correlated with shell spire height (Chase and Thomas 1995). They estimated embryo number for a female with spire height 27 mm to be approximately 113,000 per season. The fertilized eggs are often found in nearshore plankton. The developing embryos cannot survive in salinities below 10 ppt and require a salinity of at least 20 ppt for normal development (Hayes 1929). The free-swimming larvae (veligers) hatch approximately six days after fertilization (Caddy et al. 1974). The larvae appear to have salinity tolerances similar to those for the eggs/embryos (Hayes 1929). Common periwinkle larvae remain planktonic for up to four weeks and then settle to the bottom. Their dispersion is highly dependent on oceanic currents.

L. obtusata

Fertilized eggs of the smooth periwinkle are generally lightly attached to algal species of *Ascophyllum* (knotted wrack) or *Fucus* (rockweed) in sheltered locations. The upper limits of water temperature and salinity tolerances of smooth periwinkle eggs are approximately 26ºC and 25 ppt, respectively (Barkman 1955).

Habitat

L. littorea

The juveniles and adults prefer rocky shore habitat at and below mean low water (Gendron 1977). They are able to tolerate a wide and salinity temperature range (Gardner and Thomas 1987). Their preferred water temperatures are around 18ºC and their upper limit of water temperature tolerance is about 41ºC (Hayes 1929). The common periwinkle is relatively inactive once water temperatures exceed 25ºC (Caddy et al. 1974).) This periwinkle is able to withstand temperatures as low as –13ºC in winter and its minimum lethal temperature in the summer is –11ºC (Loomis 1995). Its freezing tolerance is increased if it is acclimated to high salinity. This periwinkle species is able to tolerate salinities as low as 13 ppt and therefore can exist at the head of estuaries.

Aggregations can be found on subtidal drift algae, in tide pools and along rock crevices. During winter months, the common periwinkle population migrates down the intertidal zone to around the mean low tide mark, and then returns to the higher intertidal around March. The optimal habitat of the common periwinkle is the substratum under algal canopy or the immediate subtidal. It is often associated with rockweed (DFO 1998b).

L. obtusata

The juvenile and adult smooth periwinkles are most abundant on the mid-shore canopy of knotted wrack and rockweed (Watson and Norton 1985). This species' lower limit on shore is extreme low water spring tide, perhaps due to an inability to withstand permanent immersion (Barkman 1955). They cannot live in muddy areas or areas receiving sediment deposition. They have been reported on inner intertidal flats in the vicinity of Nain, Labrador (Gilbert et al. 1984).

L. obtusata juveniles and adults become inactive at about 25ºC and can withstand water temperatures as low as –30ºC. They are unable to tolerate strong surf action but can withstand strong tidal currents. This species is quite sensitive to freshwater and will quickly die in salinities as low as 15 ppt without sufficient acclimation time (Barkman 1955).

The summer and winter temperatures for the northern boundary of its distributional area are 6 and <0ºC, respectively, and the summer and winter temperatures for the southern boundary of its distributional area are 20 and 16ºC, respectively (Golikov and Scarlato 1973). The ranges of optimum temperatures of inhabitancy and spawning were given as 6 to 16ºC, and 4 to 16ºC, respectively.

Littorina spp.

Both of these periwinkle species have been identified as key animal species of the biota assemblage often associated with the 'periwinkle/rockweed' habitat type characterized by Hooper (1997) as one classification of marine coastal habitat for Newfoundland and Labrador. Physical characteristics of this habitat type include hard bottom substratum (bedrock, boulders and stable coarse gravel), reduced to full salinities, protection from major ice scour, and low to moderate exposure to wave energy.

Feeding

Littorina littorea grazes on a wide variety of micro- and macroalgae (e.g., *Ulva* sp., *Enteromorpha* sp., diatoms, encrusting algae, juvenile *Fucus* sp.), and on the early settlement stages of sessile invertebrates (reviewed *in* Christian 2001). Periwinkle feeding can be influential in structuring benthic communities on hard substrate (Bertness 1984). The grazing activities of the common periwinkle on algae may also negatively impact mussel recruitment due to the removal of mussel settlement sites on the algae (Petraitis 1990).

The smooth periwinkle, *L. obtusata*, prefers to feed on the reproductive receptacles of fucoid algae but will also feed on vegetative tissue. It also feeds on other algae such as *Ulva lactuca* and *Ascophyllum nodosum* (Watson and Norton 1985).

5.7 Nekton

Strictly speaking the term nekton applies to those animals in the water column that can direct their movements horizontally as well as vertically (e.g., fish and squid, and sometimes jellyfish). In the present report, the term is used for juvenile (i.e., post-larval) fish living in the water column and squid, and sometime jellyfish, as this is the convention used by DFO Newfoundland Region. Adult fish are discussed separately.

DFO has been sampling plankton and nekton over a broad geographic area in Newfoundland and Labrador waters including several stations in or immediately adjacent to the study area, at least from 1994 to 1997 (Dalley and Anderson 1998). In general, these authors found nekton biomass (including jellyfish) to be greatest on the NE Shelf, including the Leading Tickles study area.

5.7.1 Squid

Both short-finned (*Illex illecebrosus*) and long-finned squid (*Loligo pealei*) occur in Newfoundland. The shortfinned squid is the more common of the two in the Leading Tickles study area and is reviewed here.

Fishery

Fisheries for short-finned squid throughout the NW Atlantic Ocean likely target a common single stock (Dawe and Hendrickson 1998). The Newfoundland inshore squid fishery in the northern part of the squid distribution area typically extends from July to November, with peak catches occurring between August and October. The fishery in the southern part of the distribution area generally peaks in May or June (Dawe 1999). The large catches in Subareas 3+4 (Newfoundland and Nova Scotia area) in the late 1970s did not appear to adversely affect the squid resource to the south in Subareas 5+6.

Distribution

In the NW Atlantic, short-finned squid occur from Greenland to Florida, being most concentrated from the Gulf of St. Lawrence/Newfoundland to Cape Hatteras. Abundance and distribution of this squid species are highly variable, both seasonally and annually (reviewed *in* Christian 2001).

Generally, during April to June, young squid (three to six months) migrate from the Slope Water beyond the edge of the continental shelf onto the Grand Banks, the Scotian Shelf, Georges Bank, and the mid-Atlantic Bight shelf area in order to feed. In June, the greatest concentrations of squid occur along the edges of the Scotian Shelf and Georges Bank, and along the southwestern edge of the Grand Banks. The schooling squid are predominantly male early in the shoreward migration but by fall, females are predominant. During July to September, short-finned squid distribution extends to cover large areas of the continental shelf, sometimes including the Gulf of St. Lawrence (Rowell 1989). Squid abundance generally peaks during September and then falls dramatically in October and November as the larger, maturing squid commence to leave the shelf. The distribution area in the fall reduces to that seen in early summer.

The inshore and offshore distributions of this squid species appear to be strongly affected by environmental conditions, particularly water temperature (Coelho 1985). Evidence suggests that squid concentrations are highest when bottom temperatures exceed 6°C.

Results of tagging studies indicate that the short-finned squid head southwest upon leaving the shelf area. It is believed that the adults migrate to a spawning area near Cape Hatteras or even further south over the Blake Plateau off southeastern United States. Since 1979, research surveys have reported the annual occurrence of larvae and juveniles extending more than 1,500 km along the Gulf Stream frontal zone and shoreward in the Slope Water off the edge of the continental shelf. It appears that the Gulf Stream might act as a transporter of the various squid stages northeastward from the spawning grounds. Neutrally buoyant squid larvae and small juveniles could be rapidly transported in the Gulf Stream as much as 100 km/day northeastward toward the Grand Bank (Trite 1983).

Spawning

Short-finned squid die after spawning and probably live no more than 12 to 18 months. Mating may occur well before spawning given that the spermatophores are implanted in the female mantle cavity. Spawning females create large, clear, almost neutrally buoyant egg masses by releasing a gel-like substance with the fertilized eggs. The gel appears to function as a buoyancy mechanism which prevents the eggs from sinking (O'Dor and Balch 1985).

The egg mass can be up to one m in diameter and contain about 100,000 one mm diameter eggs. The egg-mass buoyancy, rate of temperature equilibration and terminal velocity affect the sinking rate of the egg-mass. Depending on water temperature, hatching generally occurs about two weeks after fertilization.

The hatching larvae are approximately the same size as the eggs. The larval squid develop into juveniles with six mm long mantles and adult features. The larval proboscis has split to form the two tentacles and the eight arms have lengthened. The larvae are prey for larger planktivores and they, in turn, predate on small zooplankton.

Habitat

The juvenile short-finned squid live in the Gulf Stream frontal zone and the Slope Water off the edge of the continental shelf until they reach about 10 mm mantle length. At this time, they move into the adult feeding areas on the shelf. Growth rates of juveniles are poorly known but it is documented that adult squid add roughly 1.5 mm in mantle length per day, reaching 25 to 30 mm mantle length by October/November. It is not known what fraction of the short-finned squid population resides in continental slope waters deeper than the survey strata (366 m) or in oceanic waters (Dawe and Hendrickson 1998).

The juveniles and adults tend to remain near bottom during the day and move upwards in the water column at night.

Feeding

Juveniles feed most heavily on small crustaceans such as euphausiids (krill). As the squid grow into adulthood, their diet expands to include larger crustaceans, fish and even other squid. Most prey in Newfoundland waters, based on otoliths found in just over 8,000 squid, consists of young of the year (YOY) Atlantic cod but also included adult capelin, juvenile sand lance, Arctic cod, Atlantic herring, redfish and hake (Dawe et al. 1997). There are indications that feeding is most intense at night (Vinogradov and Noskov 1979).

5.8 Fish

Both pelagic fish (capelin, herring, mackerel and tuna, etc.) and groundfish (skate, flatfish and cod, etc.) fish species that occur in the Leading Tickles study area are not unique and occur in many other parts of the NW Atlantic. Fish are important not only as food for humans, but also ecologically as predators and food for other species such as marine birds and mammals. There appears to have been a shift in the species composition in the NW Atlantic, with a decrease in many species in addition to the much-publicized northern cod (Gomes 1993). This is discussed in more detail in following sections.

In the Leading Tickles study area, there are, or have been, directed fisheries for shark, salmon, herring, capelin, cod, American plaice, winter flounder, turbot, witch, and lumpfish (EVTA CCRI 2001). To the best of our knowledge, no research on these fish species has occurred in the study area but the following material is generally applicable. Key aspects of the distribution and biology of these species and others known to occur in the area are described below.

5.8.1 American Plaice

There is a directed fishery for American plaice (*Hippoglossoides platessoides*) in the Leading Tickles study area (EVTA CCRI 2001) (Figure 5.5).

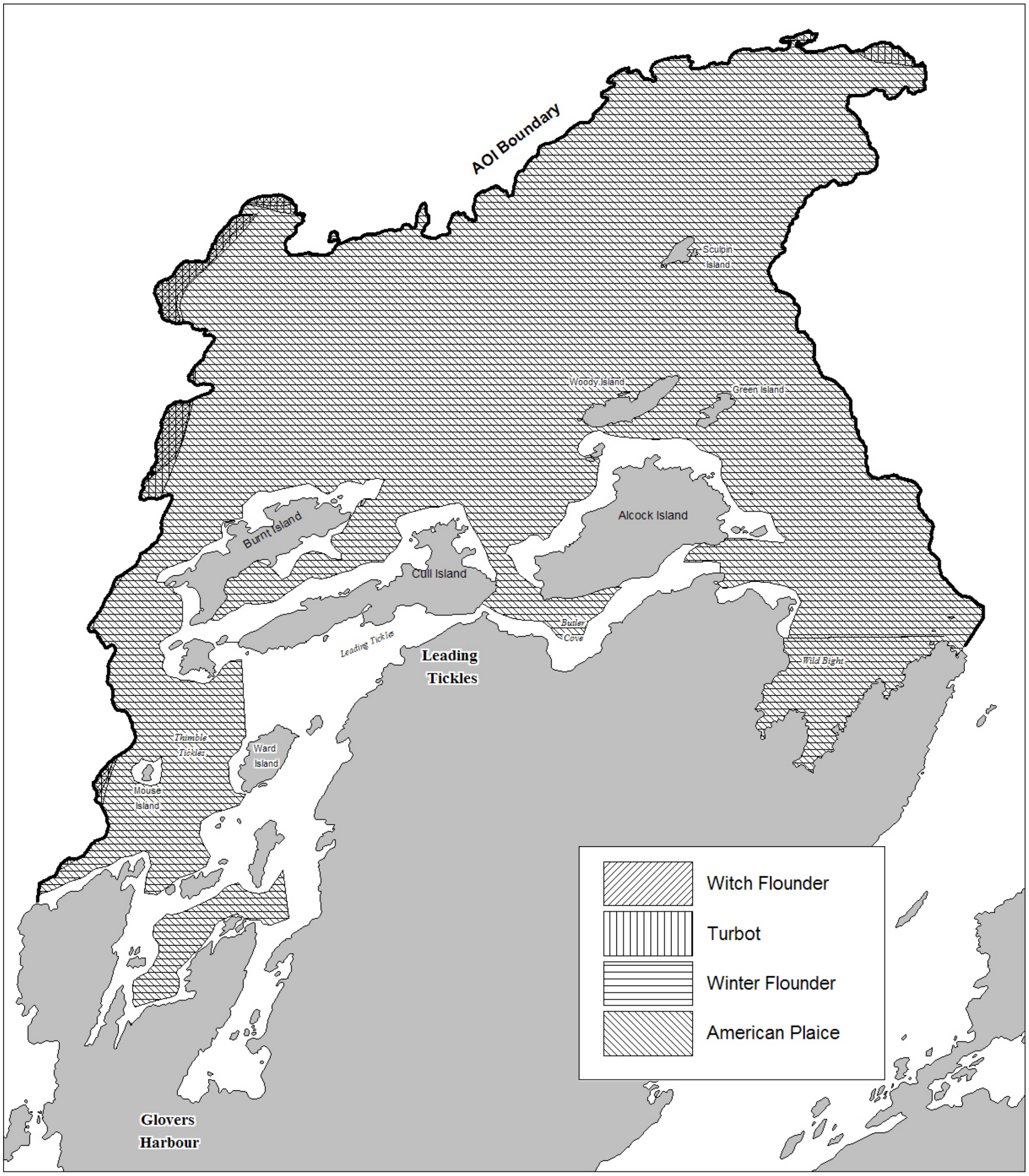


Figure 5.5 General American plaice, turbot, winter flounder, and witch flounder grounds in the Leading Tickles study area. From EVTA CCRI (Feb. 2001).

Fishery

The American plaice Grand Bank fishery used to be one of the largest flatfish fisheries in Newfoundland waters. During the 1970's this species accounted for a large portion of offshore trawler landings. Declining catches in the mid 1980s and early 1990s resulted in a moratorium in September 1993.

The American plaice fishery in the Leading Tickles study area is traditionally pursued at depths of 10 to 20 fathoms.

Distribution

The American plaice is a deep, cold water species normally found at temperatures from just below 0 to 1.5ºC (Pitt 1989). It is found on both sides of the Atlantic and in the west occurs from Baffin Island south to Rhode Island (Scott and Scott 1988). The northern and northeastern portion of Grand Bank contains the largest numbers. Tagging studies indicate that adults not appear to move great distances.

Spawning

American plaice do not appear to undergo spawning migrations and thus do not appear to form large spawning concentrations (Pitt 1969). Spawning is widespread across the offshore banks and the northern half of the Grand Bank appears to be particularly important for all life stages of the species. A discrete resident spawning stock may also exist in St. Mary's Bay as indicated by tagging studies (Pitt 1969).

Spawning occurs from mid-March to September with peak activity in the spring (Nevinsky and Serebryakov 1973). American plaice produce large numbers of eggs ranging from 250 to 300,000 for a 40 cm female to 1.5 million for a 65 to 70 cm female (Pitt 1964). The eggs and larvae are planktonic and fertilization is external. Hatching time for the drifting eggs is dependent upon temperature (e.g., 11 to 14 days at 3.9ºC—Bigelow and Schoeder 1953b). Larvae drift with the currents until they reach a length of 18 to 34 mm when they metamorphose and seek the bottom (Fahay 1983).

Habitat

Juvenile plaice may prefer muddy substrate, which may offer more shelter and food for this size of flatfish. There is some evidence of 'nursery areas' on the offshore banks but juveniles are widespread (reviewed in Grant 2001a). Juveniles have been found in Newman Sound in both shallow (<10 m) and deep inshore waters during the September-November period (Fraser et al. 1998). Inshore, juveniles may prefer fine, sandy substrate near bedrock (Keats 1991). Adults may be found over almost any substrate but generally prefer substrates finer than gravel (Morgan 2000). They are relatively tolerant of temperature (-1.4 to 15ºC) and salinity ranges (20 to 34 ppt) but generally prefer cold oceanic water (Grant 2001a).

Feeding

Larval plaice feed on plankton. Juveniles feed on bottom invertebrates of suitable sizes. Adults feed mostly on sand dollars, sea urchins, brittle stars, capelin, sand lance (Grant 2001a).

5.8.2 White Hake

Fishery

This species is exploited throughout its geographical range from southern Labrador and the Grand Bank to North Carolina but the most substantial catches have occurred in the southern Gulf of St. Lawrence (NAFO Division 4T). The fishery for this species in 4T has historically been the third or fourth most important groundfish fishery in the southern Gulf. The white hake fishery in Division 4T has remained under moratorium since 1995 (Hurlbut 2001).

Distribution

The white hake is a demersal continental shelf and upper continental slope species generally occurring as adults over mud bottom in cold water at depths of 200 to 1,000 m. This North Atlantic benthic species occurs on continental slopes from Iceland and southern Labrador south to North Carolina. White hake have even been found in deep water off Florida. Concentrations of this species are found in deep parts of the Laurentian and Fundian channels and on the continental slope off Nova Scotia (Scott and Scott 1988). Young-of-the-year less than 150 mm in length are often found inshore in depths of a few metres. As these fish grow, they move into deeper water (Scott and Scott 1988). By age 2, they are predominantly in depths of 50 to 200 m (Fowler 1998).

Spawning

White hake, one of the most fecund commercial groundfish species, shows a high degree of variability in spawning times throughout its range. In the southern Gulf, pelagic spawning peaks in early summer while in other areas spawning may occur from late summer to early spring. Eggs and larvae are pelagic in the upper 50 m of deeper water areas throughout their existence. As juveniles they are initially pelagic and migrate into the shallow coastal zone. Once they attain lengths of approximately 50 to 80 mm (~ 2 mos old), the juveniles descend to the bottom of the shallow water areas (Fowler 1998). They appear to remain in the shallow water areas during their first year of life.

Habitat

White hake older than one year are typically found near bottom in deep water areas with mud substrate where water temperatures range from 3 to 10 ºC (Fowler 1998). As explained above, the juveniles under one year of age are normally found in the shallow coastal areas with soft substrate. The eggs, larvae and early juveniles inhabit the pelagic zone prior to the shift to benthic lifestyle.

Immature white hake have been caught during beach seining within the Leading Tickles study area (M. Methven, OSC, pers. comm.) on both mud and cobble substrates (both with eelgrass). Water depths were 7 m or less and bottom water temperatures about 10ºC.

Feeding

Immature white hake caught nearshore by beach seine in the Bay of Fundy fed on a variety of organisms including amphipods, nematodes, isopods, euphausiids, polychaetes, copepods and mysids (Scott and Scott 1988). Adult white hake typically feed on other fish species such as cod, herring and various flatfish (Hurlbut 2001).

5.8.3 Atlantic Cod

Historically, Atlantic cod (*Gadus morhua*) was the traditional mainstay of the Leading Tickles fishery. Fishing grounds are shown in Figure 5.6. The fishery here involves gill nets, traps and longlines set from 1-150 fathoms (EVTA CCRI 2001).

Fishery

The Atlantic cod has been the mainstay of the Newfoundland fishery from the 1500s until the stocks collapsed in the early 1990s. The northern cod stock (NAFO 2J3KL) was once considered the largest in the North Atlantic (reviewed *in* Grant 2001a). Efforts are presently underway to establish cod farming operations in the area.

Distribution

Atlantic cod are distributed on both sides of the Atlantic. In the west, they occur from Greenland to North Carolina (Scott and Scott 1988). They are found over a wide range of depths and substrates.

Spawning

Atlantic cod aggregate in large concentrations to spawn. Spawning occurs both inshore and offshore in Newfoundland and Labrador waters in a range of temperatures from subzero to 5 to 6ºC (Grant 2001a). Inshore and offshore stocks may be genetically distinct (Pepin and Carr 1993). Offshore spawning is known to occur on the Labrador and NE Newfoundland shelves and Grand Bank, on St. Pierre Bank, and in the northern Gulf of St. Lawrence (Grant 2001a). Inshore spawning is known to occur in Bonavista, Trinity, St. Mary's, and Placentia bays (Grant 2001a).

Historically, it was thought that most spawning occurred on continental slopes, particularly off SE Labrador; later information modified this to include broader areas across the continental shelf. Most recent studies suggest distinct and well established spawning areas such as several areas on the outer Labrador and NE Newfoundland Shelves, the entrance to the Esquiman Channel in northern Gulf of St. Lawrence and three areas of Placentia Bay (Rose 1993; Kulka et al. 1995; Morgan et al. 1997; Ouellet et al. 1997;

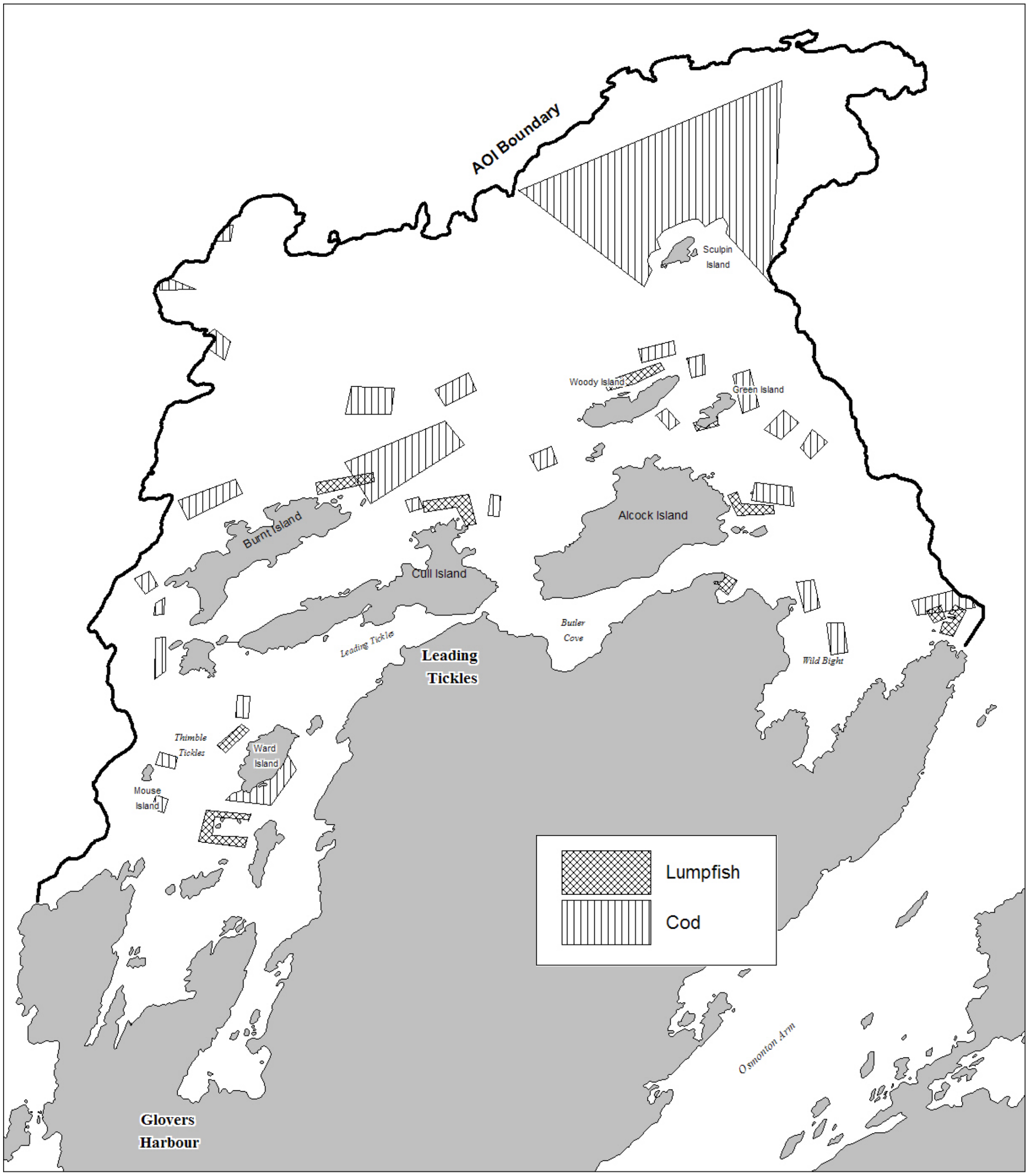


Figure 5.6 General cod and lumpfishing grounds in the Leading Tickles study area. From EVTA CCRI (Feb. 2001).

Lawson and Rose 2000).

Spawning occurs from January to September, generally peaking in the spring. Spawning inshore, including the Leading Tickles study area, may be delayed somewhat due to low water temperatures in the spring (Smedbol and Wroblewski 1997).

Number of eggs increase with body size and one cod may produce from 200,000 (51 cm female) to 12 million (140 cm female) (Powles 1958). Eggs are fertilized externally and eggs and subsequent larvae drift with the currents. Cod eggs are 1.2-1.6 mm in diameter and are often grouped with haddock and witch eggs (termed CHW eggs) because they often occur together and are difficult to distinguish.

When larvae are 20 to 30 mm in length they transform into juveniles. Juveniles remain in the water column until they reach a length of 30 to 80 mm at which time they seek bottom habitat (Grant 2001a).

Habitat

Offshore juvenile cod habitat (large pebble-gravel substrate) is similar in colouration to the fish, at least in the Georges Bank area; the juveniles rise off the substrate at night to feed on small invertebrates (Lough et al. 1989). Inshore habitat selection by juveniles is complex and varies with age (reviewed *in* Grant 2001a). On the northeast coast of Newfoundland, including the Leading Tickles study area, settlement occurs in three pulses (late summer, fall and early winter). Here demersal age 0 cod are largely confined to shallow (4-7 m) depths primarily associated with eelgrass beds but also over a wide range of other habitats as well. Juvenile and adult cod can tolerate very low temperatures because of antifreeze proteins. Juveniles may avoid low (<20 ppt) salinity water (Gotceitas et al. 1997).

Age 1 to 3 juveniles use a very wide range of habitats in inshore Newfoundland from fine sand to bedrock crevices. Tagging studies have documented movements of Age 3 cod in Conception Bay (Clark and Green 1990) and Newman Sound (Cote et al. 1998). In any event, it is clear that juvenile cod inshore prefer shallow habitats with substrates that provide some cover from turbulence and predators.

Adult cod may occur singly or in small or large groups, from one to 10 m off the bottom with forays into the upper water column for feeding. Adults are relatively inactive at night and prefer near bottom habitat with high cover, if available. During the day, they are found feeding over a wide variety of habitats (Lawson and Rose 1999). Adult cod undergo extensive annual migrations for feeding and spawning.

Feeding

The diet of juveniles and adults is varied and includes many invertebrates and fish, including cannibalism. In inshore Newfoundland, cod larvae and juveniles feed on copepods until they reach a length of 80 to 100 mm when they shift to bottom-dwelling invertebrates, mostly crustaceans such as amphipods and mysid shrimp (Grant and Brown 1998a,b). At length 120 to 130 mm, they shift to feeding on fish, including other juvenile cod. Once, cod reach 25 cm, they feed heavily on capelin, amphipods and crab (Lilly 1991). Sand lance is an important food item for cod over 35 cm in length (Lilly and Fleming 1981).

5.8.4 Lumpfish

Lumpfish (*Cyclopterus lumpus*) are fished at a number of locations by gillnet and longline during the May-June season in the Leading Tickles study area (EVTA CCRI 2001) (see Figure 5.6).

Fishery

In Newfoundland, only the female lumpfish is harvested for roe, which is used as a sturgeon caviar substitute. The lumpfish fishery is prosecuted inshore using gillnets during the spring-summer spawning season. Females are killed to remove the roe. In Newfoundland, the fishery appears to largely harvest female lumpfish ranging in body length from 35 to 45 cm (Grant 2001b).

Distribution

The lumpfish occurs on both sides of the North Atlantic. In the NW Atlantic the lumpfish occurs from west of Greenland (in Hudson and James bays) along the Labrador coast southward to Chesapeake Bay, Maryland (Scott and Scott 1988).

Spawning

In Newfoundland waters, adults move into shallow (<20 m) coastal waters in preparation for spawning in the spring (as early as April) or early summer and leave for deep water in late summer and early fall (as late as October) (Collins 1976). Males arrive on spawning grounds in coastal areas before the females (Davenport 1985). The male establishes a nest in shallow water close to shore generally in areas of high structural complexity (Goulet 1985). The male attracts one or more females to the nest and once spawning is complete the female leaves the male to fan and guard the eggs from predation, mostly from sea urchin, until the eggs hatch and larvae emerge from the nest (Davenport 1985; Goulet 1985). In Newfoundland, males and females arrive inshore early in the spring, however, spawning does not appear to begin until water warms to 4°C (Collins 1976; Shears 1980). Once temperatures reach 6.2-6.5°C peak spawning may occur (Grant 2001b). In Newfoundland, inshore waters may warm to 4°C and spawning may occur as early as May (Shears 1980). Egg bearing females have been captured on the same spawning grounds from May to August (Grant 2001b), suggesting that spawning may occur over a period of three months in Newfoundland waters.

In Newfoundland, a female 29 cm in length may produce 46,000 eggs while one 46 cm may produce up to 226,000 eggs (Grant 2001b). Lumpfish are batch spawners and fertilization is external (Davenport 1985). Females will spawn with more than one male depositing their eggs in several batches at intervals of 8-14 days (Davenport 1985). Egg colouration is variable among lumpfish (see below) and in Newfoundland, lumpfish nests have been found to contain several distinct batches of eggs that vary in colour, indicating that more than one female will spawn with an individual male (Shears 1980).

In Newfoundland, lumpfish eggs range in diameter from 1.7 to 2.4 mm (Collins 1976; Grant 2001b). Egg colour is variable between females and may be black, pink, purple, red, orange, or green, with egg colour being fairly homogeneous for each female (Collins 1976; Shears 1980; Grant 2001b). Eggs are sticky in seawater adhering to one another and the nest substrate. Egg development time is temperature dependent (Collins 1976). Apparently, lumpfish eggs exposed to temperatures of 3.8°C do not hatch (Collins 1978). Eggs may hatch in 21 days at 9°C or up to 54 days at a starting temperature of 4°C (Collins 1976). Eggs spawned in May-June hatched in 25 to 53 days in Conception Bay, Newfoundland (Goulet 1985). Guarding males usually left the area of the nest within one day of the completion of hatching (Goulet 1985).

Newly hatched larvae are uniformly five mm in length in Newfoundland (Collins 1976). An adhesive disc is present at hatching and allows for immediate attachment to weeds and hard substrates (Davenport 1985). In lumpfish larvae, the median dorsal fin separates to form two dorsal fins at a body length of eight to nine mm. The first dorsal fin becomes engulfed by a characteristic dorsal 'hump' at a length of about 32 cm at which time the juvenile lumpfish is essentially a miniature of the adult (Davenport 1985).

Habitat

Nesting habitat is typically bedrock, boulder and boulder/vegetation (Goulet 1985). There is little information on juvenile habitat other than anecdotal observations that they can be observed attached to lobster pots, buoys, and algae (Grant 2001b).

Adults spend much of their time offshore before migrating inshore to spawn. They have been found at a variety of depths from near surface, often in association with floating algae to trawler depths of 329 m. Tagged lumpfish in Newfoundland waters have moved as much as 160 km (Blackwood 1982).

Feeding

Lumpfish young-of-the-year that occur in near-surface water consume zooplankton, primarily copepods and pelagic amphipods (Daborn and Gregory 1983). When semipelagic, the lumpfish feeds on a wide variety of benthic and pelagic food items including, ctenophores, amphipods, mysids, polychaetes, molluscs, fish (sand lance), and fish eggs and larvae (Davenport 1985). Diet studies conducted inshore suggest that mature female lumpfish do not feed when inshore prior to spawning (Davenport 1985). However, a recent study in Newfoundland has found food in the stomachs of 57-60% of the pre-spawning female lumpfish examined in June-July (Grant 2001b). These females were consuming ctenophores and benthic and pelagic amphipods.

5.8.5 Skate

Nine species of skate occur in the Newfoundland region (Scott and Scott 1988), however, the thorny skate (*Raja radiata*) is by far the most common species, comprising greater than 90% of skates caught in research bottom trawl surveys and 81% of skate species captured from commercial gears (otter trawl, gillnet, and longline catches) (Scott and Scott 1988; Kulka et al. 1996). There is no directed fishery for the thorny skate in the Leading Tickles study area but they undoubtedly occur there.

Fishery

Prior to 1994, thorny skate in Canadian waters were taken only as by-catch, most of which was discarded (Kulka and Mowbray 1998). In the 1980's, skates consistently comprised the greatest 'non-commercial' bycatch in the Newfoundland offshore trawl fishery, particularly from the Grand Bank fisheries (see Kulka et al. 1996). In 1993, an experimental fishery for skate was carried out in Newfoundland waters by the provincial Department of Fisheries and a directed fishery for skate (primarily thorny skate) was established on the southwestern Grand Bank and southern St. Pierre Bank in 1994 (Kulka et al. 1996). During 1994, the directed fishery was primarily exploratory in nature, with commercial concentrations being located on the southern extent of Whale Bank, Halibut Channel, and just south of St. Mary's Bay (Kulka et al. 1996). Since 1995, Canada has a directed effort for skate in regulated fishery on the Grand Bank and St. Pierre Bank (Kulka et al. 1996).

Distribution

The thorny skate occurs on both sides of the north Atlantic (Scott and Scott 1988). In the western North Atlantic the thorny skate occurs from Greenland southward to South Carolina (Scott and Scott 1988).

In the Newfoundland region, the thorny skate is widely distributed both inshore and offshore. Recent analysis of offshore (NAFO Division 2 and 3) research bottom trawl surveys from 1951 to 1995 indicate that the thorny skate is widely and continuously distributed throughout its range on the Labrador-Newfoundland Shelf with moderate to high densities covering much of the seaward portion of the Grand Bank and onto the Labrador Shelf as far north as 50°N latitude (Kulka et al. 1996). However, there has recently been a significant contraction in distribution, particularly since 1991. In recent years (1991-94), higher concentrations occurred over a smaller area mainly south of 47°N latitude and along the outer shelf of the Grand Bank (Kulka et al. 1996).
Tagging studies in coastal Newfoundland areas indicate that the species does not move great distances (Templeman 1984a). Offshore they appear to make a seasonal migration between the banks and the slopes but distances moved are within the 110 km reported by Templeman (1984) (Kulka and Mowbray 1998).

Spawning

Fertilization is internal. The fertilized eggs remain at a very early stage of development until egg cases are formed and each egg has migrated into its own case. Once the case is fully formed with the egg inside development commences. Eggs are laid two at a time, one from each branch of the uterus every five to seven days and hatching occurs a minimum of six months after egg deposition. The number of eggs produced by an individual female increases with increasing body size. Apparently, thorny skate may produce from six to 40 eggs during each breeding season.

The thorny skate does not appear to make spawning migrations in the Newfoundland region (Templeman 1984a) and there is no information on bottom types preferred during mating or egg deposition (McKone and LeGrow 1983). However, the formation of four filamentous horns at the corners of the egg case that serve to anchor the egg case to macroalgae, pebbles, or other objects on the bottom (McKone and LeGrow 1983) suggests that spawning may take place in areas with relatively large substrates and/or vegetation. Templeman (1982a) suggested that reproduction occurs year-round in the Newfoundland region.

The thorny skate embryo lives off the yolk of the egg until it is completely absorbed into the body cavity at which time the young skate is a fully developed juvenile similar in appearance to the adult (McKone and LeGrow 1983). In American waters, hatching occurs when the embryo is about 10 cm in length from the snout to the origin of the first dorsal fin (Bigelow and Schroeder 1953a). At hatching, the juvenile exits the egg case through a transverse slit between two horns and the empty case (mermaids' purse) may persist for some time. Empty egg cases are common on beaches in the Newfoundland region, particularly after storm events.

Habitat

There is no apparent information on substrate use during the early juvenile life-stage. However, given the similarity of the recently hatch juvenile to the adult form, substrate use is likely to be similar to that of larger juveniles and adults.

The thorny skate is typically benthic throughout its distribution in the NW Atlantic and often partially buries itself in silt, sand, or gravel, which is the type of bottom generally preferred (Scott and Scott 1988). However, the thorny skate may inhabit a wide variety of substrate types including pebble, gravel, sand, silt, mud, and a combination of sand and broken shells (Scott and Scott 1988).

Thorny skate have been captured in depths ranging from five metres in Notre Dame Bay (Schneider et al. 1997) to 1700 metres offshore (Kulka et al. 1996). Centres of abundance appear to be offshore (reviewed *in* Grant. 2001a). They tolerate a wide range of temperatures (-1.4 to 14ºC) but are usually found within 0 to 10ºC and salinities of 32 to 34.5 ppt (reviewed *in* Grant 2001a).

Feeding

The mouth of the thorny skate is located ventrally, which has led to the conclusion that thorny skate feed largely by darting suddenly and settling down over their prey (McKone and LeGrow 1983). The thorny skate feeds mostly at night (McKone and LeGrow 1983) and eats mainly fishes, decapods, cephalopods, and polychaetes, in that order of volume, in the NW Atlantic (Templeman 1982b). Templeman (1982b) found that small (21-60 cm total length) thorny skate consumed high percentages (65% by volume) of invertebrates (i.e., crabs, cephalopods, polychaetes, and amphipods), while larger (61-102 cm) thorny skate consumed mostly fish (78% by volume). Large thorny skate fed on a larger variety of fishes (primarily redfish, haddock, sand lance, and sculpin) than smaller thorny skate and sand lance were relatively important as food for both small and large thorny skate. A similar (70 cm) size related shift to feeding mainly on fishes has been documented for thorny skate in other regions of the NW Atlantic (McEachran et al. 1976). Fish offal discarded from fishing vessels in regions of intensive fishing activity may also be consumed (Templeman 1982b).

5.8.6 Turbot

The turbot or Greenland halibut (*Rheinhardtius hippoglossoides*) occurs in the Leading Tickles study area and there is a directed fishery in deep water (100 to 200 fathoms) in and off the study area (EVTA CCRI 2001) (see Figure 5.5).

Fishery

The commercial fishery for turbot in the NW Atlantic has been in operation since the mid 1800's. With the decline in other groundfish stocks during the 1990's turbot became the most significant groundfish fishery in the Newfoundland region. During the late 1980's there was a shift in the distribution of turbot from the eastern Newfoundland-Labrador area to the deep waters in the southern area of the Flemish Pass (Bowering et al. 1993). High concentrations of turbot in the Flemish Pass area resulted in the development of large unregulated fishery in the early 1990's, which became a widely publicised national dispute between Canada and the European Union in the spring of 1995. Fishing pressure has been reduced in this area since 1995.

Distribution

The turbot occurs in cold boreal waters on both sides of the North Atlantic and in the North Pacific Ocean. Turbot is a highly migratory species on both sides of the North Atlantic (Bowering 1984). In the NW Atlantic, the turbot occurs from at least as far north as Smith Sound (78° N) in West Greenland, southward to the southern edge of the Scotian Shelf and southwest slope of Georges Bank, but rarely into the Bay of Fundy and Gulf of Maine (Scott and Scott 1988; Bowering and Chumakov 1989). The turbot is a deepwater offshore species occurring in channels between shallow water fishing banks in the Newfoundland region and along the continental slope to depths of 2,039 m (e.g., Flemish Pass) (de Cardenas et al. 1996). Turbot is also found in abundance in deepwater bays on the northeast coast of Newfoundland (i.e., White, Notre Dame, Bonavista, Trinity, and Conception bays), in Hermitage Channel on the south coast, as well as the Laurentian Channel and northern channels in the Gulf of St. Lawrence (Lear 1970a; Templeman 1973; Bowering 1983, 1984).

In the NW Atlantic, the largest catches of turbot occur along the slope of the continental shelf from southwest of Disko Island, Greenland to the southern extreme of the Grand Bank and Flemish Pass (Bowering and Nedreaas 2000).

Spawning

In the Newfoundland-Labrador area, fecundity has been reported in the range of 15,000 to 215,000 eggs per female, depending on size of fish (Lear 1970b). When fecundity was compared between turbot populations in southern Labrador and the Gulf of St. Lawrence it was discovered that a 70 cm female from the Gulf of St. Lawrence may produce 20,000 more eggs than a 70 cm female from Labrador (Bowering 1980). Thus, there may be geographic variation in the fecundity of turbot in the Newfoundland region.

Spawning has not been directly observed in turbot. Turbot spawn during the winter (mid-December to mid-April) in Davis Strait at temperatures from 3.0 to 4.5ºC (Smidt 1969; Jorgensen 1997). Analysis of sexual maturity of female turbot collected from the Flemish Pass area identified two peak spawning periods, a main spawning peak in the summer (July-August) and a secondary peak in December with some occurring throughout the year (Junquera and Zamarro 1994). The occurrence of large females without developing eggs has been reported during the winter spawning season throughout the North Atlantic (Morgan and Bowering 1997). However, it is not clear whether this is evidence that females skip spawning in one or more years or whether they are spawning at different times of the year (i.e., summer).

Turbot spawn at great depths (600 to >1200 m) and the planktonic eggs and larvae have been found at depths of 600 to 1000 m (Jorgensen 1997). Larvae gradually rise in the water column to drift north to major juvenile nursery areas in depths of 200 to 400 m off Disko, West Greenland (Jorgensen 1997). However, it is likely that some also drift to the south to bays on the east coast of Newfoundland (Bowering 1983).

Habitat

Turbot is a deep, cold water species that is more pelagic in behaviour than most other flatfishes. While generally associated with the bottom, the species makes extensive upward vertical migrations at night to feed. There is no information available on substrate preference or even if the species lay on the bottom as do most other flatfishes.

Feeding

The turbot is a voracious predator feeding on capelin, cod, young turbot, grenadier, barracudinas, redfishes, sand lance, crustaceans (especially pink shrimp), squid, and to a lesser degree, benthic invertebrates (Scott and Scott 1988).

5.8.7 Winter Flounder

Winter flounder (*Pleuronectes americanus*) are commonly harvested at 10 to 20 fathoms using gill nets in the Leading Tickles study area (see Figure 5.5).

Fishery

Historically, in Canadian waters the winter flounder was taken primarily as bait for lobster. By the early 1970's winter flounder was taken by gillnet as a directed species and as bycatch both for food and bait. The inshore fishery is primarily conducted in Division 3K, 3L, and 3Ps (DFO 2000c). Catches have been somewhat variable over the past seven years and increased catches in 1999 were attributed to re-opening of the cod fishery in Division 3L as winter flounder is commonly taken in nets set for cod (DFO 2000c).

Distribution

In the NW Atlantic, the winter flounder occurs from Windy Tickle, Labrador (the northern record) southward to Georgia (Scott and Scott 1988). Winter flounder are concentrated in shallow (<30 to 40 m) waters throughout their range (McCracken 1963). In the Newfoundland region, winter flounder may be captured in coastal waters to depths of 60 m (DFO 2000c). Winter flounder occur on the Grand Bank; however, this species is only rarely captured offshore during research surveys and depth of capture is not reported (Kulka and DeBlois 1996).

Winter flounder exhibit a seasonal depth related migration in inshore waters throughout their North American range, which appears to be related to their preference for water temperatures greater than –1.4°C and less than 14-15°C. In northern latitudes, particularly Newfoundland, winter flounder generally move into shallow nearshore waters in the spring to spawn, remain in shallow waters throughout the summer, and than retreat the deeper coastal waters during the fall. In Newfoundland, winter flounder may also move into very shallow water habitats that are adequately sheltered during the winter (Kennedy and Steele 1971).

Spawning

Throughout their North American range, winter flounder migrate into shallow inshore waters of bays, ponds, barachois, and estuaries to spawn (reviewed *in* Grant 2001a).

Fertilization is external. The winter flounder is unique among Atlantic flatfishes in that its eggs are benthic and adhesive (Scott and Scott 1988). Production of benthic eggs was viewed by Pearcy (1962) as an adaptation for exploiting marine shallows early in the season when ice may still be covering the estuaries. There is apparently no documentation of winter flounder spawning under the ice in the Newfoundland region. Scott and Scott (1988) report that spawning occurs over sand or mud bottom in Canadian waters, which is consistent with the bottom type in the habitats where prespawning winter flounder were observed and captured in Conception Bay, Newfoundland (Van Guelpen and Davis 1979).

Egg development time is temperature dependent lasting 5 to 31 days (Rogers 1976). The average length at hatching is 3.8 mm and larvae undergo a period of larval drift in surface waters until they metamorphose and seek the bottom at an average length of 7.8 mm (6.6 to 10.1 mm) (Chambers and Leggett 1987). During metamorphosis the left eye migrates to the right side of the head and pigmentation is lost from the left side of the larva. Left eye migration is rapid, taking approximately one week and coincides with a gradual shift from a pelagic to a benthic/demersal habitat (Chambers and Leggett 1987).

Habitat

Juvenile and adult winter flounder are generally captured in the same habitats in Newfoundland waters preferring substrates of mud, sand, and gravel and the use of 'rocky' substrates has also been documented for adults (reviewed *in* Grant 2001a). Sandy substrates with rock and boulder projections and sand-cobble-rock mixes have also been documented (Barker et al. 1994). A recent study on winter flounder distribution has also documented the use of eelgrass beds by juveniles and young adults (age 0 to 7) in shallow (<6 m) coastal waters of Newman Sound, Newfoundland (Fraser et al. 1998). In Newman Sound, winter flounder age 0 to 7 (juveniles and young adults) were captured together on mixed mud, sand, and gravel substrates with moderate to dense eelgrass cover and on sand and gravel substrates with no eelgrass cover (Fraser et al. 1998). The study conducted in Newman Sound indicated that in some years winter flounder may be two times more abundant in eelgrass habitat than in similar substrate with no eelgrass (Fraser et al. 1998).

Several studies document the movement of winter flounder to avoid extremes of temperature, particularly lows of -1.4°C and highs of 15°C. However, in Newfoundland, coastal waters rarely exceed 14-16°C, thus winter flounder movements must largely be to avoid lower extremes in temperature. Fletcher (1977) documents the gradual movement of adult (≥30 cm) winter flounder from shallow (2-8 m) water areas into deeper (>16 m) waters during autumn and an avoidance of the lowest winter water temperatures (-1.4°C) by burying in the substrate (sand/gravel) to depths of 12-15 cm. The bottom sediments appear to act as a refuge from cold bottom waters as they were 0.1 to 0.4°C (average 0.2°C) warmer from December to May. Fraser et al. (1998) documented a gradual decrease in the beach seine catch of winter flounder from September to November in shallow (<5.9 m) waters in Newman Sound, which were interpreted as an autumnal movement to deeper nearshore waters. In contrast, winter flounder may move from relatively deep (7-10 m) water summer habitats in Newfoundland to overwinter in shallow (primarily 1-2 m) water sheltered habitats in a barachois or pond (Kennedy and Steele 1971).

Seasonal movements of winter flounder from shallow to relatively deeper waters in Newfoundland may be related to the level of exposure in the coastal habitat (Van Guelpen and Davis 1979). Winter flounder also may make summer feeding migrations, when capelin-spawning beaches are close by (Fraser et al. 1998).

Winter flounder tagging studies in Newfoundland waters provide evidence of high site fidelity, which together with their shallow water residency led Fraser et al. (1998) to conclude that this species would be a useful indicator of ecosystem stress. Winter flounder (age 0 to 7) marked in both eelgrass and no eelgrass sites in Newman Sound in late August were recaptured at the same site to late October indicating high fidelity to specific localized areas. Further, recapture of marked winter flounder at the same site one year later suggests that site fidelity may extend between years (Fraser et al. 1998).

Winter flounder are not found in fresh water but may tolerate salinities as low as 15 ppt (Sumner 1907).

Feeding

Winter flounder larvae begin to feed shortly after absorption of their yolk, preying upon copepods, invertebrate eggs, and polychaetes (Buckley 1982). Juvenile and adult winter flounder are omnivorous shifting to larger prey with an increase in body size (Kennedy and Steele 1971). Polychaetes, algae, chitons, limpets and a variety of other small molluscs, sea anemones, sea urchins, brittle stars, amphipods, fish remains, and fish eggs, particularly capelin and winter flounder are important food in the diet of winter flounder in Newfoundland waters which varies seasonally (Kennedy and Steele 1971; Van Guelpen and Davis 1979; Fraser et al. 1998).

5.8.8 Witch Flounder

Witch flounder or grey sole (*Glyptocephalus cynoglossus*) are harvested at 5 to 160 fathoms during July and August in the Leading Tickles study area using gill nets (EVTA CCRI 2001) (see Figure 5.5).

Fishery

The following brief summary of the witch flounder fishery in the Newfoundland region was taken from Bowering (1990b; 2000). The witch flounder fishery dates back to the early 1940's in the Newfoundland region. Initially the witch flounder fishery was essentially a byproduct of the haddock fishery until its collapse at which time the witch flounder became a byproduct of the Atlantic cod fishery. The witch flounder fisheries came under international quota regulation in 1974, at which time the fishery was divided into four different stock areas in the Newfoundland region. During the period 1988-92 the Canadian fishery in Division 2J3KL was particularly successful when it targeted prespawning concentrations in deep (700 m) slope waters of Division 3K. However, as the resource became depleted the fishing area became increasingly smaller and deeper (1400 m) until 1993-94, when the catches were very poor. The witch flounder stocks in the Newfoundland region have been under moratorium from 1995 to present.

Distribution

The witch flounder occurs on both sides of the North Atlantic. In the western Atlantic the witch flounder occurs from waters off Labrador at about 54°N latitude (Hamilton Inlet Bank) southward to Cape Lookout, North Carolina (34°N latitude) (Scott and Scott 1988). The witch flounder is generally considered an offshore deepwater species in the Newfoundland region, however, it also inhabits deepwater bays in the region (Bowering 1976).

Spawning

Studies on the Grand Bank indicate that fecundity increases with increasing witch flounder body length such that a 45 cm female may produce approximately 200,000 eggs while a female 55 cm in length may produce up to 450,000 eggs (Bowering 1978).

Spawning has not been directly observed for witch flounder. In the Newfoundland region, witch flounder form dense prespawning concentrations in localized areas of deepwater channels or deep waters adjacent to shallower banks during the winter months (Bowering 1990a). Spawning concentrations have been identified in the following offshore locations: Hawke Channel, deepwater channels of the NE Newfoundland Shelf, northern, northeastern, southeastern, and southwestern slopes of the Grand Bank, southwestern slope of St. Pierre Bank, and the Esquiman and eastern Laurentian Channel in the Gulf of St. Lawrence (Bowering 1990a). Following spawning witch flounder disperse, apparently to shallower waters adjacent to the spawning areas, but do not appear to move into the shallowest offshore waters on the Newfoundland Banks (Bowering 1976). Witch flounder generally disperse throughout the Gulf of St. Lawrence after spawning with many being concentrated in the estuary of the St. Lawrence River during summer and large summer concentrations also occur in St. George's Bay, Newfoundland (Bowering and Brodie 1984).

The spawning season appears to be extensive in Newfoundland waters, as ripe and running females have been observed throughout the year in many areas (Bowering 1990a). However, ripe and running females occur mostly during April-September in eastern and southern Newfoundland. Around the Grand Bank spawning occurs mainly during March-June.. In the eastern region of Newfoundland, spawning occurred in progressively deeper water going from south (127 m, SW Grand Bank) to north (545 m, Hawke Channel) (Bowering 1990a). Spawning was also later in the shallower waters to the south. The near bottom water temperature preference remained relatively stable in each spawning region, between a mean of 2.0 to 3.8°C for the eastern region and 4.8 to 5.3°C for the southern and western region of Newfoundland (Bowering 1990a). The relatively small range of mean temperatures in each area led Bowering (1990a) to suggest that preferred temperature in these areas may be a more significant influence on spawning location than depth. Bowering (1990a) also suggested that the combined influence of both depth and temperature may be significant in determining spawning time.

Although deepwater bays in the Newfoundland region have historically exhibited large populations of witch flounder, in particular Trinity, Fortune, and Hermitage bays, there is no conclusive evidence of spawning in these bays (Bowering 1976; Bowering 1989).

The planktonic eggs of witch flounder range in diameter from 1.25 to 1.35 mm (Fahay 1983) and are difficult to distinguish from early stage Atlantic cod and haddock eggs. Recently hatched larvae are four to six mm in length and transformation to the pelagic juvenile stage generally occurs at 22 to 35 mm body length, but may also be delayed to larger sizes (Fahay 1983).

The pelagic juvenile stage may persist in the water column for up to a year (Bigelow and Schroeder 1953b) and is sometimes concentrated at 30 to 40 m from the surface (Powles and Kohler 1970).

Habitat

Witch flounder may be captured at depths ranging from 20 to 870 m, however, the greatest abundance has been recorded for depths of 185 to 366 m (Bowering 1976). They occur in temperatures ranging from –1.0 to 10.0°C, but the largest catches (1958-74 data) occurred on the eastern Newfoundland Shelf (southern area of Division 3K) at bottom temperatures of 3.1 to 3.5°C. The temperature range of the greatest catches throughout the Newfoundland region was from 2 to 6°C. Generally, temperatures were normally relatively stable from year-to-year at the depths where witch flounder were found in the Newfoundland region (Bowering 1976). As was outlined above, temperature was considered to have a stronger influence on witch flounder distribution than depth in the Newfoundland region (Bowering 1989).

According to McKenzie (1955), witch flounder prefer the gullies where the bottom is usually comprised of either muddy sand, clay, or pure mud rather than the tops of banks and inshore grounds, which are usually comprised of harder substrates. Witch flounder have been captured in high numbers in deep (300 m) waters on a muddy sand bottom in St. George's Bay, Newfoundland, consistently large catches were historically found to occur along the deep muddy southwest slope of the Grand Bank, and local concentrations at the mouths of Hermitage and Fortune bays were attributed to preferred depth and temperatures, and in particular muddy sea bottoms at these locations (Bowering 1976; Bowering and Brodie 1984; Bowering 1989). There is no apparent documentation as to whether witch flounder bury themselves in the bottom sediments, however, it seems likely given their benthic habit and substrate preference. Seasonal movements have not been confirmed for Newfoundland waters.

Feeding

The witch flounder has a very small mouth, which restricts its feeding to very small animals; they are primarily bottom feeders consuming mainly polychaete worms of many varieties and small crustaceans and molluscs are occasionally consumed (Scott and Scott 1988). Small fish have been found in the stomachs of larger witch flounder (Bowering 1990b). During the spawning season the witch flounder does not appear to feed much, if at all, and the energy required for survival is obtained from the body of the fish, which results in a soft 'jellied' flesh, useless for marketing (Bowering 1990b).

5.8.9 Redfish

Three species of redfish are found in the NW Atlantic, the Acadian redfish (*Sebastes fasciatus*), the deep-sea redfish (*S. mentella*), and the golden redfish (*S. marinus* [=*S. norvegicus*]) (Scott and Scott 1988; DFO 2000d). Based on external features alone, *Sebastes mentella* is indistinguishable from *S. fasciatus*. In fact, only two types of redfishes, beaked (*S. mentella* and *S. fasciatus*) and golden (*S. marinus*), are recorded during Canadian groundfish surveys, because the separation of *S. mentella* and *S. fasciatus* is very time consuming requiring dissection and special skills. Studies conducted before the late 1970's did not recognize the differences between *S. mentella* and *S. fasciatus* and most of the studies carried out since the discovery that *S. mentella* could be separated to include *S. fasciatus* have grouped the two together.

Redfish (*Sebastes* spp.) are fished in at least one area (west of Burnt Island) in the Leading Tickles study area (Figure 5.7). Normal fishing depth is 100 fathoms using gill nets (EVTA CCRI 2001).

Fishery

Redfish are commercially exploited on both sides of the North Atlantic. Canada has prosecuted redfish fisheries since the late 1940's and the most commonly fished areas in the Newfoundland region have been the Labrador Shelf and Newfoundland shelf north of Grand Bank, the Gulf of St. Lawrence, and the Laurentian Channel (DFO 2000d). As far as the commercial fishery or fisheries management is concerned, the three redfish species inhabiting the Newfoundland region are managed together as a single unit in each management area (DFO 2000d). Fisheries take place using both bottom and mid-water trawls. On average, redfish take approximately six to eight years to reach the minimum fishable size (22 cm) (DFO 2000d).

Distribution

Sebastes fasciatus is essentially a North American species (Scott and Scott 1988). It is rare off the Labrador Shelf but becomes increasingly common southward on the Canadian continental shelf, until it predominates on Georges Bank and in the Bay of Fundy-Gulf of Maine region (Scott and Scott 1988). *Sebastes marinus* is common on the northern and eastern Grand Bank, on Flemish Cap, and in the Gulf of St. Lawrence but is rare south of Cabot Strait (Scott and Scott 1988). *Sebastes mentella* is the most widely distributed of the eastern North Atlantic redfishes, occurring from Baffin Island to the Gulf of Maine (Scott and Scott 1988). *Sebastes mentella* predominates in the northern part of the range (for example, off Baffin Island), it is generally distributed deeper than *S. fasciatus* and *S. mentella*, and goes farther out to sea than *S. fasciatus* and *S. marinus* (Scott and Scott 1988).

Redfish are demersal by day and rise into the water column at night (Scott and Scott 1988). They are moderately cold (3-6°C) water species in the NW Atlantic and are found in the deep (100 to 750 m) waters at the edge of fishing banks and in deep ocean channels (Ni and McKone 1983).

Redfish occur in deepwater bays in the Newfoundland region (Lambert 1960) and McKone and LeGrow (1991) indicate that occasionally, in some areas of Newfoundland where the waters are very cool, redfish have been caught in shallow waters near shore and around wharves; however, they add that these occurrences are unusual.

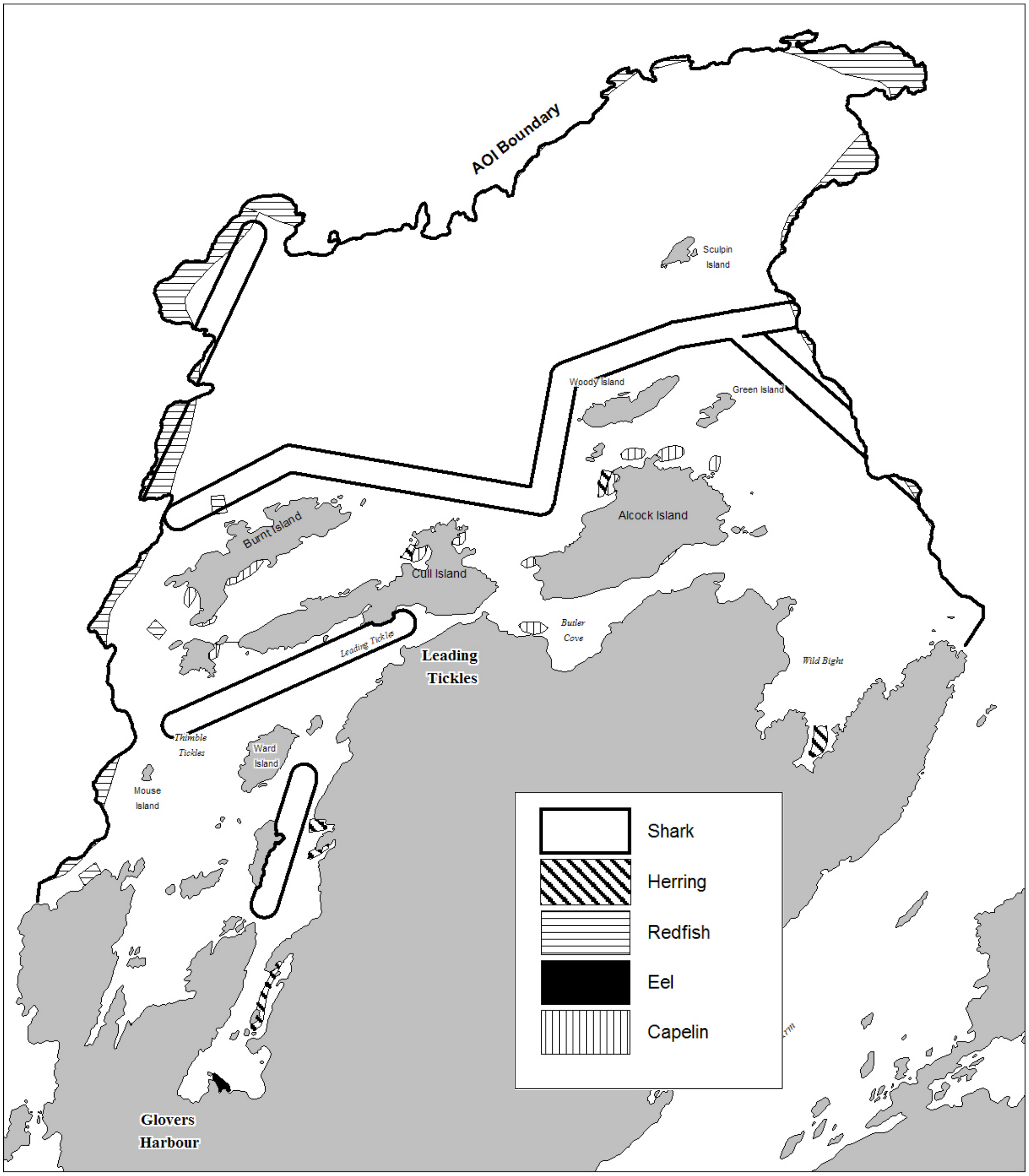


Figure 5.7 General capelin, herring, redfish, eel, sea-run brook trout and shark grounds in the Leading Tickles study area. From EVTA CCRI (Feb. 2001).

Spawning

Fertilization is internal; the eggs develop within the ovaries of the female until the yolk sac is absorbed, and the female gives birth to free-swimming larvae. Mating generally occurs in September or October in the NW Atlantic, and the young are born sometime between April and July (McKone and LeGrow 1991). *S. mentella* females appear to live deeper and extrude larvae earlier than *S. marinus* and *S. fasciatus* (Templeman 1980).

Studies conducted in the Newfoundland region and Flemish Cap show that female redfish move to deeper water to spawn (Atkinson 1989a). After larval release females immediately move to shallower water.

The number of young released by female redfish is fewer than for fishes that extrude eggs (Scott and Scott 1988). Scott and Scott (1988) cite a study by Kelly et al. (1972) carried out in the Gulf of Maine, where a female redfish (probably *S. fasciatus*), 30 cm long, was estimated to retain about 50,000 fertilized eggs at the beginning of incubation and release about 15,000 to 20,000 living young.

Habitat

Redfish exhibit considerable diel vertical migrations in the NW Atlantic, moving up from the bottom at night probably in pursuit of their prey and beaked redfish are thought to ascend somewhat higher in the water column than golden redfish (Atkinson 1989b).

All three redfishes are benthic species, living over rocky or clay-silt bottom (Scott and Scott 1988). Templeman (1959) suggested that redfish become ‘stranded’ in areas where there are current breaks (e.g., banks, ledges, depressions) and do not prefer a particular bottom type. There is however, evidence of the use of bottom structure as cover, particularly boulders and anemones (Shepard et al. 1986).

Analysis of bottom trawl surveys conducted on the Grand Bank (NAFO Div. 3L) throughout the year indicated that most often redfish (*Sebastes* spp.) were taken in waters deeper than 199 m (Atkinson 1989a). Redfish moved between deeper and shallower waters at different times of the year and distributions with depth in all four quarters of the year (i.e., January-March, April-June, July-September, October-December) were significantly different. Redfish were predominantly at depths >500 m during April-June, they spread into a wide range of depths in July-September, and in October-March they were distributed in intermediate depth ranges, between about 300 and 500 m. They occurred all along the edge of the continental shelf and there was evidence of movement along the northeast slope during the year, westerly from January-March to July-September, then back to the east in October-December. There may also have been some movement north of the Grand Bank into Div. 3K and during most of the year (autumn to late spring; October to June) there seemed to be separation between concentrations of redfish found on the southeastern slope and in the northeastern area of the Grand Bank (Atkinson 1989a).

Studies of redfish (*Sebastes* spp.) distribution in the NW Atlantic in relation to temperature have found that they may be captured over a wide temperature range, from 0 to 13°C with maximum abundance from 3 to 6ºC (reviewed *in* Grant 2001a).

Feeding

Dietary studies on redfish are difficult because stomachs are often everted when fish are brought to the surface from deep waters (Scott and Scott 1988).

Dietary studies carried out on redfish captured in deepwater bays (Trinity Bay and Hermitage Bay) and offshore areas in the Newfoundland region as well as in the Gulf of St. Lawrence indicate that redfish feed on pelagic organisms (primarily crustaceans) in the water column and not on benthic forms (Steele 1957; Lambert 1960). Amphipods, fish, and euphausiids were the most important food items in the Newfoundland region and euphausiids were the most important food in the western Gulf of St. Lawrence. Other food types consumed included copepods, shrimp, squid, ctenophores, and chaetognaths. Fish increase in importance to the diet with increasing redfish body length and larger and older redfish consume more fish than crustaceans (Lambert 1960; Gonzalez et al. 2000).

The vertical movement of redfish up from the bottom at night is believed to be in association with increased feeding activity and may be related to the vertical migration of their prey species (Steele 1957; Atkinson 1989b).

5.8.10 Sea-run Brook Trout

Both the freshwater and sea-run forms of the brook trout (*Salvelinus fontinalis*) occur near Leading Tickles. It is the most important recreational fish in the province generally and most recreational fishing effort in Newfoundland is directed at this species. Historically, sea-run brook trout were netted for commercial and food fishery purposes. The sea-run form is normally much larger than the freshwater one.

Sea-run brook trout were historically harvested in Osmonton Arm, just outside the Leading Tickles study area (EVTA CCRI 2001) (see Figure 5.7).

Distribution

The brook trout is native to eastern North America and has been reported from northeastern Georgia to Labrador (Scott and Crossman 1973). Brook trout are widely distributed throughout Newfoundland and Labrador (Scott and Crossman 1964, 1973), they have been reported from northern (Black et al. 1986) and southern Labrador (Bruce 1974; Ryan 1980) and are thought to exist within all Newfoundland freshwater ecosystems (Scott and Crossman 1964).

Reproduction

Brook trout spawning typically occurs between late September and early November in Newfoundland (Scott and Crossman 1964; O'Connell 1982), and Labrador (Dempson and Green 1985). Brook trout usually spawn in shallow stream headwaters with a gravel substrate (Scott and Crossman,1973) but have also been known to utilize lake shorelines (Dempson and Green 1985), areas of upwelling groundwater (Webster and Eiridsdottier 1976), and have been reported to utilize submerged woody debris in lake areas with sufficient upwelling (Bradbury et al. 1999).

Males usually arrive first at the spawning grounds and often outnumber the females (Scott and Crossman 1973). The female (assisted by the courting movements of the male) clears away debris from the gravel to create a redd (nest). The eggs are extruded in batches into the redd by the female and are fertilized by the male. Although one male and one female take part in spawning, they may each repeat the procedure with other mates during the spawning period (Scott and Crossman 1973). Eggs incubate over the winter in the gravel substrate, hatching between April and mid-June in Newfoundland (Scruton et al. 1997) and from mid-May to mid-June in Labrador (Scruton et al. 1997). After hatching, the young-of-the-year (alevins) remain within the redd's gravel until the yolk sac is absorbed (Scott and Scott 1988). After emerging from the redd, the young-of-the-year (fry) begin to feed upon invertebrates (Williams 1981). In northern populations of brook trout, repeat spawning is common with males spawning annually and females spawning in alternate years (or annually if food resources permit gonadal development) (Power 1980; O'Connell 1982).

Habitat and Feeding

Some brook trout populations are anadromous, spending one or two months feeding at sea in relatively shallow coastal water in the vicinity of their natal stream (Scott and Scott 1988). At sea, brook trout have been observed to form small schools and to move at least eight km from the estuary of their natal river (Scott and Scott 1988). Not all brook trout within a freshwater population will migrate to sea, and why some remain is not clearly understood (Scott and Scott 1988). Within Newfoundland and Labrador, as in other jurisdictions, brook trout can utilize lakes and ponds for spawning, overwintering, and feeding (Dempson and Green 1985). There may be an estuarine form of brook trout living mainly in estuaries and river mouths, which move in and out of the lower reaches of rivers with the tides (Backus 1957). Although movements of brook trout between fresh and salt water can occur throughout the year (O'Connell 1982) the peak of seaward migration typically occurs in May or June in Newfoundland (O'Connell 1982) and in June or July in Labrador (Scruton et al. 1997).

5.8.11 Capelin

Capelin (*Mallotus villosus*) is a key species both commercially (see Figure 5.7) and ecologically in the Leading Tickles study area and the NW Atlantic in general.

Fishery

Historically, a small domestic fishery for capelin on the Newfoundland spawning beaches existed to provide food, bait, and fertilizer (DFO 1996g). A directed foreign offshore fishery began in the early 1970's and was closed in Div. 3L and in Div. 2J3K in 1979 and 1992, respectively (DFO 1996g). An inshore fishery for capelin roe was initiated during the 1970's. Traditionally, the inshore fishery began in the St. Mary's Bay region by about mid-June and followed schools of mature capelin on their northward migration along the northeast coast, and finished in White Bay area by about mid-July (Nakashima 1996; DFO 1996g). A major problem with the fishery in recent years is the late and unpredictable arrival inshore of mature fish (Nakashima 1996).

Distribution

The capelin is circumpolar in distribution and is found in the northern regions of the Atlantic and Pacific Oceans. On the east coast of North America, capelin occur from Hudson Bay to Nova Scotia, with the greatest quantities occurring off the eastern shores of Newfoundland and Labrador (Scott and Scott 1988).

In the Newfoundland region, capelin exhibit inshore-offshore migrations associated with spawning. In general, capelin overwinter in offshore waters, move shoreward in early spring to spawn on beaches throughout the region in the spring-summer, and return to offshore waters in autumn. Juvenile capelin are found in bays surrounding insular Newfoundland; however, most larvae are rapidly carried out of the bays and inshore areas by surface currents. They end up in offshore waters on the northeast Newfoundland Shelf and northern Grand Bank (Dalley and Anderson 1997), which are thought to be major nursery areas (DFO 1996g).

Spawning

Fecundity increases with increasing body length in capelin with an individual 13.9 cm in length possessing up to 18,607 eggs while a 17.4 cm individual may possess up to 47,859 eggs (Templeman 1948).

Newfoundland is unique with respect to spawning by capelin, being the only region where both beach spawning and offshore spawning are known to occur (Carscadden et al. 1989). Beach spawning occurs throughout insular Newfoundland and on the east coast of Labrador and offshore spawning has been verified at depths of approximately 50 to 60 m on the Southeast Shoal of the Grand Banks (Pitt 1958; Carscadden et al. 1989).

A combination of factors determine beach suitability as well as when and where beach spawning will occur, these include temperature, substrate, tidal conditions, and light (Templeman 1948). Generally, where substrate conditions are suitable (see below) spawning beaches may be found in exposed, moderately exposed, and sheltered locations throughout the region. Beach spawning is demersal with the eggs being deposited in the intertidal zone. However, occurrence of egg masses indicate that subtidal spawning occurs to depths ranging from approximately one to 37 m and up to approximately 400 m from shore in years and areas where water temperatures on the beaches exceeds the preferred spawning temperatures

(Templeman 1948). Subtidal spawning is assumed to be variable from year-to-year and was likely extensive in 1999 (DFO 1996g).

In the Newfoundland region beach spawning may occur over a wide range of temperatures from 2.5 to 10.8°C (Frank and Leggett 1981a); however, the favorable temperature range reported for intensive beach spawning was 5.5 to 7.5°C on the east coast of Newfoundland and 6.0 to 8.5°C on the south coast (Templeman 1948). A detailed summary of beach spawning in Newfoundland and Labrador in 1941 and 1942 indicated that beach spawning may occur as early as late May on the south coast of Newfoundland, early June in the Gulf of St. Lawrence, mid-June on the east coast of Newfoundland, and early July on the east coast of Labrador (Templeman 1948). More recent studies of beach spawning in the Newfoundland region have indicated a delay in beach spawning times throughout the region during the early 1990's (Nakashima 1996).

Beach spawning studies on the northeast coast of Newfoundland indicate that a combination of low spring temperatures and small average size of capelin results in later peak spawning time whereas at the other extreme, larger fish size and high water temperatures result in earlier spawning (Nakashima 1996). Overall, studies indicate that capelin exhibit considerable interannual variation in spawning time, that spawning may be coherent over a broad geographic area, and that spawning time is related to water temperature.

Capelin usually prefer beaches with gravel five to 15 mm in diameter (Templeman 1948). When the most favoured substrate is occupied, or not available because of tidal conditions, beach-spawning capelin may spawn on sand less than two mm in diameter or on large gravel up to 25 mm in diameter (Templeman 1948). Capelin do not spawn on large substrates or mud (Templeman 1948). However, it appears that eggs may incidentally adhere to rocks, large boulders, and macroalgae when they are present among preferred substrates (Templeman 1948). Subtidal spawning inshore appears to be predominantly on sand (Templeman 1948).

Beach spawning occurs primarily at night and may occur during the daylight period under heavy overcast skies (Templeman 1948). The most intensive spawning always occurs during ebb tide although some spawning may occur at any stage (Templeman 1948; Frank and Leggett 1981a). Spawning increases when there is a surf and decreases when there is little or no surf (Jeffers 1931). Spawning may be protracted over several weeks with larger capelin spawning early (Templeman 1948) and Frank and Leggett (1981a) observed beach spawning at two distinct time intervals separated by 12-15 days in Bryant's Cove, Conception Bay.

Evidence of offshore spawning by capelin was discovered in 1950 and 1951 when capelin eggs were found in the diet of haddock collected on the SE Shoal of the Grand Bank (Pitt 1958). The eggs adhered to sand particles that were 0.5 to 2.2 mm in diameter indicating that offshore spawning takes place on sand substrate. Spawning occurred offshore at the same time (June-July) as inshore indicating that one or more Grand Bank populations exist (Pitt 1958; Carscadden et al. 1989).

Capelin eggs are 0.9 to 1.0 mm in diameter, exhibiting an average diameter of 0.97 mm (Templeman 1948). Capelin egg development rate is determined by average daily water temperature (Jeffers 1931; Frank and Leggett 1981b). Studies of capelin egg development for Newfoundland indicate that development may proceed successfully at 0 to 12°C, successful development is somewhat variable at 15°C, and development failure occurs at 18 to 20°C (Jeffers 1931). Frank and Leggett (1981b) provide an equation derived from *in situ* experiments that describe the days to hatching when the average daily temperature is known.

Recently hatched capelin larvae are 6 to 7 mm in length (Fahay 1983). They remain in the beach gravel until they are flushed by wave action induced by onshore winds, which can result in simultaneous larval emergence across an entire beach (Frank and Leggett 1981a). Frank and Leggett (1981a) identified patterns in larval emergence that were characterized by intermittent abrupt increases in the numbers of larvae in the nearshore waters in the immediate area of the spawning beach. The larval emergence patterns were not related to changes in tidal amplitude or day-night variation.

Once capelin larvae are flushed from intertidal sediments they are planktonic and rapidly drift from embayments into open bays on the northeast coast of Newfoundland in as little as six to eight hours (Taggart and Leggett 1987). By late summer, most larvae are further displaced onto the Grand Bank by currents flowing out of the bays. Pelagic surveys in inshore and offshore areas on the NE Newfoundland Shelf and Grand Bank (Div. 2J3KLNO) indicate that juvenile capelin are distributed throughout the inshore at central latitudes (ca. 48-52°N) during late summer (August-September) and peak abundances were found in offshore waters off Bonavista Bay (Dalley and Anderson 1997).

Habitat

Transformation to the pelagic juvenile stage (i.e., when the juvenile is a miniature of the adult form) occurs when capelin are 40 mm in length (Fahay 1983). For the most part, juvenile capelin are pelagic with no apparent substrate preference. However, when they occur in shallow (<10 m) waters close (within 55 m) to shore they may prefer eelgrass habitat (Gregory et al. 1997).

Adult capelin are pelagic with no apparent substrate preference. Large schools of capelin can be detected by echo-sounder well offshore from the Newfoundland coast (Pitt 1958). Echo-soundings on various parts of the Grand Bank in spring-summer indicate the presence of schools of capelin up to 18 m from the bottom during the day and nearer the surface at night (Pitt 1958). Capelin appear to exhibit a reverse vertical migration pattern during the autumn migrating to the surface during the daylight period (Shackell et al. 1994).

Generally, mature capelin begin migrating westward from offshore banks about March or April. However, the migration routes that maturing capelin follow from offshore feeding areas to coastal Newfoundland each spring are unknown (Nakashima 1992). During May and June when adult prespawning capelin are inshore they feed heavily on the spring bloom of zooplankton to increase their spawning condition (Winters 1970).

A combination of low acoustic biomass estimates of capelin in offshore waters of the NE Newfoundland Shelf and Grand Banks during the 1990's (Miller 1994) and occurrence of capelin on the Scotian Shelf and Flemish Cap (Frank et al. 1996) suggest that capelin distributions shifted south and east during the early 1990's. These changes in distribution were apparently related to anomalous cold ocean temperatures. Although water temperatures have been increasing in recent years, capelin continued to be reported in relatively high numbers on the Scotian Shelf (DFO 1996g).

Feeding

Food of capelin consists of planktonic organisms, largely copepods and pelagic amphipods (Scott and Scott 1988). Feeding is seasonal, intensifying in late winter and early spring in the prespawning period, declining as the spawning season approaches, and virtually ceasing during spawning (Scott and Scott 1988). After spawning capelin commence feeding and continue until cessation of feeding in early winter (Scott and Scott 1988).

5.8.12 Eel

The American eel (*Anguilla rostrata*) occurs in the Leading Tickles study area and has been subject to directed harvest just to the east of the study area in Osmonton Arm (see Figure 5.7).

Fishery

Newfoundland has been inconsistently exporting eels since 1930 but it wasn't until the mid to late 1980s that landings increased substantially although not to the level seen in other parts of eastern Canada. Between 1980 and 1995, Newfoundland's eel landings increased by over 60% before falling off in 1995. Factors identified as principally responsible for the decline in eel stocks include habitat loss, overfishing and changes in oceanographic conditions.

Distribution

The American eel (*Anguilla rostrata*) is a catadromous fish species that spawns in the Sargasso Sea and grows to onset of maturation in fresh water. During the growth phase, it inhabits Atlantic coast tributaries of North America from the Gulf of Mexico to Labrador and Greenland. Evidence exists which possibly links the status of the American eel in the northern part of its range to that of the European eel (*Anguilla anguilla*) by a common but unknown oceanic factor (Castonguay et al. 1994a,b). Both species spawn only once and the number of adults that leave continental waters on spawning migration each year represents the full reproductive potential for that year.

River surveys carried out by various government agencies in the 1970s revealed a wide distribution of eels throughout the Newfoundland's freshwater systems. Prior to 1982, the immature juvenile 'yellow eels' were the target group of the fishery. In 1982, development initiatives were refocused toward the harvest of the mature 'silver eels' migrating to sea.

Experimental fisheries for elvers (recruitment stage entering freshwater for the first time) were initiated only recently.

Rivers emptying into St. George's Bay, Notre Dame Bay and Bonavista Bay consistently accounted for the highest catches during 1987 to 1998. Other significant areas for the eel fishery during that period included rivers flowing into Conception Bay, Trinity Bay and the Gulf waters off of the Northern Peninsula (Knight 1997).

Spawning

Eels are catadromous meaning that upon attainment of sexual maturity, the adults migrate downstream to the sea where ultimately they spawn. Sexual maturation in eels appears to be related more to size than to age. Immature adult eels may range in colour from yellowish to greenish or olive brown, with the backs darker than the belly. They are known as 'yellow eels'. Sexually maturing eels, known as 'silver eels', acquire a metallic sheen, bronze or black on the back and silvery below. Males tend to be smaller than the females. The spawning migration occurs between August and December with most activity at night, usually within the first few hours after sunset. Peak migration activity usually occurs during September and October during the last quarter of the moon and is enhanced by dark stormy nights and rising water levels. Yellow eels as well as silver eels may also be migrating seaward during the autumn months but they are believed to be moving to overwintering sites within the river or estuary.

American eels spawn in the western part of the Sargasso Sea with peaks occurring between January and March. It is believed that the adults die after spawning. After hatching, most of the transparent larvae known as leptocephali drift northward with the Gulf Stream until they are distributed along the North American coast. Although the northward movement is believed to be primarily through passive drift, some active swimming may occur. It may take as long as one year for the larvae to reach Canadian waters. During the northward movement, the larvae metamorphose to a more transparent eel-like shape and are known as 'glass eels'. The glass eels actively move towards shore and by the time they reach the estuaries of the freshwater systems, they are pigmented and known as elvers. Elvers are approximately 40 to 70 mm long when they commence to enter the freshwater systems in spring or early summer. Freshwater temperatures are in the 6 to 8ºC range when the upstream migration begins. The upstream distance moved by elvers is variable, depending on river gradient and obstructions encountered. Some remain in the estuary and coastal waters.

Habitat

In freshwater, eels apparently have relatively small home ranges within which they forage. Changes of habitat tend to occur only during transitional periods such as spring and autumn. They tend to be most active at night and retire to muddy bottoms or other cover during daylight. Water temperature influences the degree of seasonal activity of this species. Eels become noticeably less active when water temperatures drop below 11ºC in the autumn. During winter, eels hibernate in the bottom mud.

Little is known about the American eel's movements, distribution and habitat at sea.

Feeding

At sea, eel larvae feed on plankton. In freshwater, juveniles and adults feed mainly at night on bottom invertebrates and small fishes, including salmon and trout. In estuaries, they are known to feed on crustaceans (including crabs), worms, and soft shell clams (Scott and Scott 1988).

5.8.13 Herring

Atlantic herring (*Clupea harengus*) have been fished in some of the inner bays of the Leading Tickles study area (see Figure 5.7).

Fishery

Prior to the 1960's, in most areas of Atlantic Canada, Atlantic herring were caught by small inshore boats using gillnets, traps, or weirs (Ahrens 1993). Between 1965 and 1972, herring catches in Canadian waters increased rapidly due in part to the introduction of a fleet of large purse seiners, but total catches have declined considerably from record levels obtained in the 1970's (Ahrens 1993). A fungus infection killed many herring during the period 1954 and 1956 and the increased catches of herring in the southern Gulf of St. Lawrence and the west and south coast of Newfoundland during the mid-1960's were believed to have resulted from reduced competition and strong year-classes produced in the wake of the die-off.

In Newfoundland the traditional herring fisheries took place in Fortune Bay and the area of the Port-au-Port Peninsula (Ahrens 1993). A strong year-class of herring occurred in coastal waters of Newfoundland in the late 1960's, which resulted in the development of a mobile purse seine fleet during the early 1970's. However, poor recruitment and dwindling stocks resulted in closure of fisheries on the east and south coast in the early 1980's (Ahrens 1993). The 2000 east and southeast Newfoundland Atlantic herring stock status report indicates that most herring stocks in the Newfoundland region are at low levels relative to peak levels of the 1970's (DFO 2000e). Year-classes produced during the 1990's were generally small, contributing to the overall decline in abundance (DFO 2000e). Herring in the Newfoundland region are at the northern extent of their geographic range in the northwest Atlantic (DFO 2000e). As such, good survival of young herring (i.e., recruitment to fishery) in these stocks is largely influenced by suitable environmental conditions, principally 'warm' overwintering water temperatures and 'high' salinities prior to spawning (DFO 2000e). As a conservation measure certain bays on the west coast of Newfoundland are protected from fishing during the spawning season (DFO 2000f).

Distribution

Atlantic herring occur on both sides of the North Atlantic Ocean (Scott and Scott 1988). In the western North Atlantic it ranges from West Greenland to Labrador southward along the North American coast to Cape Hatteras, North Carolina (Scott and Scott 1988). Atlantic herring in the Newfoundland region are at the northern extent of their geographic range distribution in the NW Atlantic (DFO 2000e,f). It occurs, usually in commercial quantities, along the coast of southern Labrador, around the coast of Newfoundland and offshore banks, in the Gulf of St. Lawrence, along the coast of Nova Scotia and offshore banks, and the Bay of Fundy, including Passamaquoddy Bay (Scott and Scott 1988). Atlantic herring is primarily pelagic and often schools, particularly prior to spawning when large schools are formed (Scott and Scott 1988).

Several stock complexes of Atlantic herring are recognized in the Newfoundland region. Some are resident populations that spawn in coastal waters while others exhibit only seasonal overwintering migrations into the region. Five resident Atlantic herring stock complexes are recognized in the large bays on the south and northeast coast (Parsons and Hodder 1973; Wheeler and Winters 1984a,b): (1) the Fortune Bay stock, (2) the Placentia Bay-St. Mary's Bay stock complex, (3) the Conception Bay-Southern Shore stock complex, (4) the Bonavista Bay-Trinity Bay stock complex, and (5) the White Bay-Notre Dame Bay stock complex.

During the summer herring from Notre Dame Bay move northward and mix with White Bay herring to form feeding concentrations that extend northward to St. Anthony and into the Strait of Belle Isle (Wheeler and Winters 1984a). These herring stay mixed during their southward migration through the White Bay area during autumn and during the overwintering period in Notre Dame Bay. In early spring there is a dispersal of herring to spawning areas in the north (Green Bay and White Bay) and in the south (Gander Bay to Cape Freels) at which time discrete groups are formed (Wheeler and Winters 1984a).

Spawning

Fecundity increases with increasing body length in Atlantic herring up to a maximum age and then the number of eggs produced declines with increasing age (Scott and Scott 1988). Hodder (1972) demonstrated that fall spawning females produce more eggs (up to 50% more) than spring spawners of similar size. In the Newfoundland area Hodder (1972) estimated that fecundity ranges from 12,720 eggs for a spring spawning 27.8 cm female to 241,630 eggs for a fall spawning 37.0 cm female.

Canadian Atlantic herring stocks are comprised of both spring and fall spawners but spring spawning dominates in most of the Atlantic herring stocks in the Newfoundland region (Pinhorn 1976).

Along the Canadian coast, Atlantic herring may spawn in any month between April and October, but spawning is concentrated in May (spring spawners) and September (fall spawners) (Ahrens 1993). In the Newfoundland region, spring spawning generally occurs in May and fall spawning occurs in late August-September (Hodder 1972).

Atlantic herring are demersal spawners depositing their adhesive eggs on stable bottom substrates (Scott and Scott 1988). Spawning may occur in offshore waters (e.g., Georges Bank) at depths of 40 to 80 m; however, most Atlantic herring stocks spawn in shallow (<20 m) coastal waters, and it appears that in the Newfoundland region Atlantic herring spawn in coastal waters only. In the case of coastal spawning, spring spawning generally takes place in shallower waters (4-6 m) than fall spawning (18-22 m) (Tibbo et al. 1963). The main spawning areas are located at the heads of the various bays and deep water inlets around insular Newfoundland (Tibbo 1956). Fishery officer reports on Atlantic herring spawning in the Newfoundland region in the early 1950's document three interesting events: (1) patches of 'white' water (milt from males) provided evidence of Atlantic herring spawning and a patch of white water about 20 miles in length was observed in Notre Dame Bay from Rocky Bay Point to Anchor Brook where coastal spawning was observed at depths of 0.3 to 7.3 m, (2) in Bay d'Est and Bay du Nord herring have gone in on high water and spawned such that when the water fell the bottom (beach) was covered with spawn, and (3) Placentia Bay herring were reported to sometimes spawn in very shallow water, just enough to cover the fish while on other occasions (apparently fall) they are known to deposit their eggs in water up to 18.2 m deep but not more than 244 m from shore. The reports from Bay d'Est and Bay du Nord imply intertidal spawning by Atlantic herring, and Pacific herring (*Clupea pallasii*) are known to spawn in or just below the intertidal zone. Tibbo et al. (1963) indicate that spawning in Atlantic herring is restricted to the subtidal zone and they report that storms may dislodge eggs and cast them on to beaches, which may explain fisheries officer observations of eggs on shore. However, intertidal spawning by Newfoundland herring cannot be entirely ruled out.

In the Newfoundland region, Atlantic herring spawn on gravel or rocky bottom where there is an abundance of seaweed and some spawning has been observed on sandy shores and on bare rock (Tibbo 1956). Spawning on stable substrates in shallow waters close to shore insures that the eggs will be exposed to well-mixed water, and tidal currents averaging 1.5 to 3.0 knots have been recorded in the area of Atlantic herring spawning beds (Reid et al. 1999). These high-energy environments provide aeration and reduce siltation and accumulation of metabolites (Reid et al. 1999).

Atlantic herring eggs are 1.0 to 1.4 mm in diameter (Fahay 1983), adhere to one another and the bottom, and they are often deposited in several layers (i.e., 3.25 cm thick egg beds have been reported) (Reid et al. 1999). Winter flounder is a major predator on herring eggs in coastal waters (Tibbo et al. 1963). Laboratory studies, apparently on Gulf of Maine herring, indicate that eggs develop normally at 10 and 15°C and that development does not occur at 0 and 5°C (Reid et al. 1999). Fertilization and hatching of Atlantic herring eggs is possible at a salinity of 4.8 ppt and a salinity of 1.7 ppt has been found on herring spawning grounds in the eastern Atlantic (see Brawn 1960a).

Habitat

Recently hatched Atlantic herring larvae are planktonic and range from 4 to 10 mm in length (Fahay 1983). Atlantic herring larvae have been found to occur at salinities as low as 10 ppt in the upper St. Lawrence River estuary (Fortier and Leggett 1983) and salinities of at least 32 ppt in the Gulf of Maine (Reid et al. 1999). They make diel vertical migrations.

Atlantic herring larvae metamorphose into juveniles at 40 to 50 mm total length. Atlantic herring is a pelagic schooling fish with no apparent substrate preference during the juvenile and adult life phase. In the laboratory the upper lethal temperature for unacclimated Atlantic herring is 19.5 to 21.2°C and the lower lethal temperature is -1°C (Brawn 1960b). Atlantic herring can survive short exposure to temperatures below -1°C (Brawn 1960b) and the preferred temperature of Gulf of Maine herring is 8 to 12°C (Reid et al. 1999). Laboratory studies indicate a general preference for salinities of 26 to 32 ppt (Stickney 1969) and juveniles (10 to 24 cm in length) are able to withstand salinities down to five ppt for at least four weeks at temperatures between 4 and 8ºC (Brawn 1960a). Atlantic herring tend to avoid brackish water as they increase in age and salinity preference is temperature dependent with a preference for salinities >29 ppt at water temperatures <10°C (Stickney 1969).

Feeding

Atlantic herring are visual feeders, consuming plankton during daylight hours (Blaxter 1966), filtering out the small organisms with their long well-developed gill rakers (Scott and Scott 1988). A review of summary documents of herring diets in the NW Atlantic indicates a varied planktonic food source with herring apparently consuming the most available zooplankter in a given region. Euphausiids, chaetognaths, copepods, amphipods, mysids, fish eggs, larvae of small fishes, and small larvae of pelecypods, cirripeds, and decapods are also important, especially to juveniles (Scott and Scott 1988; Reid et al. 1999).

5.8.14 Mackerel

Atlantic mackerel (*Scomber scombrus*) are not fished to any extent in the Leading Tickles study area but they do occur there occasionally as evidenced by their appearance in bycatch (EVTA CCRI 2001).

Fishery

Atlantic mackerel are managed under the Mid-Atlantic Fishery Management Plan for Atlantic mackerel, squid, and butterfish (Studholme et al. 1999). Both the northern and southern spawning populations of Atlantic mackerel in the NW Atlantic are assessed as one stock for management purposes.

Nova Scotia and Newfoundland (primarily west coast) are the provinces with the highest mean landings of Atlantic mackerel in the Canadian Atlantic mackerel fishery (DFO 2000g). The most commonly used gear types are gillnet, handline, purse seine, and trapnet (DFO 2000g). Gillnets are used mostly in spring and handlines in fall and purse seine catches on the west coast of Newfoundland are also significant in the fall (DFO 2000g). The success of the purse seine fishery is strongly dependent on environmental conditions, including water temperature and prevailing winds (DFO 2000g). Historically, the largest landings in eastern Newfoundland were from Notre Dame Bay (Templeman 1966).

Distribution

The Atlantic mackerel occurs on both sides of the North Atlantic (Scott and Scott 1988). In the NW Atlantic, the Atlantic mackerel has been recorded as far north as Black Island, Labrador (Parsons 1970). From Labrador the Atlantic mackerel occurs southward to Cape Lookout, North Carolina (Scott and Scott 1988).

The Atlantic mackerel is a moderately warm water fish (Pinhorn 1976) and its abundance on the southern and eastern coast of Newfoundland fluctuates in response to environmental conditions, particularly surface water temperatures (Templeman 1966). In warm years, Atlantic mackerel appear to make extensive migrations in the Newfoundland region entering coastal waters in the southeastern region in the spring and the northeastern region in late summer (Parsons and Hodder 1970; Moores et al. 1975). In warm years, Atlantic mackerel first appear in abundance in the southern and eastern Newfoundland region about the same time that they enter the Gulf of St. Lawrence, in June and July.

Atlantic mackerel are captured in the Gulf of St. Lawrence throughout the summer months (MacKay 1979) and in warm years they may make late summer (August-September) migrations along the west coast of Newfoundland through the Strait of Belle Isle and continue northward into coastal waters off the Labrador coast or a component may split off and migrate southward along the northeast coast of insular Newfoundland (Parsons 1970; Moores et al. 1975). Tagging studies in the Gulf of St. Lawrence and Notre Dame Bay indicate that Atlantic mackerel make regular southward migrations out of Canadian waters to overwintering grounds in NAFO Division 5 and 6 (Parsons and Moores 1974; MacKay 1979). They typically leave the Newfoundland region from September to November, but have been captured in Division 3K and 3L as late as December in some years (Gregoire 1993).

Spawning

Fecundity increases with increasing total body length of Atlantic mackerel in Canadian waters ranging from 211,400 eggs for a 35 cm female to 397,200 eggs for a 40 cm female (MacKay 1979).

The main spawning ground for the northern population of Atlantic mackerel is in the Magdalen Shallows in the Gulf of St. Lawrence (MacKay 1979). Spawning has also been documented in coastal waters in the Newfoundland region (Parsons and Hodder 1970; Moores et al. 1975). Prespawning and spawning Atlantic mackerel have been captured in Placentia Bay and eggs have been collected from the Bay of Islands area on the west coast of Newfoundland (Parsons and Hodder 1970). Furthermore, age 0 Atlantic mackerel have been captured in Conception Bay and Notre Dame Bay (Parsons and Hodder 1970), which has led to the inference that spawning may also occur on the Grand Bank (DFO 2000g). However, the possibility that age 0 Atlantic mackerel were spawned in these large bays should not be ruled out. In cold years, the migration of Atlantic mackerel into the Gulf of St. Lawrence may be delayed (MacKay 1979).

Atlantic mackerel spawn in the open water at temperatures of 9.0 to 13.5°C and salinities >30 ppt; however, eggs have been found in water as cool as 7.3°C and as warm as 17.6°C (Sette 1943). It appears that peak spawning occurs at 11 to 15°C in the Gulf of St. Lawrence (Ware and Lambert 1985).

The Atlantic mackerel is a broadcast spawner releasing eggs and milt into the surface waters and spawning may occur during the day or at night (Sette 1943; MacKay 1979; Walsh and Johnstone 1992). In the Gulf of St. Lawrence, Atlantic mackerel spawn from late May to early August, but the most intensive spawning generally occurs from mid-June to mid-July (MacKay 1979). In the southeastern Newfoundland region, spawning occurs during June and July (Moores et al. 1975). Spawning in the Newfoundland area has been described as sporadic probably only occurring in bays in which the waters warm to the appropriate temperature for spawning (Sette 1943).

Habitat

Atlantic mackerel eggs are planktonic floating in the upper 15 to 25 m of the water column, generally in water over 34 ppt salinity. However, eggs have been collected from the surface to 320 m in coast waters off the eastern U.S. (reviewed *in* Grant 2001a). MacKay (1979) reported that the eggs are normally concentrated in the upper 10 m in the Gulf of St. Lawrence and that half may occur within the upper one metre. However, MacKay (1979) noted that as the season progresses, the depth distribution of the eggs may deepen in association with the deepening of the thermocline, with eggs remaining between the surface and the thermocline.

Recently hatched Atlantic mackerel larvae are planktonic measuring about three mm in length (Fahay 1983). In the Gulf of St. Lawrence, recently hatched larvae were found at depths of five to 10 m and as they grew they moved progressively closer to the surface (Ware and Lambert 1985). At 50 mm in length, young mackerel become juveniles closely resembling the adult form and they begin to form schools (DFO 2000g). Atlantic mackerel grow very rapidly in their first year. In the Gulf of St. Lawrence, age 0 Atlantic mackerel may grow to 20 cm total length by November (MacKay 1979).

The Atlantic mackerel has no air bladder, which makes it heavier than water so that it must swim continuously to avoid sinking (Ahrens 1994) and thus have no substrate preference. The Atlantic mackerel is a pelagic schooling fish and may travel in very dense schools, especially during the long annual migration in spring and fall (DFO 2000g). Atlantic mackerel also commonly school with Atlantic herring, and a large (ca. 6.4 square km) mixed school of Atlantic herring and age 0 Atlantic mackerel was discovered near the surface in Conception Bay in 1968 (Parsons and Hodder 1970). Although pelagic, juvenile and adult Atlantic mackerel may occur from the surface to depths of 340 m.

In Newfoundland, the Atlantic mackerel has also been captured in shallow (<10 m) waters within 55 m of shore during the Fleming juvenile cod beach seine survey (D. Ings, pers. comm.), and is therefore assumed to move into the intertidal zone on occasion.

Juvenile Atlantic mackerel may be found in waters ranging in temperature from four to 22°C, but are most common at 10°C (Studholme et al. 1999). Field studies suggest that adults cannot tolerate temperatures below 5 to 6°C or above 15 to 16°C, they appear to prefer temperatures of 7 to 16°C under laboratory conditions, and the lower and upper lethal limits are reported to be <2°C and >28.5°C, respectively (Studholme et al. 1999). However, studies suggest that the northern population may tolerate colder waters. There is no apparent information on the range or salinity preference of Atlantic mackerel in Newfoundland waters.

Juvenile and adult Atlantic mackerel from the northern population exhibit a southward migration out of the Gulf of St. Lawrence as waters cool in late fall (MacKay 1979). Given the apparent lower temperature preference of 4°C for juveniles and lower lethal limit of 2°C (Studholme et al. 1999), it also seems likely that juvenile and adult Atlantic mackerel inhabiting bays and coastal waters of Newfoundland also migrate southward as the waters cool during late autumn.

Feeding

In the Newfoundland region, Atlantic mackerel ranging from age 2 to 10 fed predominantly on capelin during the summer months (June-August) while planktonic organisms, primarily euphausiids, were the main food item consumed during September-October (Moores et al. 1975). Pelagic amphipods, copepods, as well as decapods and gastropod larvae were also consumed in the Newfoundland region (Moores et al. 1975).

Atlantic mackerel feed by two methods, passive filter feeding and individual selection of organisms (Bigelow and Schroeder 1953b). Small organisms are filtered using the gill rakers while larger prey items are pursued and engulfed individually. Apparently, filter feeding predominates in the summer in the Gulf of St. Lawrence, while particulate feeding predominates in the spring and fall (MacKay 1979).

5.8.15 Salmon

The Atlantic salmon (*Salmo salar*) is anadromous (spawning and rearing in freshwater) and therefore not truly an oceanic species although adults spend considerable time at sea feeding. There are no scheduled salmon rivers in the Leading Tickles study area, although there are two small ones nearby (Northwest Arm Brook and Western Arm River). Salmon is included here because it is an important species that migrates through the study area and was traditionally fished commercially in the area. Historically, gill nets were deployed from headlands and islands in the study area until the moratorium in the early 1990s.

Importance

Atlantic salmon is a valuable commercial and recreational species. The Newfoundland island commercial fishery for Atlantic salmon has been closed since 1992. There are about 200 Atlantic salmon rivers (at least 187 scheduled ones) in the province. Newfoundland and Labrador contains most of the remaining wild stocks of this species.

Distribution

The distribution of Atlantic salmon ranges from the Arctic Circle south to the Connecticut River (Scott and Crossman 1973). It also occurs in western Europe, including West Greenland, Scandinavia, Iceland, Russia, British Isles, France and Spain.

Spawning

Atlantic salmon typically remain at sea for one to three years before returning to their natal river to spawn for the first time (Porter 1975). Atlantic salmon ascend rivers to spawn generally in the fall; however, the timing of upstream migration may range from May to September in Newfoundland and from July to August in Labrador (Porter 1975;). Anadromous Atlantic salmon normally spawn from mid-October to mid-November in Newfoundland and roughly two weeks earlier in Labrador (Porter 1975). Nesting sites, chosen by the female, usually consist of a gravel bottom riffle above a pool (Scott and Scott 1988). The nest (redd) is created within the substrate by strong tail movements of the female (water current creates the redd, not contact with the substrate) (Scott and Scott 1988).

When the redd is complete the female settles into the depression, the male aligns himself alongside and the eggs and sperm are released. The fertilized eggs are covered by the female (using the previously displaced gravel) and are left to incubate over the winter. Females rest after the operation and then repeat the procedure over and over until spawning is complete, this may take as long as a week for certain individuals (Scott and Scott 1988).

Some Atlantic salmon die after spawning, but some (usually females) survive to spawn a second or even a third time, these fish are sometimes referred to as “kelts”. Kelts may drop downriver to rest in a pool, they may immediately return to the ocean, or they may remain to overwinter within freshwater, returning to the sea in spring (Scott and Scott 1988). The numbers of repeat spawners can vary significantly between rivers or between years on a given river. The percentage of repeat Atlantic salmon spawners could vary from 5% to 34% in Canadian rivers (Dymond 1963).

The egg incubation period is normally four to five months with hatching occurring between mid-April and early May in Newfoundland and mid-April to mid-June in Labrador (Porter 1975).

Habitat and Feeding

Atlantic salmon spawning bed substrates usually consist of a small proportion of sand and a larger portion of coarse materials ranging from gravel to cobble (Warner 1963). Sufficient porosity is required in the substrate to provide flow for oxygen requirements and to remove metabolites of the developing eggs.

Adult Atlantic salmon are primarily pelagic and feed voraciously while at sea (Scott and Crossman 1973). When at sea, pre-grilse eat principally plankton (euphausids, amphipods, and decapods), while larger salmon consume mostly fishes such as herring, alewives, smelts, capelin, mackerel, sand lance, and small cod (Scott and Scott 1988). Atlantic salmon ascend rivers to spawn generally in the fall, however, the timing of upstream migration may range from May to September in Newfoundland and from July to August in Labrador (Porter 1975). Returning Atlantic salmon are called “grilse” after one winter at sea, and are called “salmon” if they have spent two or more years at sea (Scott and Scott 1988).

5.8.16 Smelt

The rainbow smelt (*Osmerus mordax*) is a small anadromous species that occurs throughout Newfoundland and Labrador at least as far north as Hamilton Inlet. It is not known to be common in the Leading Tickles study area but probably occurs there.

Fishery

This species is an excellent food species and in the past has been pursued commercially in Newfoundland. In the study area, it may be used recreationally.

Distribution

Rainbow smelt occur from Hamilton Inlet, Labrador south to New Jersey (Scott and Scott 1988).

Spawning

Spawning takes place in the spring in brooks, normally (but not always) above the head of tide. A female may produce 7,000 to 60,000 adhesive eggs (Scott and Scott 1988). Fry are washed down to brackish water in early May.

Habitat

Rainbow smelt may occur in fresh, brackish or salt water. In the sea, they are an inshore species inhabiting suitable bays and estuaries (Scott and Scott 1988).

Feeding

Rainbow smelt are voracious feeders on amphipods, euphausiids, mysids, shrimp, and marine worms (Scott and Scott 1988). Large individuals may also eat small fish.

5.8.17 Shark

There are a number of sharks that may occur in Newfoundland coastal waters at least sporadically. Spiny dogfish (*Squalus acanthias*) are the most numerous and are described here. Shark are fished in the Leading Tickles study area (EVTA CCRI 2001) (see Figure 5.7).

Fishery

The spiny dogfish has long been regarded as a nuisance in Newfoundland waters. Historically, the appearance of schools of this species on fishing grounds usually resulted in a cessation of fishing, as they would monopolize most of the hooks in line fishing or foul gillnets. However, in Europe the spiny dogfish is widely used for food and since 1970 the spiny dogfish has been fished in areas off the east coast of the U.S. by several European countries (Walsh 1993). In the Canadian Atlantic the fishery is small and concentrated in the southern bays of Newfoundland (Walsh 1993). The spiny dogfish is also important in high school, college, and university teachings where specimens are used for laboratory dissections.

Distribution

The spiny dogfish is widely distributed in coastal waters of temperate seas throughout the world, particularly in the Atlantic and Pacific oceans (Scott and Scott 1988). In the western Atlantic the spiny dogfish occurs from SW Greenland and southern Labrador southward to Florida with a break in distribution until it occurs again along the coast of Argentina (Scott and Scott 1988).

In North America, the wintering grounds of the spiny dogfish are off the Carolinas and Virginia (Nammack et al. 1985). In the spring, schools of spiny dogfish begin a northward migration on the continental shelf to nutrient rich waters off Nova Scotia and Newfoundland. Spiny dogfish arrive in southern Newfoundland in late May to mid-June (Templeman 1963). Some spiny dogfish move into bays on the south coast while others move westward into the Gulf of St. Lawrence or eastward along the northeast coast generally arriving at more northern latitudes by late summer or early autumn (Templeman 1963). By November-December most of the spiny dogfish have left the Newfoundland region; however, several fish may overwinter in the Newfoundland region. For example, Templeman (1963; 1965) reports the occurrence of overwintering spiny dogfish in deepwater bays of insular Newfoundland, deepwater channels in the Gulf of St. Lawrence, and the deep waters of the southwest slope of the Grand Bank and St. Pierre Bank.

Spawning

Fertilization is internal. Spiny dogfish are ovoviviparous, retaining the fertilized eggs in the uterus until the embryo (larva) fully develops into the juvenile life stage. The young are born alive after a gestation period of 22 to 24 months, the longest known gestation period of any vertebrate (Walsh 1993). As each fertilized egg passes to the uterus it becomes enclosed in a gelatinous capsule that eventually breaks down leaving the embryo free in the uterus with its own external egg sac to provide it with food for the remainder of the gestation period. The depletion of the egg sac marks the end of the gestation period at which time the female gives birth to from 1 to 15 fully developed juveniles, referred to as ‘pups’, which typically measure 23 to 29 cm in length (Nammack et al. 1985).

Neither mating nor birthing has been directly observed in spiny dogfish. Apparently, spiny dogfish mate and give birth to their young on the wintering grounds off Virginia and the Carolinas from November to December (Bigelow and Schroeder 1953a; Nammack et al.

1985). Females produce eggs (ovarian eggs, 40 to 48 mm in diameter) for the next mating while the young from the previous mating are gestating in the uterus and Bigelow and Schroeder (1953a) suggested that mating takes place shortly after the female gives birth. Templeman (1944) concluded that spiny dogfish do not give birth in the Newfoundland region.

Fecundity increases with an increase in body length in spiny dogfish (Nammack et al. 1985). The number of young produced per female per two-year period ranges from 1 to 15 for individuals examined from the wintering grounds (Nammack et al. 1985). On the wintering grounds, the average number of young per female per two-year period was 6.6, half of which were females. An overall 1:1 ratio of male to female pups is well documented for the spiny dogfish (Templeman 1944; Nammack et al. 1985). It is notable, that Templeman (1944) calculated an average of 3.7 young per female per two-year period for spiny dogfish captured in the Newfoundland region which is much lower than average.

Habitat

The spiny dogfish occurs in schools comprised of large numbers of individuals (Bigelow and Schroeder 1953a). Schooling occurs by size up to maturity and by size and sex after maturity. In the NW Atlantic, the spiny dogfish occurs principally in continental shelf waters anywhere between the surface and bottom down to depths of 165 to 185 m and overwintering spiny dogfish in the Newfoundland region have been found as deep as 373 m (reviewed *in* Grant 2001a).

In Newfoundland, spiny dogfish may occur very close to shore during the summer months, as 279 individuals were captured in salmon nets set ca. 27 to 55 m from shore during July (Templeman 1954). Spiny dogfish tagged in the Newfoundland region were recaptured in the region throughout the summer-autumn of 1963-65 and the data suggested that spiny dogfish were most abundant in shallow (<55 m) waters close to shore during July (Templeman 1984b). However, most tag recoveries were from incidental catches (bycatch) in the cod and salmon gillnet fisheries, which occurred mainly in shallow water during the summer and moved to deeper waters during autumn. Nevertheless, spiny dogfish were historically abundant in the Newfoundland region in relatively shallow coastal waters close to shore during July. Spiny dogfish (non-tagged) have also been captured in surface waters over great oceanic depths in the Newfoundland region (Templeman 1976).

Migrations of spiny dogfish throughout their North American range are well-documented and transatlantic migrations to and from Newfoundland waters have also been documented (Templeman 1984). Spiny dogfish tagged in Newfoundland waters have traveled southward over 900 miles (1,449 km) to Gloucester, Massachusetts in 132 days and one tagged spiny dogfish was recaptured in Virginia (1,300 miles; 2093 km) five years after its release in the Newfoundland region (Templeman 1954).

Overwintering of spiny dogfish in the Newfoundland region is well-documented and summarized by Templeman (1984). Historically, winter-kills of spiny dogfish have been common in the Newfoundland region and are presumably due to low water temperatures (Templeman 1965).

Water temperature appears to be the primary physical factor influencing the seasonal movements of the spiny dogfish. Northward migrating spiny dogfish do not appear along the east coast of Maine until waters warm to 6°C and they move into cooler waters when the water temperature rises above 15°C (Bigelow and Schroeder 1953a). Apparently, the preferred temperature of spiny dogfish in the northwest Atlantic is between 7.2 and 12.8°C (average, 9.8°C) (Jensen 1966). Templeman (1963) indicates that in the Newfoundland region where water of moderate depth is often 0°C or lower spiny dogfish are typically off bottom in warmer water.

Little is known of the salinity preferences of the spiny dogfish. However, their tolerance of low salinities is illustrated by their ability to ascend estuaries, which has been documented for the east Atlantic (Scott and Scott 1988).

The spiny dogfish has been captured by beach seine in nearshore (<55 m from shore) waters of Newfoundland. A review of the list of species captured during the Fleming juvenile cod beach seine survey (Schneider et al. 1997) indicates that this species was captured at least once. The Fleming survey has sampled 40 to 60 beaches on the northeast coast of Newfoundland from St. Mary's Bay to Notre Dame Bay during September-October in 1959-64 and from 1992 to present. The Fleming survey sites are generally in shallow (5 to 10 m) water and have substrates that are largely comprised of sand, gravel, and cobble. When present the vegetation is mostly eelgrass, fucoids, and kelp. The beach seine used in the Fleming survey samples the lower 2 m of the water column. The Fleming survey does not provide information on state of sexual maturity, therefore for this study the spiny dogfish was arbitrarily considered to be a juvenile.

Feeding

The spiny dogfish is an opportunistic feeder consuming whatever organisms are most readily available, but small fishes usually predominate (Scott and Scott 1988). Templeman (1944) examined stomach contents of 1,171 spiny dogfish collected in coastal waters near St. John's, Newfoundland. A surprising number (1,032, 88%) of the stomachs examined were empty or contained only bait used during their capture. Herring, capelin, and cod were important foods as were squid, amphipods, shrimp, polychaetes, sea anenomes, jellyfish, and red, green, and brown algae were found in the diet during August to November. Capelin were a major source of food for spiny dogfish collected in July (Templeman 1944) suggesting that the movement of spiny dogfish along the northeast coast of Newfoundland may be closely related to (match) the movement of spawning capelin in some years.

5.9 Marine-Related Birds

A total of 20 species of marine birds regularly breeds in eastern and southern Newfoundland (Lock et al. 1994). The great majority of seabirds in Newfoundland breed on Funk Island or the Avalon Peninsula where some of the world's largets colonies occur. The large number of seabirds that utilize this area is due to high biological productivity caused by the mixing of the cold Labrador current with warmer waters of more southern origin. The large amounts of zooplankton and capelin here provide the food base for these seabirds. Newfoundland seabird colonies are occupied from April to September.

There are no recorded seabird colonies for the Leading Tickles study area other than those noted as 'seabird colonies', in the EVTA CCRI (see Figure 4.1). The closest recorded colonies are small and some distance away. For example, there are two common eider colonies reported for Notre Dame Bay: Duck Island (21 pairs) and Penguin Island North ('present') (Lock et al. 1994). Also, a razorbill colony has been indicated for Notre Dame Bay. Leading Tickles does not appear to provide particularly important or sensitive habitat for seabirds although a number of species undoubtedly use the area for feeding and migratory purposes (see below). There are no known breeding sites for rare, threatened or endangered seabirds in the Leading Tickles study area. The closest colonies of rare (Black Headed Gulls) or vulnerable (Caspian Terns) species occur near the eastern headland of Notre Dame Bay (Lock et al. 1994).

Marine birds and are important predators on zooplankton, benthos and fish. Major feeding relationships for seabirds are shown in Table 5.2. The birds in turn serve as food for other predators as well as recycle nutrients into the upper water column through excretion.

5.9.1 Colonial Nesting Species

Seabird breeding colonies in the Leading Tickles area have not been thoroughly investigated. Local knowledge indicates that there are seabird nesting colonies within the study area (H. Chippett, pers comm.) (see Figure 4.1).

Sculpin Island, Green Island and Mouse Island were identified as locations where numbers of seabirds nested (see Table 5.3). Exact numbers are unknown.

Table 5.2 Feeding relationships of important marine-related birds and marine mammals of the study area.

Food	Birds																Marine Mammals									
	Pursuit Divers					**Plunging**		**Surface Feeders**						**Klepto-Parasites**	**Coastal Birds**		**Baleen Whales**				**Toothed Whales**					**Seals**
	Dovekies	**Murres**	**Puffins**	**Razorbills**	**Black Guillemots**	**Shearwaters**	**Gannets**	**Fulmars**	**Storm-Petrels**	**Phalaropes**	**Gulls**	**Kittiwakes**	**Terns**	**Jaegars, Skuas**	**Waterfowl**	**Cormorants, Loons, Grebes**	**Humpback**	**Minke**	**Blue**	**Fin, Sei**	**Pilot**	**Sperm**	**Killer**	**Northern Bottlenose**	**Porpoises, Dolphins**	**Seals**
Polychaetes, Nematodes								X			X		X		X											
Gastropods											X		X													
Bivalves											X	X	X		X											
Cephalopods						X	X	X	X		X	X				X		X			X	X	X	X	X	X
Sea Urchins											X															
Sand Dollars											X															
Sea Stars											X													X		
Sea Cucumbers																								X		
Copepods	X							X	X	X			X					X	X	X						
Mysids/ Euphausiids	X	X				X		X	X	X			X				X	X	X	X					X	X
Hyperiids	X							X	X									X	X							
Amphipods. Isopods	X	X							X		X		X		X											X
Decapods, Crustaceans									X				X		X											X
Pandalus		X																								X
Cancer																										X
Insects											X				X											
Misc. Small Invertebrates			X									X														
Algae															X											
Small Fish Larvae			X			X			X					X		X									X	
Fish Eggs															X											
Redfish																						X		X		
Cod			X				X		X		X					X	X	X		X	X			X	X	X
Flounders																X					X					X
Hake																X									X	X
Sand Lance		X		X	X	X					X	X		X			X			X					X	X
Pout, Gunnels					X																				X	
Tomcod					X						X															
Skate																							X	X		X
Haddock																										

Food	Birds																Marine Mammals									
	Pursuit Divers					Plunging		Surface Feeders						Klepto-Parasites	Coastal Birds		Baleen Whales				Toothed Whales					Seals
	Dovekies	Murres	Puffins	Razorbills	Black Guillemots	Shearwaters	Gannets	Fulmars	Storm-Petrels	Phalaropes	Gulls	Kittiwakes	Terns	Jaegars, Skuas	Waterfowl	Loons, Cormorants, Grebes	Humpback	Minke	Blue	Fin, Sei	Pilot	Sperm	Killer	Northern Bottlenose	Porpoises, Dolphins	Seals
Capelin		X	X	X	X		X				X	X		X		X	X	X		X						X
Herring							X				X		X		X	X	X	X		X				X	X	X
Mackerel							X														X				X	X
Lanternfish									X																	
Misc. Fish					X				X				X		X	X		X				X			X	X
Offal						X		X	X		X			X												
Vegetation, Seeds, Berries											X															
Bird Eggs, Young											X		X		X											
Seals, Birds																							X			

Source: Petro-Canada 1995

Table 5.3 Seabird colonies in Leading Tickles study area.

Location	**Cormorants** (*Phalacrocorax* spp.)	**Gulls** (*Larus* spp.)	**Terns** (*Sterna* spp.)	**Black Guillemot** (*Cepphus grylle*)
Sculpin Island	present	present	present	present
Green Island	-	present	-	present
Mouse Island	-	present	present	-

(H. Chippett, pers. comm.)

Cormorants have recently begun to nest on Sculpin Island. They were only occasionally seen in the Leading Tickles area prior to the colonization of Sculpin Island (H. Chippett, pers. comm.). The species of cormorant involved is unknown at this time. The Herring Gull (*Larus argentatus*) and Great Black-backed Gull (*Larus marinus*) are the most abundant and widespread breeding species in Newfoundland (Cairns et al. 1989). It is most likely these species that are nesting on Sculpin, Green and Mouse Island. Herring Gull have been reported nesting on Sculpin and Cull islands in the past (P. Ryan, CWS, pers. comm.). Common Tern (*Sterna hirundo*) and Arctic Tern (*Sterna paradisaea*) are the only two widespread species of tern breeding in Newfoundland (Cairns et al. 1989). Both of these species could be breeding on the tern colonies identified (H. Chippett, pers. comm.).

5.9.2 Birds of Prey

Bald Eagle *Haliaeeteus leucocephalus* and Osprey *Pandion haliaetus* are known to frequent the Leading Tickles area. A Bald Eagle nest site is known from the southeast end of Alcock Island (H. Chippett, pers. comm.). Another nest is suspected in the Glovers Harbour area based on the high frequency of adult Bald Eagles seen in the area (H. Chippett, pers. comm.). Osprey nest sites area known from the south side of Burnt Island and Forsey Cove Point (H. Chippett, pers. comm.).

5.9.3 Other Seabirds

The islands off Leading Tickles are exposed to the open ocean. Open ocean seabirds are sometimes brought within the boundaries of the study area. Northern Gannet (*Morus bassanus*), Greater Shearwater (*Puffinus gravis*), Sooty Shearwater (*Puffinus griseus*), Northern Fulmar (*Fulmarus glacialis*) and Leach's Storm-Petrel (*Oceanodroma leucorhoa*) are regularly seen from fishing boats near shore, particularly during foggy weather and northeast winds (H. Chippett, pers. comm.).

'Turr' hunting is considered good at Leading Tickles (H. Chippett, pers. comm.). 'Turrs' are the common name for murres (*Uria* sp.). Both Common Murre (*Uria aalge*) and Thick-billed Murre (*Uria lomvia*) are likely to occur at Leading Tickles. The peak of abundance is October to December (H. Chippett, pers. comm.). It is often northeast winds that bring them close to shore at which time they may be flying through the area with out stopping. Murres are also seen in spring and summer by fisherman in boats outside the islands off Leading

Tickles (H. Chippett, pers. comm.). There is no indication that murres breed in the Leading Tickles area.

5.9.4 Other Birds

The Leading Tickles area is not known to attract large numbers of waterfowl. Small numbers of the most widespread and common Newfoundland seaducks, Common Eider (*Somateria mollissima*), Long-tailed Duck (*Clangula hyemalis*) and White-winged Scoters (*Melanitta fusca*), are likely to occur (Mactavish et al. 1999).

It is not known what shorebird species use the Leading Tickles area. Small coves with limited tidal flats probably attract the common Newfoundland species of shorebirds such as Semipalmated Plover (*Charadrius semipalmatus*), Greater Yellowlegs (*Tringa melanoleuca*), Spotted Sandpiper (*Actitis macularia*), Ruddy Turnstone (*Arenaria interpres*), Semipalmated Sandpiper (*Calidris pusilla*), Least Sandpiper (*Calidris minutilla*) and White-rumped Sandpiper (*Calidris fuscicollis*) (Mactavish et al. 1999).

5.10 Marine Mammals

Fifteen species of marine mammal are known or expected to occur in the Leading Tickles study area, including 11 species of whales and dolphins (cetaceans) and four species of seals (phocids). A few additional species may occur, but because of their rarity in the area are not considered important components of the ecosystem. Although most species are seasonal inhabitants, the waters of the study area and surrounding areas may be important feeding grounds for some. The species composition, Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status, seasonal occurrence, estimated population sizes and prey of the marine mammal community are outlined in Tables 5.4 to 5.6.

There is a paucity of information on marine mammal distribution and abundance in the study area, and indeed for the waters of Newfoundland in general.

5.10.1 Mysticetes (Baleen Whales)

Five species of baleen whales or mysticetes likely occur or are known to occur in the study area: humpback (*Megaptera novaeangliae*), blue (*Balaenoptera musculus*), fin (*B. physalus*), sei (*B. borealis*), and minke whales (*B. acutorostrata*) (Table 5.4). Although nearly all of these species experienced depletion due to whaling, it is likely that many are experiencing some recovery (Best 1993). However, the humpback, blue and fin whales are still listed as special concern by COSEWIC (2001).

Table 5.4 Marine mammals in the study area.

Species	COSEWIC Status [1]	Occurrence in AOI
Mysticetes (Baleen Whales)		
Humpback Whale (*Megaptera novaeangliae*)	SC	transient and summer resident
Blue Whale (*Balaenoptera musculus*)	SC	late winter, spring, & summer visitor
Fin Whale (*Balaenoptera physalus*)	SC	transient and summer resident
Sei Whale (*Balaenoptera borealis*)	NC	late summer visitor
Minke Whale (*Balaenoptera acutorostrata*)	NC	transient and summer resident
Odontocetes (Toothed Whales)		
Sperm Whale (*Physeter macrocephalus*)	NAR	transient and summer resident
Killer Whale (*Orcinus orca*)	I	year-round resident
Long-finned Pilot Whale (*Globicephala melas*)	NAR	permanent resident
Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)	NAR	summer resident
White-beaked Dolphin (*Lagenorhynchus albirostris*)	NAR	transient and summer resident
Harbour Porpoise (*Phocoena phocoena*)	T	summer resident
Phocids (True Seals)		
Harbour Seal (*Phoca vitulina*)	I	permanent resident
Grey Seal (*Halichoerus grypus*)	NAR	year-round resident
Harp Seal (*Phoca groenlandica*)	NC	primarily winter visitor
Hooded Seal (*Cystophora cristata*)	NAR	winter visitor

[1] COSEWIC 2001

E = Endangered I = Indeterminate
T = Threatened NAR = Not at Risk
SC = Special Concern NC = Not Considered

Table 5.5 Population estimates of marine mammals that potentially occur in the study area.

	NW Atlantic Population Size	Population Occurring in the AOI		
Species	**Estimated Number**	**Stock**	**Estimated Number**	**Source of Updated Information**
Mysticetes				
Humpback Whale	5,505	NF/Labrador	1,700-3,200[d]	Katona and Beard (1990); Whitehead (1982)
Blue Whale	308 [a]	NW Atlantic	unknown	Waring et al. (1999)
Fin Whale	2200 [b]	Cdn. E. Coast	unknown	Waring et al. (1999)
Sei Whale	Unknown	Nova Scotia	unknown	Waring et al. (1999)
Minke Whale	2790 [b]	Cdn. E. Coast	unknown	Waring et al. (1999)
Odontocetes				
Sperm Whale	unknown	North Atlantic	unknown	Reeves and Whitehead (1997)
Killer Whale	?		unknown	Lien et al. (1988)
Long-finned Pilot Whale	4,000-12,000	NW Atlantic	abundant	Nelson and Lien (1996)
Atlantic White-sided Dolphin	27,200	NW Atlantic	unknown	Palka et al. (1997)
White-beaked Dolphin	unknown	NW Atlantic	unknown	Waring et al. (1999)
Harbour Porpoise	unknown	Newfoundland	unknown	Wang et al. (1996)
Phocids				
Harbour Seal	40,000-100,000 [c]	NW Atlantic	930	Reijnders et al. (1993); Boulva and McLaren (1979)
Grey Seal	154,000	E. Canada	unknown	Mohn and Bowen (1996)
Harp Seal	4.5-4.8 million	NW Atlantic	unknown	Shelton et al. (1996)
Hooded Seal	400,000-450,000	NW Atlantic	unknown	Stenson et al. (1997)

[a] Based on surveys from the Gulf of St. Lawrence.
[b] Based on surveys from Virginia to the Gulf of St. Lawrence.
[c] Mostly from the Maine coast (U.S.).
[d] The proportion that occurs in the study area is unknown.

Table 5.6 Prey of marine mammals that occur in the study area.

Species	Prey	Source of Information
Mysticetes		
Humpback Whale	Fish (predominantly capelin), euphausiids	Piatt et al. (1989)
Blue Whale	Euphausiids	Gaskin (1982)
Fin Whale	Fish (predominantly capelin), euphausiids	Piatt et al. (1989)
Sei Whale	Copepods, euphausiids, some fish	Gaskin (1982)
Minke Whale	Fish (predominantly capelin), squid, euphausiids	Piatt et al. (1989)
Odontocetes		
Sperm Whale	Cephalopods, fish	Reeves and Whitehead (1997)
Killer Whale	Herring, squid, seals, dolphins, other whales	Lien et al. (1988)
Long-finned Pilot Whale	Short-finned squid, northern cod, amphipods	e.g. Nelson and Lien (1996)
Atlantic White-sided Dolphin	Schooling fish (sand lance, herring), hake, squid	Palka et al. (1997)
White-beaked Dolphin	Fish (cod, capelin, herring), squid	Hai et al. (1996)
Harbour Porpoise	Schooling fish (capelin, cod, herring, mackerel)	Smith and Gaskin (1974)
Phocids		
Harbour Seal	Fish (primarily herring, flounder), squid, shrimp	Bowen and Harrison (1996)
Grey Seal	Fish (herring, cod, hake, pollock), squid, shrimp	Benoit and Bowen (1990); Hammill et al. (1995)
Harp Seal	Fish (capelin, cod, halibut, sand lance), crustaceans	Lawson and Stenson (1995); Lawson et al. (1998); Wallace and Lawson (1997); Hammill and Stenson (in press).
Hooded Seal	Fish (Greenland halibut, redfish, Arctic and Atlantic cod, herring), squid, shrimp, molluscs	Ross (1993)

Humpback Whale

The humpback whale has a cosmopolitan distribution. Its migrations between high-latitude summering grounds and low-latitude wintering grounds are reasonably well known (Winn and Reichley 1985). It is by far the most common baleen whale in Newfoundland waters. The peak period for humpbacks in waters of Newfoundland is July-September, but some individuals remain much longer, even through the winter (NMFS 1991). The humpback whale is considered abundant in the Leading Tickles study area (EVTA CCRI 2001).

The annual distribution of humpback whales in eastern Canadian waters seems to be driven by the availability of schooling fish, most notably capelin and sand lance (*Ammodytes* spp.) (Whitehead and Carscadden 1985; Whitehead and Glass 1985; Payne et al. 1990). Thus, humpback distribution and movements in the study area are predictable only insofar as environmental conditions are constant from year to year.
Recent research on humpbacks suggests genetic as well as spatial segregation between feeding areas within the North Atlantic (Valsecchi et al. 1997). The entire North Atlantic population is estimated at approximately 10,600 individuals (Smith et al. 1999), the NW Atlantic population at 5,505 individuals (Katona and Beard 1990) and the Newfoundland/Labrador population at 1,700 to 3,200 (Whitehead 1982).

Blue Whale

The blue whale, which has likely always been rare in Canadian waters (Mansfield 1985), probably numbers in the few hundreds in the NW Atlantic (Waring et al. 1999). Blue whales are "endangered" globally (Baillie and Groombridge 1996) and are listed as "special concern" in Canadian waters (COSEWIC 2001). Its distribution is specific to areas that provide large seasonal concentrations of euphausiids, its main prey (Yochem and Leatherwood 1985). It probably rarely occurs in the study area. Nothing is known about trends in blue whale abundance in the study area or in the NW Atlantic, but the population that summers around Iceland has been increasing at approximately 5 percent/yr (Sigurjónsson and Gunnlaugsson 1990).

Fin Whale

Fin whales are widely distributed in all the world's oceans. In Newfoundland, finbacks occur from ice breakup in late March to freeze-up in November (Katona et al. 1983). Finbacks usually found farther offshore in Newfoundland than in Gulf of Maine (Katona et al. 1983). The fin whale is found commonly in summer on the Grand Banks (Piatt et al. 1989). This species is associated with the presence of capelin, their predominant prey item in Newfoundland waters (Piatt et al. 1989; Whitehead and Carscadden 1985).

Probably at least in part because of their initially high abundance, wide distribution and diverse feeding habits, fin whales seem not to have been as badly depleted as the other large whales in the North Atlantic (see Reeves et al. 1998). They are nevertheless listed as "special concern" by COSEWIC, and "endangered" globally (Baillie and Groombridge 1996). Recent genetic studies indicate that fin whale populations that summer in Nova Scotia, Newfoundland, and Iceland may be genetically distinct from each other (Arnason 1995). The number of fin whales in the northwest Atlantic was recently estimated at approximately 2,200 (Waring et al. 1999). This is lower than estimates from previous reports, but supports the idea that fin whale numbers are decreasing off Newfoundland (Whitehead and Carscadden 1985).

Sei Whale

The sei whale has a cosmopolitan distribution, and prefers temperate oceanic waters (Gambell 1985). Sei whales are known for their high mobility and unpredictable appearances (Reeves et al. 1998). Stomachs of sei whales killed in Newfoundland contained capelin and krill, but no copepods (Katona et al. 1983). Sei whales have been taken off NE Newfoundland only in August and September (Katona et al. 1983). Incursions into nearshore waters of the Gulf of Maine, associated with high copepod densities, are well documented (Payne et al. 1990; Schilling et al. 1992).

No reliable population estimates are available for sei whales; an estimate in the 1970s for the Nova Scotia stock suggested a minimum population of 870 individuals (Mitchell and Chapman 1977). This population is thought to range as far as the Grand Banks.

Minke Whale

Minke whales have a cosmopolitan distribution that spans all ice-free latitudes. Movements in Newfoundland are very strongly related to the capelin spawning migration (Katona et al. 1983). Data from Newfoundland minke whale fishery suggests that pregnant females and juveniles come farther inshore than adult males (Katona et al. 1983). They are widely distributed in Newfoundland waters, but their seasonal distribution and migrations are not well known. The minke whale is considered abundant in the Leading Tickles study area (EVTA CCRI 2001). While some minke whales apparently migrate to low latitudes in winter, others may remain at higher latitudes throughout the year. They have been described as the "most nearly ubiquitous" baleen whales in the Gulf of St. Lawrence (Kingsley and Reeves 1998), and this may also apply to Newfoundland. Minke whales occur in shallow near-shore waters, estuaries and bays, and deep offshore waters.

Minke whales have not been hunted in Canadian or U.S. waters since the early 1970s, and the species is not endangered. Piecemeal estimates of abundance have been made in recent years in the western North Atlantic; the best available estimate is 2,790 individuals (Waring et al. 1999).

5.10.2 Odontocetes (Toothed Whales)

Five species of odontocetes or toothed whales may occur in the study area (Table 5.4). Most of these marine mammals occur seasonally in the study area and little is known regarding their distribution and population size in these waters.

Sperm Whale

Sperm whales are the largest toothed whales, with an extensive worldwide distribution (Rice 1989). The number of sperm whales in the North Atlantic and in the study area is unknown. Occurrences of sperm whales in the study area are likely rare as relatively shallow waters would not provide optimal habitat for the primary prey species of sperm whales, mesopelagic and benthic squids and fishes (Reeves and Whitehead 1997). Reeves and Whitehead (1997) caution that previous population estimates for this species are suspect given their long-distance movements and lack of any clear stock structure. Evidence that stock delineation in this species may be dependent on the time scale of the measure used, further complicates obtaining reliable population estimates (Dufault et al. 1999).

Killer Whale

The killer whale is a year-round resident off Newfoundland and Labrador (Lien et al. 1988), which, in contrast to the long-finned pilot whale, is thought to occur in relatively small numbers in the study area. On a global basis, killer whales are not endangered. There are no population estimates for the NW Atlantic.

Long-finned Pilot Whale

The most common odontocete in the area and also one of the only year-round residents is the long-finned pilot whale (also known as the Atlantic pilot whale or pothead). This species is considered abundant in the study area from July through December (EVTA CCRI 2001). The NW Atlantic population probably numbers between 4,000 and 12,000 individuals (Nelson and Lien 1996).

It is a common belief that long-finned pilot whales in the northwest Atlantic prey mainly on short-finned squid in summer. However, this statement is based largely on evidence from inshore waters of Newfoundland (Sergeant 1962), and other evidence suggests that they also prey on a variety of fish species, as well as additional species of cephalopods (especially long-finned squid) at other times and in other areas (Waring et al. 1990; Nelson and Lien 1996).

Atlantic White-Sided Dolphin

There are three stocks of Atlantic white-sided dolphins in the NW Atlantic; Gulf of Maine, Gulf of St. Lawrence and Labrador Sea. This species in known to occur from about Cape Cod to Davis Strait and Greenland (Katona et al. 1983). The combined NW Atlantic population probably numbers 27,000 individuals (Palka et al. 1997). The number of white-sided dolphins in the Leading Tickles study area is unknown. It is assumed that individuals from the Labrador Sea stock would be the ones most likely to be encountered in the study area.

White-beaked Dolphin

The white-beaked dolphin) tends to be a coastal, cool-water species (Reeves et al. 1999) and is considered abundant in the study area (EVTA CCRI Feb 2001). This species commonly called the “squid hound” by Newfoundlanders seems to remain at relatively high latitudes throughout the fall and winter (Lien et al. 1997), but the nature of their seasonal movements is uncertain. During the summer, approximately 3,500 white-beaked dolphins have been estimated to occur off southern Labrador (Alling and Whitehead 1987). There is no reliable population estimate for the study area or the entire NW Atlantic. The total North Atlantic population may range from high tens of thousands to low hundreds of thousands (Reeves et al. 1999). Ice entrapment is not uncommon in the bays of Newfoundland in years when pack ice is heavy (Hai et al. 1996).

Harbour Porpoise

The harbour porpoise is widely distributed throughout temperate waters, but its population size in Newfoundland waters is unknown (Gaskin 1992). This species commonly called the “puff pigs” by Newfoundlanders is abundant in the study area (EVTA CCRI 2001). Harbour porpoises that occur in Newfoundland waters are believed to belong to a separate stock from those in the Gulf of St. Lawrence and Bay of Fundy/Gulf of Maine regions. This is supported by differences in organochlorine contaminant levels, which are lower in Newfoundland animals (Westgate and Tolley 1999), and by differences in mitochondrial DNA haplotype frequencies (Wang et al. 1996).

5.10.3 Phocids (True Seals)

Four species of phocids or true seals occur regularly in waters off Newfoundland (Table 5.4). Populations of grey harp and hooded seals in Canada, and harbour seals in the United States, are thought to be increasing (Waring et al. 1999). Because of their potential to interact with commercial fisheries, reasonable population estimates for the NW Atlantic are now available for most seal species (Table 5.5). The main diet of seals consists of fish (including capelin, cod, halibut and sand lance) and invertebrates such as squid and shrimp (Table 5.6), with considerable seasonal, geographic and interannual variation in diet (Hammill et al. 1995; Lawson and Stenson 1995; Wallace and Lawson 1997). Recent research on various aspects of the biology of the different seal species is discussed below.

Harbour Seal

The harbour seal is a relatively small phocid species that has a broad distribution that spans much of the temperate Northern Hemisphere. Harbour seals are year-round residents along the south coast of Newfoundland. Recent information on the distribution and population size of harbour seals off Newfoundland and in the study area is lacking (Stenson 1994). However, the DFO Coastal Resource Inventory Atlas for the Leading Tickles area considers harbour seals abundant in the area (EVTA CCRI 2001). [Note: This observation may be incorrect.] In general, harbour seals have a varied diet, including pelagic and demersal fish as well as cephalopods and crustaceans (see, for example, Boulva and McLaren 1979; Bowen and Harrison 1996).

Harbour seals are not endangered; COSEWIC lists the Atlantic Canadian population as "Indeterminate". There is no reliable estimate for the number of harbour seals occurring in eastern Canada. There is thought to be a single stock in the NW Atlantic from the Arctic to the New England region. There are approximately 40,000 to 100,000 in the northwest Atlantic (Reijnders et al. 1993). The population along the Maine coast (that is, U.S. waters) numbers around 31,000 (estimated in 1997) and appears to be increasing (Waring et al. 1999).

Grey Seal

Grey seals in the study area are migrants from the Sable Island and Gulf of St. Lawrence breeding populations. This species may occur in the study area year-round, but most commonly in July and August (Stenson 1994). The Sable Island and Gulf of St. Lawrence breeding areas account for essentially all of the pup production in the NW Atlantic, which increased exponentially between 1977 and 1989 (Stobo and Zwanenburg 1990). The eastern Canadian population of grey seals was estimated at 154,000 in 1994 (Mohn and Bowen 1996). The number that occurs in the study area is unknown, but is believed low.

Grey seals are less tied to coastal and island rookeries than are harbour seals. They travel long distances, one individual having been tracked over a distance of 2,100 km (McConnell et al. 1999). The food of grey seals in the western North Atlantic includes at least 40 species, some of which are commercially important (for example, Atlantic cod, herring, and capelin) (Benoit and Bowen 1990; Hammill et al. 1995).

Harp Seal

Harp seals whelp in the spring in the Gulf of St. Lawrence and in an area offshore of the Leading Tickles study area, known as the 'Front' off southern Labrador and northeastern Newfoundland (Sergeant 1991). Individuals from these two areas spend the summer in the Arctic and then migrate south in the autumn. Harp seals are considered abundant in the study area (EVTA CCRI 2001). Harp seals may be most abundant in the study area when seals are breeding and moulting (March to May) on offshore ice (Sergeant 1991). Some harp seals may move into coastal waters during the summer period (Stenson and Kavanagh 1994). Indeed, fishermen have reported the presence of harp seals in coastal waters during the summer (unpubl. data *in* Stenson and Sjare 1997).

In 1994, the total population estimate of harp seals in the NW Atlantic was 4.5 million to 4.8 million, with a suggested growth rate of approximately five percent/yr since 1990 (Shelton et al. 1996).

The diet of harp seals foraging off Newfoundland and Labrador appears to vary considerably with season, year, age, and location. On the Grand Banks and Labrador Shelf, capelin predominate, followed by sand lance, Greenland halibut and other pleuronectids (Wallace and Lawson 1997; Lawson et al. 1998). Recent “historical” data on the diet of harp seals greater than a year old from northeast Newfoundland, indicates that there was a shift in prey from capelin in 1982 to Arctic cod in 1986 and beyond, while Atlantic cod remained relatively unimportant throughout this period. Harp seals collected from nearshore waters forage intensively on a variety of fish and invertebrate species, although most of the biomass is derived from relatively few species, particularly Arctic cod, capelin, Atlantic cod, Atlantic herring and some decapod crustaceans. A recent consumption model estimates that harp seals consume less Atlantic cod than once believed as seals apparently spend more time offshore (Hammill and Stenson, in press).

Hooded Seal

Like the harp seal, the hooded seal is a North Atlantic endemic species that reproduces on the spring pack ice of the Gulf of St. Lawrence and at the Front, then migrates northward to the sub-Arctic and Arctic to feed during the summer (Lydersen and Kovacs 1999). Unlike harp seals, hooded seals are rarely reported from inshore areas (Stenson and Kavanagh 1994). This species was not listed as abundant in the DFO Coastal Resource Inventory Atlas (EVTA CCRI 2001).

A recent (1990) estimate of pup production at “the Front” off Labrador was approximately 83,000 (Stenson et al. 1997), suggesting a current total population of hooded seals in the northwest Atlantic of 500,000 (Whitehead et al. 1998).

Hooded seals consume a variety of prey. In nearshore areas of Newfoundland, prey (in decreasing order of total wet weight) includes: Greenland halibut, redfish, Arctic cod, Atlantic herring and capelin. Relatively small amounts of squid (*Gonadus* spp.) and Atlantic cod were also found (Ross 1993).

6.0 Summary, Conclusions and Recommendations

The present study provides a detailed overview of the biophysical environment of the Leading Tickles study area. The following sections provide some salient points with emphasis on the identification of data gaps.

6.1 Physical Environment

The main focus of the present study has been on the biological resources of the Leading Tickle study area (i.e., species that are of value for fishery, recreational, tourism, ecological or scientific purposes). Nonetheless, four points are clear:

1. The Leading Tickles Study physical environment can be considered typical of the rocky exposed, island-dotted coast of Notre Dame Bay, part of the NE Newfoundland shelf ecosystem, central Newfoundland.

2. The distribution and abundance of biological resources are highly related to physical conditions and processes.

3. While there have been a number of broad geological and physical environmental studies that are generally applicable to the Leading Tickle study area, there is very little site-specific information. The MPA program has conducted sponsored some bathymetric work, which is presently being worked up (A. Power, DFO, pers. comm.) and this is a good start.

4. Because of the above three points, any future studies of the ecosystem or biological resources of the study area, insofar as possible, should include collection of data on the physical environment (geology, geomorphology, temperature, salinity, currents). Data should be collected according to standard technical and scientific procedures to allow use by a variety of users.

6.2 Plankton

To the best of our knowledge there have been few if any plankton collections made in the Leading Tickles study area. There have been few in Newfoundland nearshore waters in general. The DFO studies conducted further offshore in Notre Dame Bay are generally applicable but nearshore species composition, abundance, biomass and timing may be somewhat different. Future plankton work should best be done as part of invertebrate, fish, bird, mammal, or ecosystem studies (see following sections, below).

6.3 Marine Plants

The general distribution of seaweed (at least rockweed) and eelgrass is known within the study area (see EVTA CCRI maps). Nonetheless, given the potential commercial importance and proven ecological importance of seaweeds and particularly the nursery value of eelgrass, more detailed information and mapping is warranted for *all* of the important species, not just rockweed.

6.4 Benthic Invertebrates

To the best of our knowledge there have been no scientific collections of benthic invertebrates in the Leading Tickles study area. The distribution of commercial invertebrates such as lobster, crab, mussels, scallops, squid, periwinkles and whelk is reasonably well known and documented in the EVTA CCRI.

Additional biological information on the local spawning and nursery habitat and movements of these invertebrate species, particularly lobster (arguably the most important invertebrate species in the area) is highly desirable for the purposes of further judging the importance of the area.

6.5 Fish

The distribution of commercial fish species is reasonably well known and documented in the EVTA CCRI. What is less well known is the relative importance of the Leading Tickles study area for spawning and nursery habitat. It would be highly desirable to obtain further information on the movements and habitat for the locally important species. Capelin, Atlantic cod, plaice, and perhaps lumpfish, would be obvious priority choices.

6.6 Marine Birds

Obvious data gaps include the lack of site-specific information on the species, distribution and abundance of birds present and the relative importance of nesting areas. Therefore, we recommend the following.

- Knowledgeable people should survey Sculpin Island, Green Island and Mouse Island during the breeding season (June to mid-July) in order to determine the species and populations of breeding birds.

- All the islands in the study area should be investigated during the breeding season (June to mid-July) for other seabird nesting sites.

All known Bald Eagle and Osprey nest sites should be checked to determine whether the nests are still being used. Any possible new nest sites should be investigated.

6.7 Marine Mammals

Clearly, there is little information on the distribution and seasonal abundance of marine mammals, particularly cetaceans, in the Leading Tickles study area. Data provided from an appropriately designed aerial survey that included coverage in all four seasons would address a lot of the unknowns. Obviously, surveys that spanned many years would provide better estimates of species numbers in the area, but even a comprehensive survey during a single year would provide invaluable information.

Also, a study of available by-catch data for the study area may also provide more information about marine mammal occurrence and relative abundance.

6.8 Ecosystem

Another important issue in judging the value of the Leading Tickles AOI for an MPA would be its relative importance as an ecosystem (i.e., Leading Tickles as an 'ecosystem' on its own merits) or its relative importance to the broader ecosystem such as the NE Newfoundland Shelf and Coast. Both of these issues are complex. The following are a few recommendations that would assist considerably in this regard.

- Identify areas of upwelling. It can be argued that upwelling of nutrients into surface waters is one of the driving forces of productivity in the marine ecosystem. Such areas can be identified by their physical 'signatures' and are important to all components of the ecosystem, most notably fish, birds and mammals.

- Identify spawning and nursery areas for key species and assess their importance relative to other areas.

- Study movements of key species to assess the degree and type of utilization of the study area. Some species may be very important commercially outside the AOI but venture into the Leading Tickles area for some specific part of their life cycle.

- It is advisable to couple all of the above with feeding studies to gain information on relative importance of different food species and feeding areas.

- The habitat classification system proposed by Hooper (1997) should be 'ground-truthed' for the Leading Tickles study area. This would provide important ecosystem information applicable not only to the specific area but the region as a whole.

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Appendix A. Some potential important energy pathways on the NE Newfoundland Shelf. From Lawson (1998).