BROWN COD AND BAY STOCKS: SCIENCE AND FISH HARVESTERS' KNOWLEDGE OF COLOURATION IN POPULATIONS OF ATLANTIC COD (Gadus morhua) IN NEWFOUNDLAND AND LABRADOR

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Brown Cod and Bay Stocks: Science and Fish Harvesters' Knowledge of Colouration in Populations of Atlantic Cod (*Gadus morhua*) in Newfoundland and Labrador.

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Abstract

This research investigated the reliability of colouration as an indicator of inshore populations of Atlantic cod (*Gadus morhua*) in Newfoundland and Labrador, using a combination of fish harvesters' knowledge of cod colouration and scientific experimentation. Thirty-two interviews with fishing experts were conducted in 23 communities throughout the west coast and Northern Peninsula of Newfoundland and the southeastern coast of Labrador to gather fish harvesters' knowledge about cod colouration and ecology. Five main colourations of cod were identified through interviews: brown, yellow-brown, red to reddish-brown, black-backed, and dark/black. Harvesters generally associated these colourations with the environment (shallow water and/or fresh water and/or presence of "kelp") and/or diet (cod feeding on crustaceans and/or "kelp"). Thirteen areas were identified where brown cod were believed to overwinter and remain year-round.

Brown to reddish-golden-brown cod and countershaded cod (cod that are black on back, white underneath with silvery grey sides) were captured within the bay and on the headlands of Gilbert Bay, Labrador. To determine the stability of colouration, these cod were held in net pens from August to October 2001 and fed a piscivorous diet of capelin and herring. Initial and final colouration of each individual fish were compared using a colouration scale. Results of the pen-holding experiment demonstrated that cod will lose their brown colouration within 2.5 months when fed a diet of fish. The absence of carotenoids in the diet of cod held in net pens was concluded to be the main factor contributing to this loss of brown pigmentation.

I conclude that colouration cannot be used in isolation to identify inshore stocks of cod. However, colouration acts as a time-dependant dietary index and can be used to deduce recent feeding histories of individuals or groups of fish. Thus, colouration acts as a general indicator of inshore groups of cod and probable locations for resident coastal cod stocks. Fish harvesters' observations provide a valuable base line of information on which to plan further scientific studies.

Acknowledgments

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1. Introduction

1.1. Fish harvesters' knowledge and science research methodologies

With the failure of management plans to prevent the collapse of the cod fishery on the east coast and the salmon fishery on the west and east coasts of Canada, many fish harvesters have lost faith in the ability of scientists, as well as government, to protect their livelihoods (Coward et al. 2000). This lack of confidence, exhibited by an industry that wants more say in issues that concern it, makes it imperative to devise new approaches to stock assessment and management (Gendron et al. 2000). One approach is the active involvement of local harvesting experts in decision-making, working with scientists and managers in assessing stocks, in management planning and other fisheries research. Finding ways to integrate fish harvesters' observations with scientific data could improve the potential for successful collaboration and more informed and more accepted decisions related to stock status and management (Neis et al. 1999a).

1.1.1. Elements of fish harvesters' knowledge

The ecological knowledge of resource users consists of facts obtained from first-hand experience during years of observation and interaction with their local environment. Fishery resource users develop a detailed knowledge of their resources, their environments, and their fishing practices (Neis et al. 1999a; 1999b). Throughout their careers, fish harvesters observe fish morphology (e.g. colouration and body size), fish behaviour (e.g. spawning and migration), trends in fish landings, and changes in fishing effort. From patterns and trends observed over time, many fish harvesters use a process of inductive-deductive reasoning (Figure 1.1) to distinguish between different runs of fish, to explain observed behavioural differences and changes in behaviour, and to account for trends in abundance and effort. They then make predictions about the state of resources and arrive at assessments of the appropriateness of different management initiatives. This inductive-deductive reasoning of harvesters can provide important insights but lacks rigorous means to validate deductions and interpretations about how nature works and interacts with human behaviour.

1.1.2. Scientific hypothesis testing

The value of the scientific method of investigation lies in the rigors of hypothesis testing, which can test the validity of theories through experimentation and field studies. This also involves the replication of experimental or field study results and further testing of published results by colleagues. Theories are refined or refuted on the basis of how well they stand up to this testing. Occasionally new theories arise to replace existing theories. Through the scientific method (Figure 1.2), science closes the induction-deduction loop of knowledge development used by fish harvesters, providing a more complete understanding of nature.

A major limitation to science, however, can be an insufficient observational base to verify scientific hypotheses and theories. Such a situation may result from the monetary and time constraints that often limit the amount of scientific research that can be conducted (Fischer 2000). Furthermore, scientific knowledge is often based on sporadic observations covering large spatial scales whereas local expertise is based on continuous observations within small local fishing areas (Fischer 2000). In this context, the knowledge and observations of local resource users can supply a wealth of information for scientific hypothesis testing and information that helps to provide ecological contexts for issues under study.

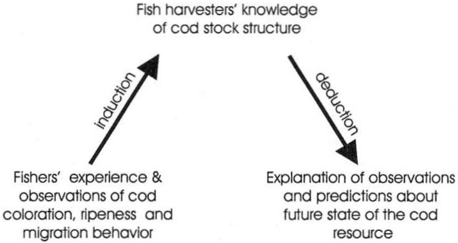

Figure 1.1 The inductive-deductive method of reasoning used by many fish harvesters to distinguish between different types of Atlantic cod (*Gadus morhua*), to explain and account for their observations and to make predictions and assessments about the future state of the cod resource.

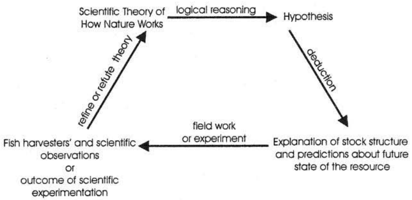

Figure 1.2 Method of hypothesis testing used by fisheries scientists to validate theories regarding stock structure (adapted from Wroblewski 1983). Science closes the loop of inductive-deductive reasoning used by many fish harvesters.

1.1.3. Fish harvesters' knowledge, science and management

The strength of fish harvesters' knowledge lies in their years and sometimes generations of continuous interaction with local environments, whereby they acquire a wealth of information that is often not readily available to scientists. This type of knowledge can be particularly useful in identifying local cod stocks that may or may not exist in the present (Ames 2000). The strength of science lies in the rigorous procedures that allow scientists to test some of the assumptions found in harvesters' knowledge and the validity of their interpretations, as well as to develop models for use in hypothesis testing. The observations and detailed information fish harvesters provide, combined with the method of validation used by science, allow for improved predictions and assessments of the state of our marine resources. Through this two-way flow of information, scientists and harvesters can work together to provide a more detailed assessment of stock structure to be used in management decisions for utilization and conservation of the resource (Figure 1.3). Harvesters, scientists, and managers would all benefit from management regimes based on more informed estimates of fish populations, a greater knowledge of ecosystem dynamics, and from shared responsibility for management and stewardship (Felt et al. 1998).

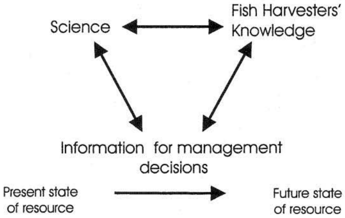

Figure 1.3 Idealized flow of information between fish harvesters, scientists, and managers

1.2. Objectives of this research

This research seeks to combine fish harvesters' knowledge with scientific knowledge of cod colouration to determine the reliability of colouration as a morphometric of local inshore populations of cod. The recently identified, genetically distinguishable (Ruzzante et al. 2000) and variably coloured (Wroblewski 2000) group of cod in Gilbert Bay, Labrador, suggests that other such populations exist or may have existed in the past in similar oceanographic areas in coastal Newfoundland and Labrador and in other coastal areas (see Ames 1997). Colouration, in combination with presence year round in the bay, was successfully used by fish harvesters to indicate a local group of cod in Gilbert Bay. Their observations prompted scientific research needed to distinguish these cod from other populations (Wroblewski 2000). The identification of local inshore stocks, such as the one in Gilbert Bay, has implications for management. Gilbert Bay has been declared an "Area of Interest" under DFO's Marine Protected Areas (MPA) program (DFO press release, 13 October 2000) and efforts of scientists and local residents are now directed toward establishing Gilbert Bay as eastern Canada's first MPA.

Fish harvesters' knowledge of reddish- and golden-brown cod in Gilbert Bay and the fact that colour is readily observable leads us to inquire whether cod colouration can be used as a reliable indicator of stock components. To this end, using a combination of fish harvesters' and scientific knowledge, I investigated colouration change in Atlantic cod and the relationship of colouration to inshore stocks of cod. Templeman (1979) defines a stock as a recognizable unit which has certain area-occupying and migratory patterns, and whose spawning area (or season in that area) is separate from those of other stocks. For the purpose of this research, an inshore stock of cod is defined as cod that are resident (local) in the shallow water inshore environment year-round (i.e. overwinter, spawn, and feed in the bay/along the coast in relatively shallow water) (see inshore bay cod in Table 2.1). The term "offshore" is reserved for cod that overwinter and spawn in the deeper waters of the continental shelf and slope and either remain offshore or migrate to the coast to feed in the summer.

The primary objectives of this research were:

1. To collect and document fish harvesters' knowledge about cod colouration, locations of spawning cod, overwintering behaviour, and presence/absence in bays and coastal areas throughout southern Labrador and the Northern Peninsula and west coast of Newfoundland.
2. To scientifically document colouration change in Atlantic cod held in a net pen, and to determine how quickly and to what extent colouration changes in response to a change in diet.
3. To combine fish harvesters' knowledge with scientific research on cod colouration, to determine the reliability of cod colouration as an index of cod stock structure, and to identify locations along the Northern Peninsula, west

coast of Newfoundland, and along the south coast of Labrador where inshore populations of Atlantic cod may exist or may have existed in the past.

This thesis is structured to provide a background of existing scientific knowledge and fish harvesters' understanding of cod colouration and cod stock structure in Chapter 2. The collection and documentation of fish harvesters' knowledge of different colourations of cod (objective 1) are described in Chapter 3. Fish harvesters' observations of brown to reddish-golden-brown cod then set the basis for the scientific colouration change experiment (objective 2), as described in Chapter 4. Chapter 5 brings together interviews with fish harvesters and the scientific colouration change experiment through discussions of similarities and differences between results and an analysis of the role of colouration as an indicator of cod stock structure (objective 3).

2. Colouration and stock structure of Atlantic cod

2.1. Newfoundland and Labrador cod stock structure

Since the collapse of the northern Atlantic cod stock in the early 1990s, most of the adult cod remaining in Newfoundland waters are found in inshore areas (DFO 2002). Historically, offshore components of northern cod stock migrated to the coast in a summer feeding migration (Rose 1993) and contributed to the inshore catch during summer and fall (Lilly 1996). These fish would then migrate back offshore to overwinter and spawn on or near the edge of the continental shelf (Myers et al. 1993; Wroblewski et al. 1995; Morgan and Trippel 1996) (Figure 2.1). During the summer feeding period, cod from offshore would mix with inshore cod, which are year-round residents of coastal waters (Ruzzante et al 1996; 1997). Before being decimated by overfishing between the 1960s and 1990s (Hutchings and Myers 1995; Myers et al. 1997), the offshore components constituted the major portion of the population (Lear and Parsons 1993). Coastal components associated with the bays and headlands of the coastline (Templeman and Fleming 1956; 1963) had been documented but were considered of minor importance in managing this resource (Lilly 1996). In Newfoundland and Labrador, as elsewhere and with different marine species, cod were managed in very large spatial units and, within these, were treated as though they were panmictic (Wilson and Kornfield 1997). As a result, limited effort was directed toward the systematic scientific study of inshore components and there were no separate management units for such components.

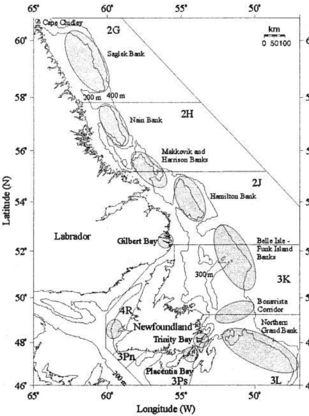

Figure 2.1 Bathymetric chart of the Newfoundland and Labrador shelf, showing the major banks and the Northwest Atlantic Fishery Organization (NAFO) management units (2GHJ, 3KL, 3PsPn, 4R). Shaded regions represent the approximate locations of local populations of Atlantic cod (*Gadus morhua*) associated with scientifically documented inshore and offshore spawning grounds (modification of Fig. 1 in Smedbol and Wroblewski 2001; Ouellet 1997).

The collapse of the inshore and offshore northern cod stocks off Newfoundland's northeast coast and the coast of Labrador in particular (Atkinson et al. 1997; DFO Science Stock Status Report 2001), and scientific and harvester documentation of aggregations of cod in the major bays of eastern and southern Newfoundland (Rose 1996; Smedbol et al. 1998) have heightened scientific interest in the population structure and ecology of inshore cod. Recent research has indicated that inshore overwintering and spawning components exist in Trinity (Smedbol and Wroblewski 1997) and Placentia Bays (Bradbury et al. 2000; Robichaud 2001), Newfoundland and in Gilbert Bay, Labrador (Ruzzante et al. 2000; Green and Wroblewski 2000) (Figure 2.1). Research has also revealed that populations of Atlantic cod inhabiting the marine waters off Newfoundland and Labrador consist of genetically distinguishable inshore and offshore spawning components (Taggart et al. 1998 and references therein). This research suggests that these localized spawning groups may be relatively independent subpopulations. Fishing effort directed towards such groups may have unknowingly resulted in local depletions in some areas. Thus, in order to manage such stocks effectively, it is necessary to assess them independently, understand their relationship to other populations, and establish a management regime that will prevent localized overfishing and promote the recovery of depleted local stocks (Wilson and Kornfield 1997). Current management strategies that define stock boundaries by existing NAFO divisions ignore the potential existence of separate inshore and offshore stocks. Differences in the timing and level of exploitation of these stocks may lead to the elimination of some stocks (Hutchings et al. 2002).

Previous work with harvesters (e.g. Neis et al. 1999b) and recent scientific work (e.g. Green and Wroblewski 2000; Ruzzante et al. 2000) suggest the presence of six categories of cod in Newfoundland and Labrador, classified by overwintering and spawning habitat, post-spawning migratory behaviour and colouration on their wintering grounds (Table 2.1). Although significant variation exists between individual fish, there are two general colouration patterns (countershaded and brown) that dominate. Countershading, a phenomenon of gradual shading from light underneath to darker on the back, provides camouflage to a pelagically swimming cod (Helfman et al. 1997) and is often found in cod inhabiting deep (100-500 m) waters (Table 2.1 and Figure 2.2).

Shallow water cod have a characteristic brown to red or reddish- to golden-brown colouration (Table 2.1 and Figure 2.3). This colouration allows the fish to blend with its shallow water habitat, a phenomenon known as protective colouration (Helfman et al. 1997). Brown coloured cod are generally found in shallow water bays and salt-ponds. Cod in Gilbert Bay are often reddish or golden-brown. Wroblewski (2000) suggested the red-brown colouration results from an abundance of red pigments (carotenoids) obtained through ingestion of invertebrates containing carotenoids synthesized by plants and passed through the food chain.

Table 2.1 Categories of Newfoundland and Labrador Atlantic cod (*Gadus morhua*), based on overwintering and spawning habitat, post-spawning migratory behavior, and body colouration. "Brown" includes brown to reddish-golden-brown colourations

Overwintering habitat	**Location of spawning grounds**	**Post-spawning migratory behaviour**	**Colouration**[1]
Offshore- continental shelf [2]	continental shelf [1]	migrates to coast to feed on capelin[1,3]	countershaded [4]
Offshore- continental shelf [1]	continental shelf [1,2]	non-migratory - remains on shelf feeding on capelin[1]	countershaded [3]
Inshore- bays (e.g. Trinity, Placentia, Gilbert Bay) [5,5]	bays [6,7,8]	remains at coast feeding on either capelin or shallow-water invertebrates[3,4]	countershaded (deep) brown (shallow) [9,10,11]
Coastal- headlands [3]	coastal deeps [12]	remains at coast feeding on capelin [11]	countershaded [3]
Salt-pond (e.g. Holyrood Pond; Occasional Hr.) [13]	salt ponds [12]	non-migratory, landlocked, feed on shallow-water invertebrates [12]	brown [12]
Inshore juveniles -bays and coast [11]	pre-spawning (juveniles of types 1-4) [11]	immature- non-migratory, feed on shallow-water invertebrates [11]	brown[14]

[1] A countershaded colouration pattern in cod refers to a gradual shading from darker on back to lighter, almost white underneath, with silvery gray sides.
[2] Templeman 1974
[3] Lear 1984
[4] Templeman 1966
[5] Green and Wroblewski 2000
[6] Smedbol et al. 1998
[7] Morris 2000
[8] Lawson and Rose 2000
[9] Neis et al. 1999b
[10] Wroblewski 2000
[11] Bradbury, I. pers. comm., Memorial University of Newfoundland. September 2001.
[12] Templeman 1979
[13] O'Connel et al. 1984
[14] Methven and McGowan 1998

Figure 2.2 Countershading in Atlantic cod (*Gadus morhua*).

Figure 2.3 A brown colored Atlantic cod *(Gadus morhua)*.

2.2. Colouration of Atlantic cod

Colouration in fishes is primarily due to skin pigments. Pigment granules are housed in specialized cells known as chromatophores. Brown-black pigment granules (melanins) are generally associated with melanophores, and red and yellow pigment granules (carotenoids) are generally found in erythrophores and xanthophores respectively (Waring 1963).

Melanophores are probably the best known of all pigment cells, and are perhaps the most important cells active in colour change (Bagnara and Hadley 1973). Melanin is generally thought of as a black pigment; however it may be brown, reddish-brown or, in rare cases, even yellow (Fox and Vevers 1960). Melanin pigments are synthesized directly within the melanophores. In fish, and poikilotherms in general, dermal melanophores are prevalent and appear in far greater numbers on the dorsal integument.

In the animal kingdom, carotenoids are the most widely occurring pigments after the melanins (Thommen 1971), though much less studied (Derek Burton, Memorial University, pers. comm.). A carotenoid may appear yellow, orange or red depending on the concentration of pigment (Fox and Vevers 1960). Carotenoids are synthesized by plants and reach animals in their food (Fox and Vevers 1960; Bagnara and Hadley 1973; Weedon 1971). Animals have the ability to modify ingested carotenoids and, as such, establish a definitive carotenoid pattern based on selective uptake by tissues (Bagnara and Hadley 1973). Fishes tend to concentrate carotenoids in the skin, ovary, liver, muscle and other tissues (Bagnara and Hadley 1973). The exact mechanisms involved in carotenoid modification and concentration in certain tissues are unknown. It is believed that carotenoids, and presumably colouration, are lost through metabolic reactions in animals (Thommen 1971). The length of time it takes for carotenoids (and colouration) to be lost from an individual once the source of carotenoids has ended is also unknown.

In addition to chromatophores, iridiophores are a second cell type found in fishes that influence colouration. These cells are responsible for the iridescent colouration of some species. Iridiophores reflect light efficiently and appear either silvery or golden when viewed with reflected light (Bagnara and Hadley 1973).

There are two mechanisms whereby fish change shade or colouration. One way fish do this, known as a physiological colour change, is through redistribution of pigments within chromatophores via the autonomic nervous system (Grove 1994). A variety of cues ranging from direct nervous stimulation to hormone action can produce such changes (Bagnara and Hadley 1973). Physiological colour changes are often rapid, ranging in duration from seconds to hours, and are most often in response to some immediate environmental stimulus such as a change in background colouration or alteration in conditions of illumination (Bagnara and Hadley 1973). Usually this response is transitory and the organism can revert to its original colouration or assume some intermediate colouration (Bagnara and Hadley 1973). Melanophores, because they are synthesized directly by animals, are most often associated with physiological colour changes (Bagnara and Hadley 1973).

Rapid physiological changes are contrasted with slow morphological changes that involve the accumulation or reduction in the total amount of pigment contained in the integument (Bagnara and Hadley 1973). With morphological colour changes, relatively large amounts of pigment are synthesized or destroyed due to either the persistence or lack of chromatophore stimulation (Bagnara and Hadley 1973). A diet containing a particular pigment will result in an absolute increase in the concentration of that pigment in some species (Myers and Sanderson 1992; Evans and Norris 1996; Ahilan and Prince Jeyaseelan 2001). Thus, carotenoids are generally associated with morphological colour changes. As well, conditions resulting in pigment dispersion or aggregation (physiological change) may cause an absolute increase or decrease (morphological change) in pigment (Waring 1963).

2.3. Scientific understanding of cod colouration and stock structure

Scientific research on stock structure has generally concentrated on the potential for reproductive isolation (i.e. temporal and spatial variation in reproduction) identified through studies of spawning times and locations, life history traits (e.g. overwintering and spawning site fidelity), phenetic distinctiveness (length- weight- and fecundity-at-age) and genetic differentiation of independent groups (see Smedbol and Wroblewski 2002 and references therein). Such research has traditionally relied on methods such as tagging, scales and vertebral counts (Thompson 1943; Templeman 1962), hydroacoustic and ichthyoplankton surveys (Smedbol and Wroblewski 1997), and in more recent years, sonic tagging and tracking (Wroblewski et al. 1996; Green and Wroblewski 2000).

Colouration has generally been dismissed in debates about stock structure due to its variability and dependence upon the environment (Thompson 1943 as cited in Hutchings et al. 2002). Research by Dannevig (1953), Love (1974) and Wroblewski (2000) described below, however, suggests that an understanding of the relationship between cod colouration and cod stock structure exists in the literature.

Scientific studies focusing on Atlantic cod colouration are limited in number. Dannevig (1953) studied the littoral cod of the Norwegian coast. Red shelf cod, yellow fjord cod and black deep-water cod are found there (Note that whether "black" refers to countershaded cod or cod that are black all over is unclear, as no description or photographs of these cod are provided). Several extreme cases of red pigmentation were observed where even the flesh of the cod had taken on a pink colouration. The predominant diet of the red cod was crustaceans, though diet was not described as having a major influence on body colouration. Fox and Vevers (1960) later suggested that Norwegian fjord cod likely derive their red colouration from astaxanthin, an abundant carotenoid in animals, obtained through their diet of shore crab (*Carcinus maenas*).

Love (1974) reported on the effect of a change in environment on the skin colouration of Aberdeen Bank and Faroe Bank cod. Cod from Faroe Bank are described as having the lighter skin of the two groups. Referencing Dannevig (1953) and others, and based on results of his own research, Love (1974) noted that the origin of a fish would affect the degree of change in its body colouration. He raised the issue that a range of pigment movement (within which the darkness of the fish can vary according to background colouration) either genetically characterizes a stock or becomes fixed at some stage of growth in response to the environment.

Wroblewski (2000) observed red-brown to golden-brown cod in Gilbert Bay, Labrador. Their colouration was believed to result from either a carotenoid rich diet of crustaceans, a morphological adaptation to the background of the bay, or a combination of both (Wroblewski 2000). Given that cod can change colouration in response to background colouration (a rapid physiological change), Wroblewski (2000) suggested that colouration is a questionable indicator of stock structure. He noted that the brownish colouration of the Gilbert Bay population provides evidence of their non-migratory behaviour. Thus, the colouration of offshore northern cod and inshore bay cod indicates their respective primary habitats in a manner similar to that exhibited in Norwegian cod (Wroblewski 2000).

2.4. Fish harvesters' understanding of cod colouration and stock structure

Fish harvesters often recognize "groups" or "runs" of cod. These groups are generally distinguished through observations of colouration, shape, diet, size, depth fished, whether fish are in spawning condition (running with eggs/"milk[1]"), the timing and direction of movements (Neis et al. 1999b), the presence of cod year round in a bay (Wroblewski 2000), and texture of the flesh (Hutchings et al. 2002).

[1] "milk" is a term used by harvesters to refer to milt released by spawning male fish

In 1889, Reverend Moses Harvey, a natural historian, argued that harvesters could distinguish cod by macroscopic appearance alone, and could distinguish cod from northern and southern bays. He referred to the fact known to every fisherman that cod were "local" and individual bays could be "restocked" successfully (as cited in Hutchings et al. 2002). Disagreeing with Harvey at this time, Judge Prowse argued that cod were extremely migratory, thus making it impossible to restock "local" groups of cod (Hutchings et al. 2002).

In 1922, through conversations with local fish harvesters, local merchants and others, Munn identified three runs of cod passing through the Strait of Belle Isle (running between Newfoundland and Labrador) that differed in size, colouration, condition, school density and timing of arrival (as cited in Hutchings et al. 2002). The second of these runs was distinguished by their "golden tinge" (Munn 1922 as cited in Hutchings et al. 2002). These fish were believed to be feeding on capelin. Munn identified three other runs of cod along the coast of Labrador, also distinguished in part by colouration (Hutchings et al. 2002). The second run of these cod were described as generally having a brown colouration.

Fish harvesters today use these same observations (i.e. colouration, diet, season, habitat, spawning, migration, etc.) to indicate different groups of cod. Though colouration is seldom used in isolation from other observations in distinguishing cod, observing when and where cod of different colourations occur, direction and timing of movements, what these cod are feeding on, and whether or not they are "ripe" allows fish harvesters to make generalizations about relationships between colouration and different groups of cod that may exist. Harvesters often associate colouration with a particular season (catching black backed cod early in summer), behaviour (harvesting brown cod that seem to be "lying around on the bottom"), or feeding habits and habitats (associating red coloured cod with "kelp" or "red moss"). Fish harvesters in Placentia Bay, Newfoundland, identify a "capelin scull" that have a much blacker back and lighter belly than the "bay cod" that are relatively grayer (Hutchings et al. 2002). Other colour gradations are used to distinguish sub-groups within the bay and are linked to water depth, food or both (Hutchings et al. 2002). Similarly, cod resident in Gilbert Bay, Labrador, are recognized by their distinctive golden- to reddish-brown colouration. Harvesters' observations of brownish coloured cod and historic catches within the bay before the migration of offshore cod to the coast in the summer, prompted scientific research that led to the genetic identification of this group of cod (Wroblewski 2000).

In other areas of Newfoundland and Labrador, fish harvesters have unique names to refer to cod of different appearances. For example, a *tom cod* or *harbour tom cod* refers to a small, immature cod fish (Dictionary of Newfoundland English 1990). The term *foxy tom-cod* is used to describe a small reddish-brown cod that is usually caught close to the shore (Dictionary of Newfoundland English 1990). Harvesters also use the terms *foxy cod*, *shoal-water cod*, and *kelp fish* to refer to red coloured cod and *harbour fish* or simply *brown cod* to describe brown to yellow/red-brown varieties (this research). Fish harvesters in Norway also use colouration to distinguish between *taretorsk*, red shallow-water cod of the skjærgård, *fjordtorsk*, yellow shallow-water cod of the fjords and sounds and *dyptorsk*, black cod found in the deep waters of fjords and the skjærgård (Dannevig 1953).

3. Documenting fish harvesters' knowledge of colouration in Newfoundland and Labrador Atlantic cod

3.1. Introduction

Systematically researching fishers' knowledge can reveal their observations on cod, what and how harvesters think about cod, and characteristics they use to distinguish different groups of cod. Observations of overwintering and spawning grounds, unique morphological features, and descriptions of cod migration and behaviour in the inshore environment can provide indications of local stocks of cod. Fish harvesters' knowledge of variations in cod colouration within and between groups of cod can provide insight on links that may exist between colouration and local populations of cod. Below I discuss retired fish harvesters' observations of colouration, abundance, and spawning and overwintering behaviour of Atlantic cod, and then combine these observations to determine the potential role of colouration as an indicator of cod stock structure.

3.2. Interviews with fish harvesters

Fish harvesters living between Lark Harbour, Newfoundland, and Cartwright, Labrador (Figure 3.1), were interviewed in a series of taxonomic and career history interviews to gather information on which to base assessment of historical changes in the fishery over the past 100 years. In this thesis, information from these interviews was used to learn about the location and history of fish harvesters' interactions with Atlantic cod. In total, 32 fish harvesters were interviewed from 23 communities. Interviewees were mainly small boat, inshore fishermen (fishing along the coast and within the bays) who used a combination of jiggers, hand lines, cod traps, gillnets, and line trawls.

Dr. Barbara Neis, Memorial University of Newfoundland, and Dr. Craig Palmer, University of Colorado, led taxonomic interviews along the west coast and Northern Peninsula of Newfoundland during 2000 (Figure 3.1). Further interviews, led by Dr. Neis, Danny Ings, and Karen Gosse of Memorial University of Newfoundland, took place between 6 and 17 December 2000 in southeastern Labrador (Figure 3.1). Career history interviews, led by Dr. Neis and Danny Ings, were conducted between April and June 2002 along the west coast and Northern Peninsula of Newfoundland (Figure 3.1). Interview arrangements were made by Danny Ings, a research assistant with the "Coasts under Stress" research project. Fish harvesters' committees and development organizations were contacted and asked to provide a list of retired harvesters ("experts") in their area. Interviewees were selected from this list throughout the study area. Additional interviewees were selected from suggestions provided by fish harvesters interviewed (snowball sampling).

Interviews were semi- structured (Appendix 1) and lasted up to five hours. Marine charts were used to document locations referred to during discussions. Occasionally interviewees were too tired near the end to participate in chart work, or were unfamiliar with the charts, resulting in only 23 charts available for analysis. Individuals chose whether to have interviews tape-recorded. Twenty-eight of the 32 interviews were recorded and later transcribed for analysis.

In the taxonomic interviews, interviewees were shown a series of black and white pictures of different fish species, including Atlantic cod, and encouraged to talk about whether they had observed the species. If so, harvesters were asked when they had observed them, local names used to describe them, if they had fished for them commercially, and if they had any other uses for them (e.g. food, fertilizer, bait). Many questions were asked concerning spawning and migration patterns for cod, observations on historical distributions, and changes in abundance over time (Appendix 1). Information provided was from memory and not from logbooks or other sources. To obtain information on inshore cod, colouration was used as an entry point into discussions on cod observations. Interviewees were shown a picture of the golden-brown Gilbert Bay cod (Figure 3.2, above) and/or Norway cod (Figure 3.2, below) and asked whether they had seen cod this colouration in the area where they fished. Positive responses led to further discussion about the abundance of these "brown" cod, what time of year they had seen them, if they fished them, where and how they were caught (e.g. if they ever fished for them through the ice), and also whether they had seen them in "ripe" condition (i.e. running with eggs or "milk").

Questions during career history interviews were organized according to type/size of fishing boats (e.g. trap skiffs, longliners) and gear (e.g. cod traps, line trawls, jiggers, gillnets) used, starting from when they first entered into the fishery and lasting until they retired from fishing. Interviewees were shown a picture of cod from Gilbert Bay (Figure

3.2 above) to prompt discussions on colourations of cod and locations where different colourations were observed throughout their careers. Similar questions were asked regarding season(s) of observation, if they fished them, where and how they were caught, and whether these cod were observed in spawning condition.

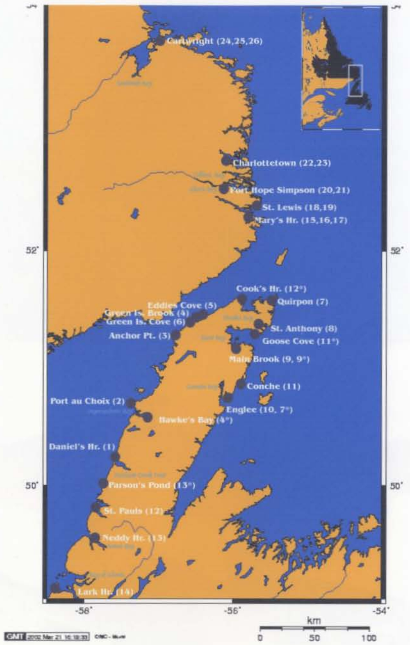

Figure 3.1 Locations of taxonomic interviews with fish harvesters in November (Neis and Palmer) and December (Gosse, Neis, Ings and Chaffey) 2000, and career history interviews in April-June 2002 (Neis and Ings). Individual interview numbers (from 1-26) are indicated in brackets. Career history interviews are distinguished with an asterisk following the interview number.

Figure 3.2 Photographs of Atlantic cod (*Gadus morhua*) used during interviews with fish harvesters to encourage discussions of brown cod.

3.3. Fish harvesters' knowledge of Atlantic cod

Fish harvesters' observations of differences in size, colour, condition, diet, migrations, and the timing and location of spawning are shaped by their fishing practices (Hutchings et al. 2002). Interviewees for this research were mainly small boat inshore fishermen (fishing along the coast and within bays) who had grown up in coastal communities throughout the study area (Figure 3.1). Harvesters had used a combination of jiggers, hand lines, cod traps, gillnets, and line trawls. Nine harvesters owned or had fished from a longliner at some point in their lives. Longliners were generally used to set/haul gill nets inshore and along the coast between the 1970s and 1990s. A majority of harvesters had fished seasonally for cod, beginning early in spring and fishing until ice formation in the winter. Results of this research are therefore largely limited to harvesters' observations in bays and along the coast of southeastern Labrador and the west coast and Northern Peninsula of Newfoundland between April and December.

Fishermen interviewed during taxonomic interviews (n=26) ranged from 51-85 years of age with an average age of 69 years. These harvesters began fishing anywhere between 1927 and 1964 and between the ages of 5 and 27. They had fished from 27 to 64 years. Three harvesters had retired in the 1980s but the majority (n=12) ceased any fishing activity with the implementation of the northern cod moratorium in 1992 or the gulf moratorium in 1994. Several fishers (n=9) continued fishing after 1992. These latter harvesters were usually fishing crab, shrimp, eel, and/or lumpfish, in addition to cod.

Fishermen interviewed during career history interviews (n=4) ranged in age from approximately 50 to 65 years of age. These harvesters began fishing between 1945 and 1967 and had fished between 25 and 37 years. All harvesters participating in career history interviews had retired between 1991 and 1994.

Most fish harvesters had heard of, or had seen cod of a variety of colourations and tended to differentiate between resident shallow water inshore cod and migratory offshore cod by colouration and season of capture. Reports of different coloured cod came from all parts of Newfoundland and Labrador visited during the interview process (Figure 3.3). Harvesters also identified areas where spawning cod were observed (Figure 3.4) and locations where cod were believed to have overwintered (based on observations of cod in early spring or late fall/winter) (Figure 3.5).

Results of interviews will be discussed beginning with the diversity of colourations observed, seasonal observations related to spawning times and locations, the abundance of cod of different colourations, and finally areas where different coloured cod were believed to be overwintering. Relatively little information was provided on spawning behaviour of brown cod. Templeman (1979) suggests that the winter-spring distribution of mature cod is the spawning area (as cited in Wroblewski et al. 1994). As such, a combination of overwintering behaviour and colouration were used to provide insight into the relationship between colouration and inshore stocks of cod.

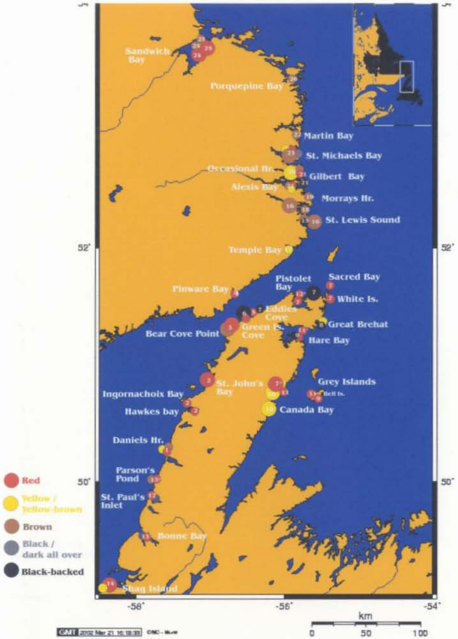

Figure 3.3 Enlargement of the Northern Peninsula of Newfoundland and southeastern Labrador, showing locations of brown, yellow-brown, red to reddish-brown, black and black-backed Atlantic cod (*Gadus morhua*) reported by fish harvesters interviewed in November and December 2000 and June-April 2002. Colours of circles represent the different colours of cod observed by fish harvesters. The size of the circles suggests the amount of detail surrounding the observation, where larger shapes represent more information. Interview numbers are indicated within the circles. Career history interviews are distinguished with an asterisk following the interview number.

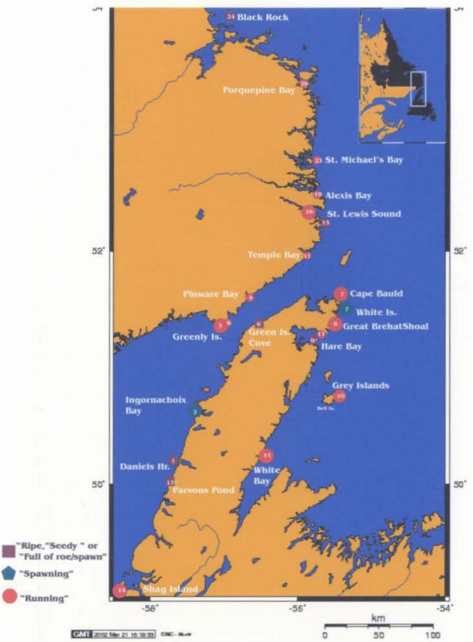

Figure 3.4 Enlargement of the Northern Peninsula of Newfoundland and southeastern Labrador, showing locations where Atlantic cod (*Gadus morhua*) were observed to be "ripe," "seedy" or "full of roe/spawn" (■), "running"(●), or "spawning" (⬟), by fish harvesters interviewed in November and December 2000 and June-April 2002. The size of the circles suggests the amount of detail surrounding the observation, where larger shapes represent more information. Interview numbers are indicated within the circles. Career history interviews are distinguished with an asterisk following the interview number.

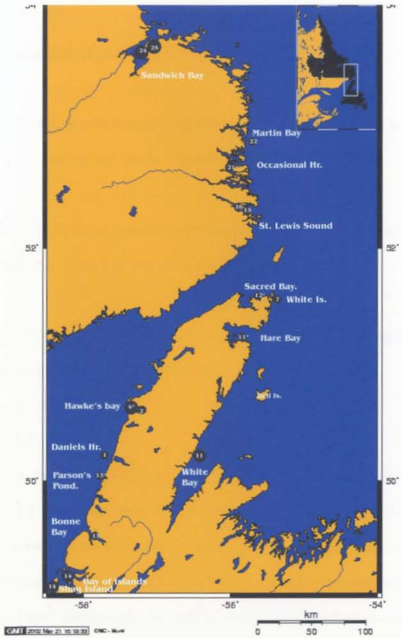

Figure 3.5 Enlargement of the Northern Peninsula of Newfoundland and southeastern Labrador, showing locations where Atlantic cod (*Gadus morhua*) were believed remain year-round, a possible indicator of a local population, as revealed by fish harvesters interviewed in November and December 2000 and June-April 2002. The size of the circles suggests the amount of detail surrounding the observation, where larger shapes represent more information. Interview numbers are indicated within the circles. Career history interviews are distinguished with an asterisk following the interview number.

3.3.1. The colourations of cod

Fish harvesters described many gradations in colours of cod ranging between countershaded, red, yellow, and brown. Fisherman 7 from Quirpon noted:

> *"There's a lot, they're not all the same thing. You know what I mean, not all the same colour... There's no one of the cod all the same colour."*

Despite this diversity, several key colourations were identified during interviews: brown, yellow-brown, red to reddish-brown, black-backed, and dark/black.

Brown cod

Many fish harvesters (n=14) had observed brown cod throughout their fishing careers (Figure 3.3). Fishermen from Parson's Pond, Newfoundland (Figure 3.1), referred to these cod as *shoal-water cod*. Fisherman 23 from Charlottetown, Labrador, described brown cod as having speckles on their bellies. He also described brown cod as "more up in the bays." Brown cod were reported as small (8-10 inches) to medium sized (up to 24 inches) by three harvesters. One other harvester believed these cod to be of "no particular size." Fisherman 4*[1] from Hawke's Bay, Newfoundland, believed these cod were fatter than other cod.

[1] Interviewees from career history interviews will be marked with an asterisk to distinguish those from harvesters interviewed during taxonomic interviews.

Three harvesters felt that offshore (countershaded) cod move into fresh ("dirty") water and turn brown, and generally associated a brown colouration with bay environments. Harvester 16, who fished in St. Lewis Sound, Labrador (Figure 3.1), believed:

> *"Brown ones? In the summer time. They get into the bay, up at the end with the fresh water[2]. They used to turn it then; they turn burnish a bit, eh? That's in the fresh water."*

Fisherman 26 from Sandwich Bay, Labrador, described two groups of brown cod. He distinguished between a lighter brown cod that could be caught all summer long within the bay and a darker brown cod that left Sandwich Bay in August/September that were harvested outside the bay. This fisherman believed that the brown colouration resulted from a combination of fresh water and shallow water encountered in the bays.

Yellowish-brown cod

Five fish harvesters described yellow-brown cod (Figure 3.3), a common description of resident cod in Gilbert Bay. Fisher 10 believed these cod were generally found in shallow water. Referring to the photo of Gilbert Bay cod (Figure 3.2) he asked:

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[2] Fresh water refers to seawater that is diluted with river run-off

> *"Do you want me to tell you the reason that cod got a different colour from that [countershaded] one? That fish was caught in shoaler water than this one. This fish came up out of the deep water, [the one] with the white belly"* (Unpublished research transcript # 10, 2000).

He further states:

> *"If it's in shallow water so long, it will turn right dark...I always thought that the fish changed its colour when it came in shoaler water and I can't believe anything else."* (Unpublished research transcript # 10, 2000).

It is unclear what he means by "dark" in this statement, as he is referring to the picture of the Gilbert Bay cod, which are generally described as brown or yellow-brown. Fishermen 3 and 20 from Anchor Point, Newfoundland, and Port Hope Simpson, Labrador, respectively (Figure 3.1), also believed that the yellow-brown colouration resulted from cod being in shallow water. Fisherman 17 from Mary's Harbour, Labrador, said that the yellow-brown colouration resulted from a fresh water environment. Discussions with local residents from Port Hope Simpson and Williams Harbour, Labrador (Figure 3.1), in June 2002 revealed the belief that cod are golden brown in fresh water. The general theory is that fresh water is "dirty," or brown in colour, and cod that are in this water turn a brown colouration.

Opposite to what most harvesters described, fisherman 7* from Englee, Newfoundland (Figure 3.1), characterized "darker bellied" cod (described as like the photo of the Gilbert Bay cod), that migrated out of Canada Bay in the fall, as deeper water gillnet fish and "white-bellied" (countershaded) cod as cod caught in traps shallower waters.

Red to reddish-brown cod

Red to reddish-brown coloured cod were frequently described during interviews. Two fish harvesters referred to these cod as *shoal-water cod* and believed shallow water was responsible for the colouration. One harvester from Conche, Newfoundland (Figure 3.1) believed the colouration was due to the sun:

> *"That's the theory we always thought.... I always come up with that [the red cod] was right up in shoal water all the summer [and] he's sunburned... That was handed down and down. You know, the first fella ever said it to me was my father I'd say."* (Unpublished research transcript # 11, 2000).

Four others associated red cod with the presence of "kelp" beds or "red moss"[3]. Fisherman 4 from Green Island Brook, Newfoundland, asserted that the colouration resulted from "being on the kelp." Fisherman 13* from Parson's Pond, Newfoundland, said cod were red in order to provide camouflage while swimming in red "kelp" beds. Fisherman 14 from Lark Harbour, Newfoundland, referred to their presence in areas of "red moss" (see below). Fisherman 7 thought *kelp fish* stayed year-round, near Quirpon,

[3] A sample of the "red moss" described by harvesters was collected and identified by Dr. Nancy Turner (University of Victoria) as the Rhodophyta *Ptilota serrata*. The "kelp" is likely a species of brown seaweed.

Newfoundland, lying on the rocks and "kelp." Discussions with residents of Port Hope Simpson and William's Harbour, Labrador, revealed the belief that a red colouration results from spending years up in Gilbert Bay and generally related the colouration to the presence of "kelp" beds. Other harvesters (n=3) claimed that a red colouration resulted from cod spending time in fresh water. Fisherman 25 from Sandwich Bay, Labrador, believed that cod would come into the bays (in fresh water) and turn "reddish-brown" within 1-2 months.

Fisherman 14 from Lark Harbour, Newfoundland, perceived diet as the leading cause of red colouration in cod. He believed that red cod feed on crab and in/on what he referred to as "red moss."

> *"... Sometimes you haul them up and their stomachs be full of that old red... that old red moss... or you could clean up a fish about this big, you rip his stomach open, you might find two or three crabs, but you could probably pick out a handful of this old red moss"* (Unpublished research transcript # 14, 2000).

He believed that red cod could *only* be found in red moss areas in shallow water and that these fish were the "real natives" of the area. "Yellow" cod were noted to be mixed in with the red cod and were believed to also be native to the area. These red and yellow coloured fish were described as smaller (<24 inches), fatter, plumper, and thicker than the white-bellied (countershaded) cod. Red cod were also described as having drier flesh than that of differently coloured fish by fisherman 13* from Parson's Pond, Newfoundland, though fisherman 11* from Goose Cove, Newfoundland, who fished in

Hare Bay (Figure 3.1), recalled that "the old people" wouldn't eat the red cod because the flesh was too watery. Red cod in Canada Bay (Figure 3.1), locally known as *Salvation Army fish,* were considered "good to eat" by fisherman 7* from Englee, Newfoundland. He said that fishermen in the area would often catch these fish in the fall as their food for the winter.

Along with the terms *shoal-water cod, Salvation Army fish* and *kelp fish,* fishermen used the terms *Harbour fish, foxy cod,* and *tomcod* to refer to red cod. Red cod were generally described as small to medium sized. An explanation for their relatively small size was provided by fisherman 4 from Green Island Brook, Newfoundland, who believed that red cod are generally small and "as they go older they lose this colour." However, fisherman 11 from Conche, Newfoundland, recalled that *foxy* red cod would weigh up to 7 or 8 pounds.

Black-backed cod

The term *kelp fish* was used by one fish harvester to refer to black-backed cod (cod darker on their backs and white underneath). Fisherman 16 from Mary's Harbour, Labrador (Figure 3.1), described black-backed cod as having "black and white specks on 'em over their skin." Fisherman 7 from Quirpon, Newfoundland (Figures 3.1 and 3.3), recalled:

> *"You get some dark on the back. We used to call that kelp fish.... It was dark on the back right?"*

He believed these cod are "still the same as the other fish... only just the colour." In Port Hope Simpson and William's Harbour, Labrador (Figure 3.1), harvesters believed that cod turned "darker" on their backs when in shallow, "clear" (salt) water.

It was unclear from interviews to what colouration "black-backed" referred. The term may have been used to describe countershaded cod that are darker on the back (as Port Hope Simpson and William's Harbour residents believe) or possibly cod that were dark all over (as discussed below).

Black or dark cod

Five fish harvesters reported "black" or "dark" cod. Fisherman 12 from St. Paul's, Newfoundland, described "dark" cod (Figure 3.3) that were "all mixed up" with other coloured fish. Fish harvester 13 from Neddy's Harbour, Newfoundland, described these cod as "pretty well black all over. Not black, but dark." Similarly, harvester 23 who fished near St. Michael's Bay, Labrador (Figure 3.3), described cod that were dark all over (on their backs and bellies) that were caught while trawling "off of the banks" and "when it come to the shore, it'd be a dark [cod]." Fisherman 26 from Cartwright, Labrador, believed cod would be dark when leaving Porcupine Bay (Figure 3.3). This conversation went as follows:

Researcher: *Do you see different coloured codfish?*

Interviewee: *Yeah. We used to get some codfish was light and some was dark.*

Researcher: *Did you see brown ones or red ones?*

Interviewee: *Yeah, you do.*

Researcher: *Very many?*

Interviewee: *Yeah. You'd get cod fish in the bay, all summer long; when they're coming out they're darker, where they're in closer to fresh water.*

Researcher: *O.k. But other than that, you wouldn't see them?*

Interviewee: *No, not...*

Researcher: *So would you see them in August, in your traps, those darker ones that had been in the...?*

Interviewee: *Oh, yeah. Yeah.*

Researcher: *What is the bay near where you were fishing? What bay would they be coming out of?*

Interviewee: *Porcupine Bay.*

Researcher: *Would they be darker, or more yellow, or...*

Interviewee: *Yeah, they're a darker fish when they're coming out of the bays.*

Researcher: *Yeah. Darker all over?*

Interviewee: *Yeah, I guess that's the fresh water doing it.* (Unpublished research transcript # 26, 2000).

Fisherman 7* from Englee, Newfoundland, also observed dark "bay fish," caught on trawls in deeper water, mixed with other colourations of cod while leaving Canada Bay.

It is not clear whether all four harvesters are describing cod that are dark *all over*. Note that in the above conversation with fisherman 26, only the researcher used the description "dark all over."

3.3.2. Seasonal distribution, location and depth

Brown cod

Brown cod were generally caught by harvesters in shallow water in traps, gillnets, and on jiggers (as described by four fish harvesters). These fish were usually harvested in the spring, summer, and fall. One fisherman from Charlottetown, Labrador (Figure 3.1), claimed brown cod could be found almost any time of the year, though they were most common in the fall. In St. Lewis, Labrador, fisherman 18 briefly recollected jigging brown cod in late August, and catching a scattered one throughout the rest of the fall. Fisherman 19 from the same area reported catching "one or two all summer, but [in] the winter there'd be none." Fisherman 20, who fished in Gilbert Bay, Labrador, also reported the presence of brown cod (Figure 3.3) in the summer time "anywhere around the bay." Several fishermen believed that the brown cod would be caught on their way out of the bays (migrating towards offshore areas) in the fall. Fisherman 16 from Mary's Harbour, Labrador, believed that "when the time comes they go out." This same fisherman, however, goes on to say that "a scattered one might stay in [St. Lewis Sound] you know, not very many."

The presence of brown cod during winter in other areas was also reported. In Occasional Harbour, Labrador (Figure 3.1), brown cod were caught one winter while ice fishing. Along the coasts near Daniel's Harbour, Newfoundland, and Martin Bay, Labrador, brown cod were believed to stay year-round in deep waters just offshore by harvesters 1 and 22 respectively (Figure 3.5).

Yellowish-brown cod

Fish harvester 10 from Englee, Newfoundland, described yellow-brown cod present in shallow water in Canada Bay in the spring and fall. In June these cod were believed to be coming into the bay close to the surface and "you'd get [them] in the floating traps." In September, these fish were harvested on trawl lines and were believed to be moving out of the bay. In Temple Bay, Labrador (Figure 3.3), fisherman 17 described yellow-brown cod as the last run of cod out of the bay. This "last of the fish" would be harvested in cod traps in August.

Red to reddish-brown cod

Cod described as red to reddish-brown in colouration were trapped, jigged, or gillnetted in different seasons. Fisherman 9 from Main Brook, Newfoundland, described catching red cod in June. Fisherman 11 observed *foxy* red cod in shoal water near the Grey Islands, north of White Bay, Newfoundland (Figure 3.3), all summer long. In contrast, fisherman 2 from Port au Choix, Newfoundland, described red cod as most abundant in the fall – the most common belief held by fish harvesters – in depths of 15-20 fathoms. He believed:

> *"They turns red and in the fall you get more than what you will in the spring, those little red fish... you go jigging in June, and you won't get those, you won't get very many but you go out there now [in October] and you get, 90% you get those little red ones."* (Unpublished research transcript # 2, 2000).

Furthermore, this harvester noted you could catch away at red cod when there was nothing else left (i.e. after the main group of cod had migrated south to the deep waters off Port aux Basques). Fishermen 24 from Cartwright, Labrador, 11* from Goose Cove, Newfoundland, and 12* from Cook's Harbour, Newfoundland (Figures 3.1 and 3.3), expressed a similar belief. Fisherman 11* further observed that red *tomcods* were most easily harvested in the evenings when the tide was high.

Black-backed cod

Black-backed cod were reported in the fall on the tip of the Northern Peninsula near L'Anse aux Meadows, Newfoundland, in ~4-5 fathoms of water. Fisherman 7 from the area believed that these cod might stay year-round in Pistolet Bay (Figures 3.1 and 3.3) on the rock and "kelp" beds. Fisherman 21 from Port Hope Simpson, Labrador, (Figure 3.5) suggested black-backed cod would be common on the headlands in the spring, after migration to the coast.

Black or dark cod

Fisherman 13 recalled that cod that were "dark all over" usually came into Bonne Bay, Newfoundland (Figure 3.1), with the capelin around June. These fish may have overwintered in the bay, as this fisherman reported catching mixed coloured cod in Bonne Bay through the ice in 20 – 30 fathoms of water. Fisherman 23 from Charlottetown, Labrador, talked about black cod that migrated to the coast. This suggests that these cod were also observed in the spring of the year. In contrast, fish harvester 26, who fished near Porcupine Bay, Labrador, believed these fish were most common in August in their cod traps after spending the summer up in the bay near fresh water.

3.3.3. Spawning

Harvesters used various terms to refer to cod in spawning condition. Fourteen fish harvesters described cod "running" with eggs or "milk" (Figure 3.4). The term "mother fish" was used by 10 of these harvesters to refer to such cod. Harvester 6 from Green Island Cove, northern Newfoundland, described "mother fish" as:

> *"Well, he was full of spawn. What we call the britches then... you got a big pant shape, britches we call it... and that are a bag full of spawn."*

When questioned whether the spawn was loose and running, he says:

> *"In the later part of the year they would. But you had to handle them with care. If you didn't, this bag would break.... but you get some of it now, where the spawn wasn't mature. I don't know how long it takes a spawn to come from a spawn to a mature egg you might say... you know, before it lets go... but some time when they're pretty much mature this bag containing the roe, the spawn, would be pretty tender."* (Unpublished research transcript #6, 2000).

"Running" cod were caught in gillnets (n=7), cod traps (n=6) and on line trawl (n=5). Five fish harvesters reported these cod from April-July; six between June and August; and five in the fall around September or October (Figure 3.4). One fish harvester from St. Anthony, Newfoundland, observed "breeding fish" that were "running" in the "later part of the year." Most harvesters (n=13) observed "running" cod at depths between ~5 and ~50 fathoms. One fisherman from Conche, Newfoundland (Figure 3.1), however, reported cod "with the milk running out of it" in depths of up to 190 fathoms in a deep-water trench in White Bay. Few interviewees specified the abundance of these "running" cod. One harvester from Englee, Newfoundland, though, recalled, "just about every fish that you picked out of the net there, the milk was running out of it." In contrast, Fishermen 4 and 26 reported only ever catching a few of these cod in Pinware Bay and Porcupine Bay, Labrador (Figure 3.4), respectively.

Cod described as "running" were generally countershaded in appearance. Fisherman 7 from Quirpon, Newfoundland, who had observed such cod in the Cape Bauld Area (Figure 3.4), suggested that a few red cod would be mixed in with these. One harvester from Mary's Harbour, Labrador, reported "running" cod in St. Lewis Sound that were brown in colouration.

A second term, "spawning" cod, was used by two interviewees (Figure 3.4). Fisherman 2 from Port au Choix, southwestern Newfoundland, provided this description of "spawning" cod:

"Oh, you saw them spawning...them fish wasn't moving. They were on the bottom spawning. And when they get them up and pile them in the boat, well, they run out of them just the same as you... run out of a kettle."

Harvester 7 from Quirpon, Newfoundland, also described "spawning" cod. These cod were observed between July and September in depths of up to 50 fathoms near White Island, northern Newfoundland, and in ~20 fathoms of water just outside of Sandwich Bay, Labrador (Figure 3.4). This harvester reported that a scattered "spawning" cod in the White Island area would be red in colouration, though he noted that he had not seen spawning cod there in over 30 years. It is unclear whether the cod this harvester described were running with spawn or were full of "milk" or eggs.

Six fishermen described cod as either "ripe" (n=1), "seedy" (n=1) or "full of roe/spawn" (n=4). One harvester described catching cod "full of roe" between April and July in ~20 fathoms of water off Daniel's Harbour, Newfoundland (Figure 3.4). One other reported cod "full of spawn" in deep water in St. Lewis Sound, Labrador, in the fall (September/October). The remaining harvesters did not specify a season when these cod had been observed.

At least two fish harvesters expressed a strong belief that the introduction of gillnets had a significant impact on the abundance of mature cod. A harvester from St. Anthony, Newfoundland, commented:

"When we were trapping fish we'd get them big spawny fish. Well, I always says, that's all happened to the fishery. When we was going, like I said, when we was

going fishing all we had was the jigger and the dabbler for catching fish, and the six and seven line trawl, and by and by the gillnets come up. Go out there off Brehat about a mile or so, and put down your gillnets, you'd haul up those great big old fish, old spawny fish. Two or three years that was all gone. Killed hundreds of thousands of quintals[4]." (Unpublished research transcript # 8, 2000).

Another spoke of the role of both gillnets and draggers in the declining numbers of larger, breeding fish:

"Cuz in my thinking that was one of the biggest things that destroyed our codfish, right? The gillnet and the dragger. Too much technology. They went out and caught the breeding fish in the gillnets that never came to the land, that you used to probably get in the cod trap right? You hardly ever get these big fish in cod traps right? And every year you were destroying the mother fish and you know, same way with the dragger." (Unpublished research transcript # 11, 2000).

3.3.4. Abundance

Harvesters from Port Hope Simpson and Williams Harbour, Labrador (Figure 3.1), described an abundance of brown, yellow-brown, and reddish coloured cod in

[4] A measure of dried and salted cod-fish equal to 112 pounds (Dictionary of Newfoundland English 1990).

Gilbert Bay. Harvester 20 recalled catching "over three-hundred quintals" for the three summers he fished in the bay. He believed that there was "more fish in the bay than there was on the outside" when he first began fishing in Gilbert Bay about 25-30 years ago. Fisherman 21 recalled similar abundances. Though he did not fish in Gilbert Bay himself, he spoke of a man who would catch "40 or 50 quintals of fish before either fish comes to land, just fishing from the bay all winter." He further recalled that during a small commercial fishery in the bay in 1999 "each fisherman got 2600 pounds of fish."

Outside of Gilbert Bay, cod of brown, yellow-brown, and reddish colourations were described as relatively fewer in numbers. Most harvesters recalled catching only a "scattered few" or "one or two a summer." Fish harvester 12 from St. Paul's, Newfoundland (Figure 3.1), estimated his catches of red cod have been about 100 pounds per boatload (1000 pounds) of fish. Fisherman 7 from Quirpon, Newfoundland, recalled catching only 6-12 red cod each time he hauled his cod trap. In certain areas, however, harvesters targeted and caught significant numbers of red or brown cod. Fisherman 14 from Lark Harbour, southwestern Newfoundland (Figure 3.1), observed that in any given year there would be "quite a lot of them" red cod on certain "spots on the grounds" near Shag Island (Figure 3.3). One fall in particular, approximately 1600 pounds of red cod were harvested on one day. This fisherman recalled:

> *"Because in the fall there was no fish here, [in the] bay[5]. And me and my uncle left here, one day we were up on the shoal, we got what, sixteen hundred pound.*

---

[5] Bay of Islands

That's all we got was the red [cod] .... I guess that was probably around September month. Nobody wasn't getting anything here and the next morning, well, the word went out, as soon as we got down, there was a lot of fish...So the next morning, my god, we was here, probably left here about three-thirty, quarter to four. And when we got up along shore there was a whole bunch of dories there waiting, waiting there. We went on the shoal and the next day we went right back on the same marks, perfect weather, and I don't think we got 500 pounds." (Unpublished research transcript #14, 2000).

Fish harvester 7* from Englee, Newfoundland (Figure 3.1), also described high catches of reddish coloured cod in recent years:

Interviewee: *But you know, I mean they're nice fish. They're good fish, eh, and their right white, eh. You know when you fillets 'em. Oh nice fish. But here like the last years, like when we was goin', like even.... I don't know about this year 'cause I wouldn't home. But the year before, when we go out to get some, you know jiggin' and that, or catchin' it, what ever it might be for your winter, bye lot of red fish. I never seen so much in me life, I don't think. No, not when I fished.*

Researcher: *Oh really.*

Interviewee: *Yeah, like you know, you don't have to go that far, only just off here where the lighthouse is to in Englee, eh. Just off in around there. I wouldn't say it's more than a quarter of a mile.*

Researcher: *Yeah.*

Interviewee: *And I am tellin' you. You get a lot of red fish.*

Three accounts from fishermen suggested brown cod were in higher abundance in the past. Fisherman 23 from Charlottetown, Labrador, reported catching a lot of brown and red cod "late in the season" during the early years of his fishing career. Similarly, fish harvester 3 from Anchor Point, Newfoundland (Figure 3.1), suggested that brown cod had disappeared in recent years:

> *"Down here off Bear Cove a little ways. That's where I said I had them brown fish you get...Yes, but you don't get none of those, those years now. That's all gone past, long ago."*

Additionally, fisherman 26 recalled catching a lot of brown and yellow-brown cod in the past just outside of Porcupine Bay, Labrador (Figure 3.1).

Interviewee: *We used to get a lot of fish.*

Researcher: *A lot of brown ones?*

Interviewee: *Yeah. We'd get quite a few brown ones, yeah. That's when the fish was thick.*

He further commented that though these fish were caught year-round in the bay, they were in highest abundance in the fall of the year.

3.4. Identification of bay stocks

Fishermen used several characteristics to identify different groups of cod. Interviewed harvesters for this research used a combination of colouration, morphology, seasonal distribution (i.e. catching cod through the ice, early in spring before the arrival of the offshore migrating cod, or late in the fall after the main group of cod had migrated offshore), texture of the flesh (dry vs. watery), and sometimes spawning behaviour and local knowledge of tides to identify areas where cod that lived in the bays ("bay cod") were believed to exist. Combining all observations, several key areas were identified where uniquely coloured cod were thought to have overwintered (Table 3.1). These areas consist of observations of overwintering cod inside and just outside of various bays (Figure 3.5).

Table 3.1. Summary of harvesters' observations of different colourations of Atlantic cod (*Gadus morhua*) believed to remain year round in bays and coastal areas throughout Newfoundland and Labrador, as reported during interviews in November-December 2000 and April-May 2002 (locations are show in Figure 3.5).

Location	Spawn -ing?	Coloration	Season	Depth	Abundance	# of reports
Sandwich Bay, Lab.	-	Red to reddish brown	Late summer/ early fall at the end of the trap season and wintertime through the ice	-	Scattered few	2
Occasional Hr., Lab.	-	"Darker"; Countershaded	Early spring	-	> 40 caught one evening	2
Gilbert Bay, Lab.	Believed to spawn within the bay	Brown; Yellow-brown "bay cod"	Early spring and November through the ice	Shallow water (< 20 fa)	300 quintals each summer for 3 summers; 40-50 quintals early spring before offshore cod arrived; 40 –50 one day in Nov.	2
St. Lewis Sound, Lab.	Observed "spawnin g cod"	Brown	Early spring and wintertime through the ice	Shallow water	Scattered few	2
Sacred Bay, NF	-	Red	Late in the fall	-	-	2
Hare Bay, NF	-	Not reported (but red cod were found in the area)	Winter (December)	8 ft	40 – 50 cod caught one day in December	1
White Bay, NF	"running" cod reported ("mother fish")	Not reported (but red cod were found in the area in shallow coastal waters). Believed to feed on shrimp	Winter (Nov./Dec.)	180-190 fa trench	Caught a fish every time put out their line one Nov./Dec.	2
Hawke's Bay, NF	Full of spawn but not running	Countershaded	Wintertime through the ice	15-20 fa	-	2
Parson's Pond, NF	-	Red		< 10 fa	Scattered few	1
Bonne Bay, NF	-	Countershaded ; Red; Black	Wintertime through the ice	-	Scattered few	1

Table 3.1 (continued)

Location	Spawn-ing?	Coloration	Season	Depth	Abundance	# of reports
Near Martin Bay, Lab.	-	Brown	Fall	Deep water just offshore	1-2 per 10-12 quintals of fish	1
White Is., NF	"Spawny" cod in area	Red	Early spring and late fall	4-5 fa	6–12 per haul of their cod traps in the past	1
Near Daniel's Harbour, NF	-	Brown; Black; Grey	Early spring and late fall	Deep water just offshore	-	1
Shag Island, NF	-	Red and Yellow	Believed were native to the area (stayed year round)	< 20 fa	Always some in fall but one year caught 1600 pounds	1

3.4.1. Cod overwintering in bays

Sandwich Bay, Labrador

Two fishermen from Cartwright provided evidence of resident cod in Sandwich Bay, Labrador (Table 3.1 and Figure 3.5). Fisherman 25 suggested that cod migrate into the bay during the spring and summer and after 1-2 months turn red. This harvester recognized a red colouration as "the mark of a fish been in [the bay] for quite a while." These cod are harvested just outside the bay as they begin to migrate out in the fall. It is believed, however, that the odd reddy cod, "one in a thousand," will get caught up with the rock cod and stay in the bay year round. Fishermen in the Sandwich Bay area were able to jig a scattered cod through the ice in the winter, though fisherman 25 noted that cod had not been in abundance in the Sandwich Bay area since 1968.

Fisherman 24 provided similar evidence for the existence of bay cod in Sandwich Bay. Though he had never himself caught cod there in the winter, he had seen red cod in the bay and his belief in a resident population arose from "elders" who spoke of cod overwintering in the area. One remark, based on his own experiences, implied that red cod may have overwintered in Sandwich Bay. He recalled that:

> *"On the tail end of the fishery you'd get some little red tom cods... When you see them it's just as well to take up your trap, you're not going to get any more fish... That's what they used to say around here... It wouldn't be a run, but when*

you sees them little tiny fish in your trap you might as well haul them up 'cause trapping was over." (Unpublished research transcript #24, 2000).

Sandwich Bay is a potential nursery area for juvenile Atlantic cod. Fisherman 25 was able to show researchers a small cod that he had stored in his freezer. Danny Ings, a specialist in this field, identified this fish as a 1-year old Atlantic cod. This juvenile cod was captured in a "little brook" within "a shoal water bay" on the north side of Sandwich Bay.

Occasional Harbour, Labrador

Dark coloured cod were reported in Occasional Harbour, Labrador, in early spring, before offshore cod were believed to have migrated to the land (Table 3.1 and Figure 3.5). Fisherman 21 reported that a resident of Port Hope Simpson had caught cod in early spring (May-June) in the small, salt-water pond at the head of Occasional Harbour. He believed that the cod "had to be there all winter 'cause that was early in spring before the fish come to the land [when] they started catching 'em there." The individual who had been out fishing described these cod as "darker" in colour (Nigel Earle, Port Hope Simpson, pers. comm.). Another fisherman from Port Hope Simpson spoke of a similar experience in the same pond. One spring while trouting in the area, they caught "lots" of cod in the pond, over 40 in one evening (Ruben Burden, Port Hope Simpson, Pers. comm.). He also believed that these cod remained there in the winter, based on season of capture, but questioned why they had what he described as an "outside" colouration.

Gilbert Bay, Labrador

Fish harvester 20 from Port Hope Simpson, Labrador, reported yellow-brown cod present in shallow water in Gilbert Bay. This harvester went ice fishing for trout one November, between 25 and 30 years ago, and discovered these "bay cod."

> *"When I went up, I went up to try for trout see. Cuz, the young fella seen trout, I went up to try for a trout and when I got one, it wasn't trout at all. It was a fish! So, I don't know how many I got, it must have been 15 or 20. [In] November. Anyway was just starting to freeze up. So, I went back and got more hooks then, but it was getting late then. But I must have had 40 or 50 altogether. The summers then following, I used to go up to the end of the bay, never went outside at all. [Went] up around the bay, up around here, Main Tickle, Rexton's Point and all those places. 300 quintals [each] summer, for them three summers. All fished in the bay. Yeah, there was more fish in the bay then there was on the outside."* (Unpublished research transcript #20, 2000).

This fisherman believed that these bay cod were outside fish that had moved into the bay in the spring where they remained throughout the fall in deeper waters, feeding on capelin and herring.

Fisherman 21, also from Port Hope Simpson, reported cod overwintering in Gilbert Bay. Referring to his brother who had fished in Gilbert Bay, he commented:

"He'd have 40 or 50 quintals of fish before either fish comes to land at all, just fishing from the bay all the winter, eh? ... Yeah, they would be in the bay all the winter, that didn't come, that stayed all the winter in the bay there, eh?" (Unpublished research transcript #21, 2000).

This harvester believed that these "bay cod" migrated towards the headlands near Williams Hr. (see Figure 4.3) during the summer and moved back into the bay in late summer/fall. Though this harvester had not seen bay cod in spawning condition, he believed these cod spawned within Gilbert Bay, in an area known as the Shinneys. He described cod resident in Gilbert Bay as "yellow and kinda red" in colouration and believed that the yellow colouration resulted from lying on the "kelp" in fresh water. He distinguished these cod from cod that migrated to the coast during the spring/summer, darkened ("but [did not] turn yellow"), and migrated back offshore in the fall.

In the fall of 1999, this harvester recalled that commercial fishermen gillnetted within Gilbert Bay. Each fisherman reportedly caught their entire 2600-pound quota within the bay.

St. Lewis Sound, Labrador

Brown "stray away fish" were reported in St. Lewis Sound, Labrador, early in spring at ice break up, before the arrival of the offshore migrating cod (Table 3.1 and Figure 3.5). Fisherman 15, from Mary's Harbour believed offshore cod migrated into the bay and changed colour in the fresh water. Fisherman 16, also from Mary's Harbour, reported catching "spawning" cod through the ice in a small cove within St. Lewis sound. He remarked:

> *"Spawning fish? In the bay? Oh, my God yes... at first when it freezes over eh, froze over with the ice? And drill a hole through the ice and we were trying for some smelts eh? We used to get some fish then that long, see. And the spawn would be into them and some with the looks frightened right out of them. Right White eh? They used to be there all winter, see."* (Unpublished research transcript # 16, 2000).

Later in the interview, however, he recounted only catching a scattered cod through the ice while trouting.

Sacred Bay, Newfoundland

Similar to Sandwich Bay, small red cod were harvested after the offshore cod had migrated off the land in the fall in Sacred Bay, Newfoundland (Table 3.1 and Figure 3.5). Fisherman 12* from Cooks Harbour said that it "seemed you'd always get a meal of [those] red ones when you couldn't get the other kind." This suggests that these cod were believed to stay around and possibly overwinter in the bay after the main group of cod had left the bay to overwinter offshore.

Fish harvester 7 from Quirpon reported black "shoal water cod" or "kelp fish" in Sacred Bay, near Little and Great Sacred Islands that seemed to stay in the area.

"You get the black cod. You go up where they calls up there off of L'Anse aux Meadows... There's shoal water there, four or five fathom of water... seem like that fish stays on that ground there... Kelp fish, some people calls them. The old people call them shoal water fish, right." (Unpublished research transcript # 7, 2000).

This harvester believed that the cod stayed on these grounds because when fish were plentiful there, he would often try fishing in an area just one mile south of this, but with no success. The area was described as having a significant amount of rock and kelp present.

Hare Bay, Newfoundland

Cod were jigged one year by fisherman 11* on 22 December in Hare Bay, Newfoundland, while out duck hunting (Table 3.1 and Figure 3.5). Between him and his friend, they jigged from 45-50 cod in very cold ("it was that cold that the line used to freeze in the boat"), shallow (~ 8 ft) water. This was the only time he fished during the winter like that, but his father used to jig cod in the winter for the dogs when he was younger. The colouration of these overwintering fish was not mentioned, however, this same fisherman also spoke of small red tomcods that were often mistaken for rock cod. The "young fellas," he said, would tell him they were Atlantic cod. Usually 50-60 of these red cod were caught in the traps each day. Most of these cod were small enough to pass through the mesh of their traps but had been observed swimming in the water nearby. These fish could be found when all the other fish had "moved off" and there was nothing else left.

White Bay, Newfoundland

Fish harvester 11 from Conche, Newfoundland (Figure 3.1), spoke of "White Bay cod" that overwintered in a deep water trench off Little Harbour Deep and declared "I can guarantee you there was a bay stock of fish in the White Bay" (Table 3.1 and Figure 3.5). This same fisherman reported the presence of "running" cod along the coast of White Bay in May.

Researcher: *So, the fish in the bay were mother fish?*

Interviewee: *Lots of mother fish out there. You'd get that big fish, you know the female, and you get the male with the milk running out of it, right?*

Researcher: *So, in this area here you were getting spawning cod?*

Interviewee: *I'd say it was, yeah. Yeah earlier on in the gill nets, yeah...I'd say it was the cod that use... I'd say there was a stock of cod, of mother cods, in the White Bay, right. I'd say that was the cod*

Researcher: *What depth do you think that spawning cod lived in?*

Interviewee: *I'd say there's a trench up here in the White Bay, right? Farther up off of William's Fort and those places. Right here look, Little Harbour Deep area, right up here at the top of this, right here.*

Researcher: *There's deep water here?*

Interviewee: *Yeah, it's deeper water. See the depths, la? Way deeper water, right? And you know, I'd say that's where that cod would go in the wintertime right? I know up here, what we used to call the White Bay cod, this deep water up there, and...*

Researcher: *You had a term for it? It's a White Bay cod?*

Interviewee: *When the gill nets come up, there was an awful mess of codfish caught up here... White Bay stock, right?* (Unpublished research transcript # 11, 2000).

Fish harvester 8 from St. Anthony believed that water currents held cod in White Bay.

"[Cod] usen't to be all the year long here, but it'd be pretty early in the spring when you'd get it. Yeah. But the water don't hold here now, not the same as up around in White Bay and Green Bay and Bonavista Bay. All them bays up there got a big indrift see, and the fish gets in there and stays in there all winter long up there."

The colouration of bay cod in White Bay was not reported, though harvester 11 reported red cod in the "shallow water" of the bay. Cod in White Bay were believed to feed on shrimp by fish harvesters 10 and 11 (see Chapter 4). Fisherman 10 recalled catching cod in the spring that were full of shrimp.

Researcher: *Did you see shrimp, when you were fishing?*

Interviewee: *Yes.*

Researcher: *Where would you see them?*

Interviewee: *In White Bay. In the spring of the year, when we went fishing into White Bay for cod, every cod that we ripped open was full of shrimp. And I've hauled up the net with the codfish in it, and the live shrimp on the net and we've picked 'em off. When they come out of the water they're right green, and you let 'em die and he turns red like a squid. So the same kind of shrimp as that, and big.*

Hawke's Bay, Newfoundland

Two fishermen described overwintering cod in Hawke's Bay, Newfoundland (Table 3.1 and Figure 3.5). Fisherman 2 from the community of Hawke's Bay had heard that people from the area fished for cod through the ice in the winter. In the second set of interviews, fisherman 4* verified this report. This fisherman described jigging large cod through the ice in the bay, any time during the winter, that were full of spawn. These overwintering cod were countershaded in appearance. Fisherman 4 believed that cod overwintering in Hawke's Bay were feeding on herring:

Researcher: *Now you said that you use to catch cod through the ice out here?*

Interviewee: *Oh God, you could jig away at them.*

Researcher: *What did those cod look like?*

Interviewee: *Oh nice cod.*

Researcher: *What size?*

Interviewee: *Big cod, medium size ones.*

Researcher: *And were any of them spawny?*

Interviewee: *Oh yeah.*

Researcher: *They would have spawn in them?*

Interviewee: *Oh yeah.*

Researcher: *Were any of them running, were the eggs running when you...?*

Interviewee: *No, no, never ever seen that. I never ever seen that in a fish.*

Researcher: *Never saw a runny roe?*

Interviewee: *No. Never ever seen it.*

Researcher: *So what months would you jig em through the ice here?*

Interviewee: *Any time throughout the winter.*

Researcher: *Anytime at all.*

Interviewee: *Yeah.*

Researcher: *So some cod were in the bay all winter?*

Interviewee: *I'd say it is because I believe the bay here fills up full of little herring.*

Researcher: *And you think they stay in feeding?*

Interviewee: *They stay in, yeah. They stays, 'tis good feed for 'em.*

Fisherman 4* also reported catching small cod, less than 6 inches in length, in eelgrass beds in Hawke's Bay.

Parson's Pond, Newfoundland

Fisherman 13* from Parsons Pond, Newfoundland (Table 3.1 and Figure 3.5), spoke of red coloured cod jigged in the pond "at one time." This fisherman thought "they [were] there all winter long" feeding on smelt, crab and *frost fish*[6]. Frost fish are described as small, reddish coloured fish, similar in appearance to Atlantic cod, but with a slightly rounder head. Red coloured cod are also caught outside the pond, but he does not believe that these are the same group of fish as in the pond. This fisherman also suggested that cod might overwinter just off shore from Parson's Pond. He recalled that the skippers of longliners, who had fished about 5-6 miles offshore, would occasionally go out in late December or January and jig cod.

Bonne Bay, Newfoundland

Three colourations of cod are believed to exist in Bonne Bay, Newfoundland (Table 3.1 and Figure 3.3). Fisherman 13 reported countershaded, red, and black cod that were generally mixed together in their catches, but believed that the red cod were the "real natives" of the area. This harvester was able to catch mixed colourations of cod through the ice in the winter:

> *"I jigged the scatter one [through the ice]. It was like the rest of it, there was different colours, you know?"* (Unpublished research transcript # 13, 2000).

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[6] Frost fish is a common reference for the true tom cod (*Microgadus tomcod*), which are known to run into areas of fresher water (Richard Haedrich, Memorial University, pers. comm.)

3.4.2. Cod overwintering along the coast

Near Martin Bay, Labrador

Small, "light brown" cod were reported by fisherman 22 off Martin Bay, Labrador (Table 3.1 and Figure 3.5). Observed during the fall, the local name for these brown cod was "foxy tom cods." Though there was only a scattered brown cod that actually came in to Martin Bay during the spring/summer, harvesters believed that these brown cod overwintered with countershaded cod in a deep hole about 4 miles off from the land.

Near Daniel's Harbour, Newfoundland

Fish harvester 1 believed an overwintering group of cod existed off Daniel's Harbour, Newfoundland, in depths of about 200 fathoms (Table 3.1 and Figure 3.5). Fishermen in the area would catch cod in the early spring, before the main run of cod had migrated to the coast, and late in the fall of the year, after the main group of cod had moved south. These cod were believed to feed on fish and crabs, at least up until November when harvesters ceased fishing for the year. Some of these overwintering cod were described as brown in colouration, however this harvester believed that the different colourations of cod observed in the area (grey, black, and brown) were "all the same [cod]."

White Island, Newfoundland

Fisherman 7 reported harvesting cod in the winter near White Island, a small island approximately 5 miles offshore Quirpon, Newfoundland (Table 3.1 and Figure

3.5). White Island was described as "a really good place fishing [for] cod" up until November or December, if the weather was good. Fishermen from the area, however, had been able to catch cod in their seine nets in the shallow water (< 40 fa) near the island in the winter (January). Mother fish, fish with "the big spawn in it," were found in the same area between July and August. When asked the last time he has seen spawny cod, he replied: "My dear, a good many years ago. I say about thirty years ago now." The spawny cod were described as grey in colouration. Red, grey, black, and countershaded cod were also found throughout the same area "all mixed through." The red cod were described as few in numbers. This harvester would "only [catch] a scattered one" while fishing.

Shag Island, Newfoundland

Fisherman 14 from Lark Harbour described overwintering just outside of the Bay of Islands, near Shag Island, Newfoundland (Figure 3.5). This fisherman reported the presence of cod that were "always thought [to be] native to that area." One year in particular many red coloured cod were caught near Shag Island:

Researcher: *Ever see cod that colour or a reddy kind of colour?*

Interviewee: *Yes.*

Researcher: *Do you have a term for it?*

Interviewee: *Not really. Up around our fishing ground, there's some places up there, we always put it down to the different type of feed that they was using... And there's places up there on the fishing ground, Shag Island*

and on the shoals.... You get nice white-bellied fish... Well, that's [what is] migrating [or] whatever, but we always see some a different colour like this and you figure that was the real natives of the ground.

Researcher: *You assumed it stayed there?*

Interviewee: *That's what we figured that they stayed there... And the old moss and old stuff like that they'd be eating, we figured that...*

Researcher: *Would they be more reddish than this one or is that what he looked like?*

Interviewee: *You see them sometimes there, well, that's a yellow cast on that one there...But you see them red and you see them yellow or something like that...Yes, certain pieces of ground up here...Because one fall there was no fish here, [in the] bay. And me and my uncle left here one day, we were up on the shoal, we got what, sixteen hundred pound. That's all we got was the red [cod].*

Researcher: *About what time of year?*

Interviewee: *I guess that was probably about September month...*

Researcher: *Would you get them at other times too? Would you just get a few mixed in? Is that how it would be?*

Interviewee: *There's spots on the ground up here...In the summertime you would get quite a lot of them.* (Unpublished research transcript #14, 2000).

Yellow cod were also harvested near Shag Island. This fisherman believed that both red and yellow cod were most abundant during late summer and that "there's a certain time around August or September you could get five hundred pounds, you could get a thousand pounds." The red and yellow cod were believed to be feeding on "red weed/moss" and/or crab in the area.

Ripe cod with their "bellies popping, bursting" were described near Shag Island. However, none of the red cod were observed in spawning condition.

3.5. Discussion

Based on observations of when and where fish were harvested and what they were feeding on, harvesters often used the process of inductive-deductive reasoning to explain the occurrence of cod of varying shades of red, brown, yellow, and black. Fishermen who observed brown/golden-brown cod within bays with substantial freshwater inputs attributed the colouration with being in fresh (brownish coloured) or shallow water environments. Red/reddish-brown cod were generally observed in shallow water areas both inside and outside of bays where "kelp," "red moss" and/or crab were present. Both red and brown cod were sometimes identified as the real natives of the area. Black-backed cod were generally associated with cod that migrated from offshore to the coast in the spring and turned dark before returning offshore in the fall. Two harvesters indicated that black/dark cod might have overwintered inshore.

Fish harvesters' association of brown to reddish-golden-brown coloured cod with inshore areas and a diet rich in carotenoids is consistent with current understandings of cod colouration and cod stock structure, as discussed in Chapter 2 and summarized in

Table 2.1. Cod scientifically documented in shallow inshore areas in Newfoundland, such as in parts of Trinity and Placentia Bays, are brown in colouration. (Note, however, that cod in deeper waters in Trinity Bay are countershaded) (see Table 2.1). Cod in Gilbert Bay, Labrador feed heavily on crustaceans and have a distinct brown to reddish-golden brown colouration (Table 2.1).

Some harvesters associated cod with algal beds ("kelp" and "red moss") where crab were present. The relationship between such habitat and resident populations of cod, which has not been discussed in the scientific literature, needs to be addressed in future scientific and local knowledge research of this sort.

3.5.1. Fish harvesters' knowledge and scientific understanding of bay stocks

Scientific reports of cod resident in the inshore waters of Newfoundland and Labrador are relatively few in numbers. Resident, spawning populations of cod have been scientifically documented in only three bays: Gilbert Bay, Labrador and Trinity and Placentia Bays, Newfoundland (Smedbol et al. 1998; Green and Wroblewski 2000; Lawson and Rose 2000). In Holyrood Pond, Newfoundland, a unique situation occurs where cod overwinter as a direct result of the landlocked conditions of the pond throughout most of the year (O'Connell et al. 1984). Some of these cod may leave when the pond is opened up in the spring/summer for flood control, and new individuals may enter (O'Connell et al. 1984).

It has long been suspected that adult cod are year-round residents in most major bays throughout Newfoundland (Thompson 1943; Wroblewski et al. 1994; Lilly 1996; as cited in Wroblewski 2000). Many habitat characteristics may influence whether cod reside year-round in an area including, but not limited to, water depth, temperature, food availability, freshwater inflow (estuarine circulation), and the degree of isolation from the Atlantic. The habitats that exist in Holyrood Pond and Trinity, Placentia and Gilbert Bays are likely not unique. Similar habitats may exist in other parts of coastal Newfoundland and Labrador – and one may expect the presence of cod overwintering in areas with similar bathymetry and biota to areas that have been scientifically documented, such as Trinity Bay (Richard and Haedrich 1991 as cited in Wroblewski et al. 1996). However, these other areas have not been scientifically investigated.

Fish harvesters interviewed for this research identified 13 locations throughout Newfoundland and Labrador where cod of different colourations and behaviours were believed to remain year-round (i.e. were resident) (Table 3.1). Within these areas, and between these areas and locations scientifically documented to support resident populations of cod, some structural similarities exist that may be significant. For instance, similar to Gilbert Bay, Sandwich Bay was reported as a possible location of overwintering cod (Table 3.1 and Figure 3.5). These bays are characterized by a significant amount of freshwater inflow, they have relatively shallow (<135 m) waters, and they have an archipelago configuration at their mouths. Estuarine circulation in these bays may contribute to local retention of eggs/larvae (Morris and Green 2002). Combined with reports of juvenile cod in Sandwich Bay, it is plausible that cod might remain throughout the winter, and possibly spawn, in Sandwich Bay. Similarly, White, Trinity, and Placentia Bays are wide, deep water bays completely open to the adjacent Atlantic (Figures 2.1 and 3.5). The deeper waters present in some parts of these bays may provide the ideal temperatures (above 0°C) (Templeman and Flemming 1963) for overwintering cod. (Note, however, that cod in Gilbert Bay and Trinity Bay reside in relatively shallow, subzero waters throughout the winter) (Wroblewski et al. 1996; Wroblewski 2000.) Arguably, the northern Gulf region has similar characteristics (i.e. deep water channels and unimpeded access to the Atlantic). This area also has a scientifically documented spawning population of Atlantic cod (Ouellet et al. 1997). Fish harvesters' observations suggest there may have been others in the northern Gulf.

As a third example, Parson's Pond, Occasional Harbour (salt-water pond), and Holyrood Pond are all relatively small, shallow water areas separated from the ocean by the presence of a sill. Cod in Holyrood pond, completely isolated for most of the year (only being open to the Atlantic for periods typically ranging from days to one or two weeks), feed on the available inshore invertebrates and other fish species that become trapped within the pond. Given the isolated nature of these areas, reports from fish harvesters of cod in these areas in the winter, and that similar food sources would be expected to exist in either Occasional Harbour or Parson's Pond, it is conceivable that cod could overwinter in either location.

Of course, similar physical and biological conditions present in an area do not necessarily mean that the area will be occupied by cod. There are many factors that interplay to influence cod distributions and spawning and migration patterns. However, I propose that the bays identified by fish harvesters through this research, where cod are believed to reside year round, represent ideal starting points for future investigations by scientists attempting to identify locations where bay stocks of cod exist/existed in the past.

3.6. Emergent issues

Through the process of conducting interviews with fish harvesters, it became apparent that a diversity of colourations exists in the inshore/coastal environment. By using photographs of a golden-brown cod from Gilbert Bay, a reddish-brown cod from Norway (Figure 3.2), and a black-and-white drawing of a countershaded cod to stimulate discussions with fish harvesters, the ability to grasp this diversity was limited. During some interviews, interviewees merely responded to the picture of Gilbert Bay cod and said "cod like that" were in their area. By default, this was considered to mean a yellow-brown colouration, as the photos clearly show such colouration. However if not for the picture, would harvesters have described the colouration in some other way?

Several important questions were identified while summarizing and analyzing interview transcripts. These include: Are "black-backed" cod the same as countershaded cod? Is a "dark" cod the same as a "brown" cod? How do "yellow" and "brownish-yellow" cod differ? Is what one fish harvester describes as "brown" (or red, yellow, etc.) the same or different from what another describes as "brown"? Is what one harvester refers to as "kelp fish" (or shoal water fish, frost fish, etc.) the same as what another refers to as "kelp fish?" To complicate matters, harvesters sometimes used different names to refer to the same fish (e.g. "kelp fish" and "shoal water cod" to describe resident red coloured cod) or used different colourations of cod interchangeably (e.g. "brown" and "red" to describe to the same group of cod). To further complicate matters, researchers often asked specific questions about "brown" or "red" coloured cod, to which most harvesters replied, even if they had previously described a different colouration. This often made it difficult to interpret results (i.e. do they mean brown? Would they have used this term on their own?). Similar problems were encountered with questions about "spawning cod." Researchers would often ask if/when/where harvesters had observed spawning cod and harvesters often used this term themselves to describe cod behaviour. Whether the "spawning" cod discussed during interviews were ripe (i.e. full of "milk"/eggs) or running (i.e. releasing "milk"/eggs) was often not clarified.

Also emerging from this research was the question: What do the terms "bay cod," "bay stock" and "bay fish" mean to fish harvesters? Scientists generally use these terms to refer to cod that overwinter and spawn in the bays. In Gilbert Bay, Labrador, fishermen used the term "bay cod" to refer to cod that were resident year-round in the shallow waters of the bay. The term "bay cod" had similar meaning to fish harvester 11 from Conche, Newfoundland, who spoke of the "White Bay cod" and "White Bay stock" that he believed overwintered in a deep water trench in the bay and spawned in shallower waters within the bay. In Englee, Newfoundland, however, harvesters used the term "bay fish" to refer to cod that migrate into the bay to feed in the summertime and turn dark by the time they leave again in the fall. Throughout most other interviews, fish harvesters used neither of these terms. Thus, for many harvesters, the terms "bay cod," "bay stock," and "bay fish" may have had no meaning at all.

These issues that have emerged throughout the various stages of this research – problems in research methodologies, the need to understand similarities and differences between harvesters' use of different terms, and the need to address differences that exist between harvesters and scientists definitions of terms – need to be dealt with in future interviews with fish harvesters that attempt to gather their knowledge of local populations of cod.

3.7. Summary

Fish harvesters described several colourations of cod that were generally associated with a particular food, location, water depth, and/or behaviour. Three main colourations of cod associated with inshore/coastal areas were identified: red, brown, and yellow/golden. Fish harvesters generally attributed these colourations to the environment (water depth, presence of fresh water, and/or presence of red algae) and/or diet (feeding on crustaceans and/or red algae). Cod of these colourations were generally contrasted with countershaded cod. Countershaded cod were associated with offshore, deep water environments, and an annual migration pattern of inshore feeding–offshore overwintering/spawning.

Based on harvesters' observations of overwintering and spawning grounds, unique morphological features, and descriptions of migrations and behaviour in the inshore environment, several areas were identified where brown to reddish-golden-brown cod were believed to remain year-round. These areas represent ideal locations where future scientific studies of cod stock structure should be directed.

4. Change in colouration of Atlantic cod: A scientific field experiment

4.1. Introduction

Interviews with fish harvesters revealed a general association between a reddish- to golden-brown colouration and inshore shallow water cod, and between a countershaded appearance and offshore cod. Thirteen areas were indicated to have supported resident cod. Only 3 inshore areas that support resident populations of cod have been scientifically documented. However, many areas have not yet been studied and it is likely that local stocks of cod exist/existed in most bays in Newfoundland (Thompson 1943; Wroblewski et al. 1994; Lilly 1996; as cited in Wroblewski 2000).

This study seeks to combine information obtained during interviews with fish harvesters with scientific research on fish colouration to investigate colouration as an indicator of cod stock structure. Towards this end, a colouration change experiment was set up in Gilbert Bay, Labrador (Figure 4.1), in August 2001. This experiment considered the following questions:

1. Do cod have the ability to change colouration when their environment (diet and physical location) is changed?
2. How quickly can a colouration change occur?

3. Based on a devised colouration scale, to what extent does colouration change?

For the colouration change experiment fish were captured and held live in net pens in Captain Jack's Cove, Gilbert Bay, Labrador (Figures 4.1 and 4.2), and fed a piscivorous diet of capelin and herring. Colouration was assessed according to the colouration scale at the time of capture and after a period of 78 days. The fish were scored from 1 to 5, where 1 is a countershaded cod, 3 is a brown cod and 5 a cod with red pigmentation.

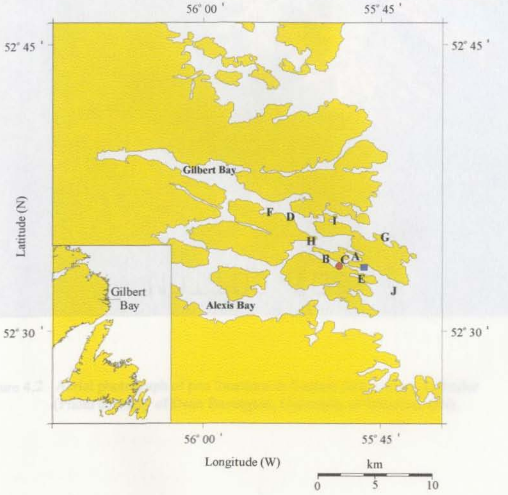

Figure 4.1. Map of Gilbert Bay, Labrador, showing the locations of Williams Harbour (■), the coloration change experiment in Captain Jack's Cove (•), and locations of angling for Atlantic cod in August 2001. (A – Airport, B - Williams Harbour Run, C - Captain Jack's Tickle, D - Kelly's Point., E - Merchants Harbour., F - near Peckham's Cove, G - Pipers Tickle, H – Rexton's Cove Point., I – "Bill's Place", J - Copper Island).

Figure 4.2 Aerial photograph of pen locations in Captain Jack's Cove, Labrador (Photo courtesy of Dean Bavington, University of Waterloo, ON).

4.2. Study area

Gilbert Bay (52°34.93' N, 56°01.25' W) is a shallow water bay on the coast of southern Labrador, near Williams Harbour and Port Hope Simpson (Figure 4.1). The archipelago configuration of Gilbert Bay leaves a narrow passageway, approximately 500 m wide, to the adjacent north Atlantic. Depths range from approximately 80 m near the mouth of Gilbert Bay to approximately 20 m at the inner reaches. Gilbert Bay connects to Alexis Bay via a channel (Main Tickle) between Denbigh Island and the mainland. By December most of the bay is frozen over. Temperatures are subzero throughout the winter (December/January – May/June). Ice out usually occurs early to mid-May. Local residents frequent Gilbert Bay in the winter by snowmobile and summer by boat as a major route between communities, as well as for recreational and commercial fishing. Marine species found in the area include Atlantic cod, scallops, capelin, sandlance, spider and hermit crab, and shrimp (Morris and Green 2002). Sampling of Atlantic cod for this study was concentrated in the outer reaches of Gilbert Bay (Figure 4.1). The colouration change experiment took place in Captain Jack's Cove (Figure 4.2), a small sheltered cove located near the mouth of the bay.

4.3. Hypothesis

The hypothesis for this research was that brown colouration is a morphometric characteristic of inshore cod in Newfoundland and Labrador. The null hypothesis was that brown colouration in Atlantic cod cannot be attributed to inshore residency. If brown colouration is a characteristic of Gilbert Bay cod, then their colouration should not change when held in a net pen and fed a piscivorous diet. If brown colouration is not a reliable indicator of bay residency, then brown Gilbert Bay cod may change colouration (Figure 4.3).

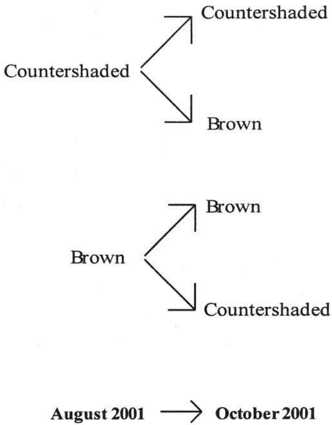

Figure 4.3 Possible outcomes of the colouration change experiment: Colouration of Atlantic cod (*Gadus morhua*) will change when held in net pens and fed a piscivorous diet, or alternatively, no change in coloration will occur.

4.4. Research methodology

4.4.1. General procedures

Samples of Atlantic cod were collected from 30 July – 12 August 2001 from ten locations near the mouth of Gilbert Bay (Figure 4.1). The goal was to capture what harvesters refer to as offshore (countershaded) coloured and inshore (brown to reddish- or golden-brown) coloured cod. Angling was conducted at a time when both inshore and offshore cod were believed to be present. Fish were angled using a fishing rod with a 3-inch lure (unbaited). Local residents of Williams Harbour and Port Hope Simpson, who had been hired to work with us, chose sampling locations considered "good fishing grounds" for offshore migratory cod (e.g. Pipers Tickle and Merchants Harbour) (Figure 4.1) and Gilbert Bay cod (e.g. Peckham's cove and the Airport) (Figure 4.1).

Fish caught were transported live to Captain Jack's Cove in 0.6m x 0.9m x 0.3m plastic tote boxes ("fish boxes"). On one occasion a larger 0.6m x 0.9m x 1.5m tote box was used. A maximum of 3-5 fish were placed in the smaller box and 10-12 in the larger. Water was changed approximately every 5-7 minutes to ensure an adequate supply of oxygen.

Each fish was tagged for later identification, measured and weighed, given a score based on colouration (ranking from 1-5, where 1 is a countershaded offshore cod, 3 is a brown cod and 5 is a cod with red pigmentation), and photographed at the time of capture.

Fish <= 35 cm were placed in a black twined 3cm mesh pen ("small mesh pen") and those >35cm were placed in a black twined 5cm mesh pen ("large mesh pen"). Separation of size classes was to prevent cannibalism of younger fish and as part of a second experiment led by Geert Van Biesen (MSc. candidate, Memorial University). Fish in the small mesh pen were fed herring, capelin, and commercial feed[1] and fish in the large mesh pen were given a piscivorous diet of herring and capelin only.

A second examination of each fish took place 78 days later from 23-29 October 2001. Lengths, weights, and photographs were taken of all fish. Each fish was again given a number based on colouration. Additionally, blood samples were taken from each individual. Fish from the large mesh pen were sacrificed to obtain otoliths for length at age analysis. Stomach contents of approximately five fish were opened and investigated.

In total, 238 fish were caught, however only 149 were present at the end of the experiment. Most of the largest fish were missing upon final examination in October 2001. It is speculated that these fish may have been poached. We have some evidence for this: fish lures were found caught in the bottom of the net pen. Temperature data also suggest that the nets may have been hauled up the week prior to our return. In addition to this loss, 28 fish had lost their identification tags between sampling periods. As a result, a complete set of before and after data exists for only 121 fish (Appendix 3). Only these fish were used in the analysis.

[1] Haddock Grower 46-14 (6.5 mm), pellet form; fish <=35cm TL were fed commercial feed as part of Mr. Van Biesen's research.

4.4.2. Length and weight

Fish lengths and weights were recorded in August and October (n=121). Fish were placed on a wooden measuring board and total length (TL) recorded to the nearest 0.1 cm (Figure 4.4). Weights were measured to the nearest 0.1 kg in August and again in October 2001 using a hand held weigh scale (Figure 4.4).

4.4.3. Photographically documenting colouration

Fish were placed on either white Styrofoam (August 2001) or white melamine board (October 2001) and photographed (Figure 4.5). Fish were digitally photographed in August and October. Pictures were stored in a ".jpg" format under the highest resolution and quality possible. Thirteen fish were photographed on 35mm slide film in August and all fish in October. A flash was used at all times to keep the total amount of light consistent between photographs.

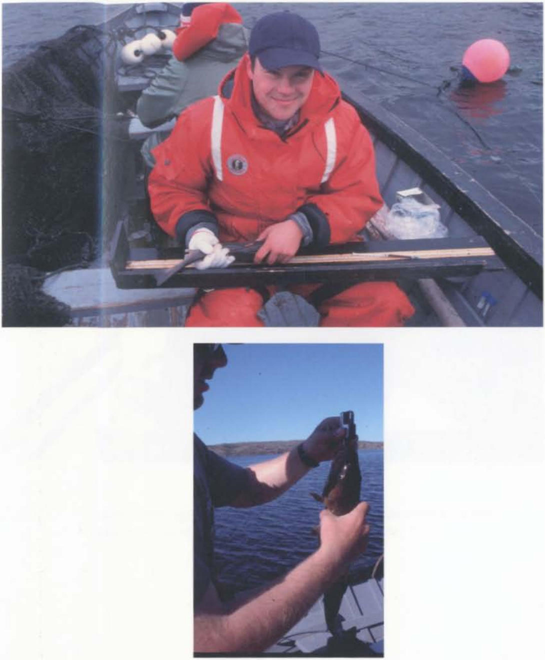

Figure 4.4 Research assistants Dean Bavington measuring lengths (above) and David Sampson taking weights (below) of Atlantic cod (*Gadus morhua*) in August and October 2001.

Figure 4.5 The author photographically documenting colouration of Atlantic cod (*Gadus morhua*) in Gilbert Bay in August and October 2001.

4.4.4. Diet

Fish were fed 2-3 times weekly from 16 August to 11 October 2001 (Table 4.1). Fish from the small mesh pen were fed commercial feed, capelin, and herring. Fish from the large mesh pen were fed capelin and herring only. Food items were placed in a bucket and weighed before and after feeding to determine the total amount fed to fish in each pen. During the last two weeks of the study, fish were not fed.

Two times throughout the study period the fish pens were "switched." This is a term used by fish harvesters in the area to refer to cleaning the nets (by beating nets with a switch) and removing any uneaten food items from the bottom of the pen.

Table 4.1 Food type and amounts fed to caged Atlantic cod (*Gadus morhua*) from 16 August to 13 October 2001.

Date	Time	Small mesh pen (n=54)		Large mesh pen (n=67)	
		Food Type	Total fed (kg)	Food Type	Total fed (kg)
16-Aug-01	9:55	Capelin	7.27	Capelin	6.36
20-Aug-01	17:00	Capelin	5.00	Capelin	8.18
25-Aug-01	15:00	Capelin	1.82	Capelin	9.09
27-Aug-01	13:30	Commercial	0.45	Capelin	6.82
		Capelin	0.68		
29-Aug-01	15:40	Capelin	0.45	Capelin	10.91
31-Aug-01		Capelin	0.91	Capelin	9.09
3-Sep-01		Commercial	0.45	Capelin	11.36
		Capelin	0.45		
7-Sep-01		Commercial	0.45	Herring	9.77
		Herring	1.82		
10-Sep-01	15:00	Commercial	0.45	Herring	10.45
		Herring	1.82		
13-Sep-01	13:03	Herring	2.95	Herring	10.23
17-Sep-01	12:25	Herring	1.82	Herring	12.27
21-Sep-01	13:00	Commercial	0.45	Herring	4.55
		Herring	5.45		
24-Sep-01		Herring	2.05	Herring	8.86
28-Sep-01	10:30	Herring	2.73	Herring	6.82
2-Oct-01	14:00	Commercial	1.14	Herring	10.00
		Herring	3.64		
5-Oct-01		Herring	1.82	Herring	12.73
		Commercial	1.82		
8-Oct-01		Herring	3.64	Herring	10.91
11-Oct-01		Commercial	3.41	Herring	5.91

4.4.5. Otoliths

All fish in the large mesh pen (n=67) were sacrificed in October 2001 to obtain sagittal otoliths for age analysis. Otoliths were wiped clean and stored dry in paper envelopes. Norm Batten, a former employee of DFO, St. John's, who had worked in this field for many years, aged otoliths. Otoliths were cut across the sulcus with a scalpel and partially embedded into plasticine, with the fractured surface upwards. Otoliths were examined using transmitted light under low power of a binocular microscope. Rings formed during periods of slow winter and spring growth appear as translucent hyaline zones, while growth increments formed during periods of rapid summer and autumn growth appear as gray opaque zones. One opaque zone and one hyaline zone together constitute 1 year. Otoliths 3 years and older were examined to approximate first spawning zone (age first spawned).

4.4.6. Length-at-age analysis

Cod from Gilbert Bay are slower growing than cod from Trinity Bay and from NAFO division 2J, and have significantly different length-at-age relationships (Ruzzante et al. 2000). To determine whether brown and countershaded cod used in this research were inshore (Gilbert Bay) and offshore (NAFO division 2J) cod respectively, length-at-age analyses were performed on all aged specimens (n=67). Fish were grouped according to colouration (brown or countershaded) based on the devised colouration scale and length-at-age relationships calculated. Length-at-age relationships were then compared with cod collected from Gilbert Bay in 1996/97 (from Smedbol 1999) and cod collected in NAFO division 2J by the Department of Fisheries and Oceans during their annual research vessel surveys (from Shelton et al. 1996). Length and ages of all fish used in the analysis are presented in Appendix 2.

Growth in length-at-age is a non-linear function (Smedbol 1999). As such, it was necessary to perform linear regressions on log-transformed data (Smedbol 1999). An Analysis of Covariance compared the slopes of the regression lines using the MINITAB© 2000 software package. Significant differences between slopes indicated a difference in growth rate between groups. Where no significant differences were observed, data were pooled and compared with remaining groups.

4.4.7. Environmental conditions

4.4.7.1. Temperature

A Vemco Ltd. Mini Log-T data logger recorded temperature profiles near the pens in Captain Jack's Cove. Samples were taken once a week from 25 July – 28 September 2001. A second temperature logger was attached to the bottom of the small mesh pen in Captain Jack's Cove between 25 August and 21 October. Temperature was recorded continuously every 4 s until removal. Readings were taken at a depth of approximately 4.5 m.

4.4.7.2. Turbidity

Turbidity is a measure of the clarity of water (Wilber 1983). The greater amount of total suspended solids in the water, the murkier it appears and the higher turbidity. Turbidity levels affect the intensity of light in the water column. A Secchi Disk was used to record the turbidity at the pen location on 3, 10, 17, and 28 August. The mean depth between when the Secchi Disk was no longer visible while lowered and just visible when raised in the water column was recorded.

4.4.7.3. Pen biofouling (Slub samples)

"Slub[3]" is a term used by many fish harvesters to refer to the biofouling that occurs on nets during certain seasons when placed in the water. To determine composition of the accumulated slub, samples were taken from the pens on a weekly-biweekly basis at depths of approximately 1m to 4 m. Samples were stored in 95% ethanol. Dr. A. Whittick, Department of Biology, Memorial University, identified their composition. Organisms were identified to the species level.

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[3] Slub is defined in the Dictionary of Newfoundland English (1990) as a deposit of brownish-green mucous on nets. Harvesters use the term "slub" rather loosely to describe many kinds of biofouling.

4.5. Results

4.5.1. Colouration

Colour scores assigned to individual fish were planned according to a ranking scheme from 1-5, where 1 is a countershaded offshore cod, 3 is a brown cod and 5 is a cod with red pigmentation. A colour score of 2 describes a cod that is dark on back, with some brown pigmentation, and white underneath. A colour score of 4 describes a reddish- to golden-brown colouration. Many gradations of colourations were observed in fish sampled in August and October (n=121) and it became necessary to modify the colouration ranking scheme. Under the new ranking system, fish were scored from 1-5, but could be given a colour score between values when individual observers were in disagreement. Thus, a fish considered red (a colour score of 5) by one researcher and reddish-brown (a colour score of 4) by another, was given a colour score of 4.5. For the purpose of simplification, "brown" will hereafter be used to refer to red, reddish-brown, yellow-brown ("golden") and brown cod (colour scores 3 through 5), unless otherwise stated.

In total, 45 countershaded and 76 brown cod, believed to be offshore and bay cod respectively, were caught and placed in the small mesh (n=54) and large mesh (n=67) pens. In the small mesh pen, 11 fish were countershaded and 43 brown in colouration. In the large mesh pen, 34 fish were countershaded and 33 brown in colouration (Table 4.2).

Table 4.2. Total numbers of brown and countershaded Atlantic cod (*Gadus morhua*) held in net pens in August and October 2000 in Gilbert Bay, Labrador.

	August 2000		October 2000	
	Brown cod	*Countershaded cod*	*Brown cod*	*Countershaded cod*
Small mesh pen	43	11	1	53
Large mesh pen	33	34	19	48

4.5.2. Angled catch

Fish were caught from 10 locations near the mouth of Gilbert Bay (Figure 4.1 and Appendix 3). Most fish were caught in shallow water (<30m) on the headlands in Pipers Tickle (n=45) and Merchants Harbor (n=46). The majority of countershaded cod were caught in Pipers Tickle (n=26) and the majority of brown cod in Merchants Harbor (n=28). All but four of the brown cod caught in Merchant's Harbor were < 35 cm TL.

4.5.3. Length and weight

Lengths of brown cod in August 2001 ranged from 17.2 cm, the smallest fish captured, to 60.8cm, the largest fish caught (mean TL=34.8 cm) (Appendix 3). Countershaded cod ranged in length from 21.6 cm to 58 cm (mean TL=40.8 cm) (Appendix 3). The majority of brown cod (n=43) were < 35 cm, whereas the majority of countershaded cod (n=34) were > 35 cm. The largest fish in the small mesh pen was 34.9 cm. The smallest fish in the large mesh pen was 36.3 cm. The largest fish (mean TL=47.8 cm) were caught near Peckham's Cove and the smallest (mean TL=31.1 cm) in Merchant's Harbor.

Lengths of fish in October ranged from 21.4 cm to 55.4 cm (Appendix 3). The mean total length of countershaded cod increased from 40.8 cm in August to 45.7 cm in October. Similarly, the mean length of the brown cod increased from 34.6 cm TL to 40.3 cm TL.

Weights of cod sampled in August 2001 ranged from less than 0.10 kg to 2.20 kg (Appendix 3). Weights were greater in the large mesh pen (mean=0.90 kg) than in the small mesh pen (mean=0.22 kg). Weights remained the same for 11 fish throughout the experiment and two lost between 0.10 kg and 0.25 kg. The mean weight of fish in the small mesh pen increased from 0.22 kg to 0.37 kg and in the large mesh pen from 0.90 kg to 1.29 kg between sampling periods. Mean weights of countershaded cod increased from 0.69 kg in August to 0.99 kg in October. Mean weights of brown cod increased from 0.52 kg in August to 0.80 kg in October.

4.5.4. Photographs

Digital pictures of all fish (n=121) were taken in August and October. Thirty fish were photographed on 35mm slide film in August and all fish (n=121) in October. Four wild cod were photographed on slide film in June 2002.

Many pictures taken with the digital camera were bright and barely discernible. All pictures taken with the slide film were satisfactory. However, only a complete set of initial and final photographs exist for 13 fish due to the fact that many fish that had originally been photographed using slide film in August 2001 were missing upon re-examination of fish in October (as previously discussed). These photographs were used in combination with initial and final colour scores collected for all fish (n=121) to analyze colouration change.

4.5.5. Diet

Fish from the small mesh pen were fed only commercial feed on one day (Table 4.1). For the remaining days, these fish were fed capelin (5 days), herring (5 days), or a combination of capelin or herring plus commercial feed (7 days). Fish from the large mesh pen were fed capelin (7 days) or herring (11 days) (Table 4.1). Fish from the large mesh pen were fed greater amounts than fish from the small mesh pen on all days.

All fish (n=121) were gutted in October 2001. Stomachs were empty and flaccid. This was expected, as fish had not been fed for approximately 2 weeks prior to this. Stomachs of wild fish caught in early November, however, were full (Joe Wroblewski, Memorial University, pers. comm.). Individual stomachs examined at this time usually contained a single prey item. One stomach contained mysids only, another was full of limpets, a third small scallops or clams, and a fourth had small fish. Morris and Green (2002) similarly found a small number of different prey items in stomachs of Gilbert Bay cod, with fish comprising only a small portion of their diet.

4.5.6. Analysis of colouration change experiment

Visual analysis in October revealed a change in colouration had occurred, in particular among the brown coloured cod. A 2x2 chi-square analysis was performed to test the significance of this difference. The total proportion of fish given a colour score of

1 through 2.5 (countershaded cod) increased significantly ($p < 0.0001$, $\alpha = 0.05$) while the total proportion of fish scored from 3 to 5 (red-brown cod) decreased significantly ($p < 0.0001$, $\alpha = 0.05$) (Figure 4.6). Of the 45 countershaded fish in August, 6% were given a score of 1.5, 19% 2 and 12% 2.5 (Figure 4.6). In October, the total number of countershaded cod had increased to 101 (8% 1, 20% 1.5, 44% 2, 12% 2.5) (Table 4.3 and Figure 4.6). The total number of brown cod decreased from 76 in August (29% 3, 8% 3.5, 17% 4, 1% 4.5 and 8% 5) to only 20 (12% 3, 3% 3.5 and 1% 4) in October (Table 4.3 and Figure 4.6).

The majority of countershaded cod had become slightly darker on back and whiter on their bellies by October. The mean colour score decreased from 2.1 in August to 1.8 in October (Appendix 3). An example of this observed colouration change is shown in figure 4.7a. Four countershaded cod were given a higher colour score in October (Table 4.3). Of these, three increased from 2 to 2.5. One fish became browner in colouration, increasing in colour score from 2.5 to 3. Such small changes in colouration score are likely due to sampling error.

The degree of colouration change observed for brown cod was much larger. The mean colour score decreased from 3.6 in August to 2.3 in October. Thus the majority of brown cod (n=57) became countershaded (Table 4.3). Of these fish, most were given a colour score of 2 (43%) or 2.5 (17%) in October. Five fish that were originally red in colouration completely lost this colouration (Table 4.3 and Figure 4.7b). Many others that were brown or yellow-brown all over experienced a similar colour loss (Figures 4.9 c-e).

Twenty fish retained a brown colouration throughout the experiment (Table 4.3). Seventeen of these were given lower scores in October, one was given the same score, and two were given a higher score (one increasing to a 4 from a colour score of 3 and the other from 2.5 to 3). Five of the 20 fish that retained a brown colouration were originally red in colouration. All 20 fish gained weight during the experiment, indicating that they had been feeding. No fish were given a colour score of 4.5 or 5 in October (Table 4.3).

Fifteen fish maintained the same colour score between sampling dates. All of these fish had gained weight. Four other fish increased in colour score and similarly all gained weight. The increases in colour score, however, were relatively small (from 0.5 to 1.0) and may have been due to the subjective nature of the scoring. Only two fish lost weight throughout the experiment. Both fish were originally scored a 2 and decreased to either a 2 or 2.5 in October.

The general loss of brown/red/yellow pigmentation was observed in both pens. Forty-two of the 43 brown fish in the small mesh pen (98%) became countershaded. The one brown fish remaining in October decreased in colour score from 3.5 to 3. In the large mesh pen, 15 of the 33 brown cod (45%) became countershaded.

Cod are described as having numerous rounded brownish spots overlaying a grey-green to brown-red colouration on their backs (Scott and Scott 1988). The overall change from a brown to countershaded colouration consisted of both a change in the colouration of these spots and the colouration underlying them. In August, the majority of fish had dark brown or black spots on a light (grayish) background. In October, these spots were darker on a lighter, almost silvery background (Figures 4.7 b, d, and e).

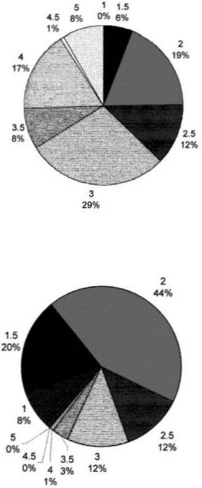

Figure 4.6 Proportions of Atlantic cod (*Gadus morhua*) countershaded and brown in colouration in August (above) and October (below) 2001.

Figure 4.7a Colouration of an individual Atlantic cod (*Gadus morhua*) before (August; above) and after (October; below) being held in net pens in Gilbert Bay, Labrador, and fed a piscivorous diet.

Figure 4.7b Colouration of an individual Atlantic cod (*Gadus morhua*) before (August; above) and after (October; below) being held in net pens in Gilbert Bay, Labrador, and fed a piscivorous diet.

Figure 4.7c Colouration of an individual Atlantic cod (*Gadus morhua*) before (August; above) and after (October; below) being held in net pens in Gilbert Bay, Labrador, and fed a piscivorous diet.

Figure 4.7d Colouration of an individual Atlantic cod (*Gadus morhua*) before (August; above) and after (October; below) being held in net pens in Gilbert Bay, Labrador, and fed a piscivorous diet.

Figure 4.7e Colouration of an individual Atlantic cod (*Gadus morhua*) before (August; above) and after (October; below) being held in net pens in Gilbert Bay, Labrador, and fed a piscivorous diet.

Table 4.3 Total numbers of different colours of Atlantic cod (*Gadus morhua*) rated by colour on a scale from 1-5 (where 1 is a countershaded cod, 3 is a brown cod and 5 is a cod with red pigmentation) in August and total numbers remaining in October 2001.

Colouration in August 2001		Colouration in October 2001								
Colouration	n	***1***	***1.5***	***2***	***2.5***	***3***	***3.5***	***4***	***4.5***	***5***
1	*0*	0	0	0	0	0	0	0	0	0
1.5	*7*	1	5	1	0	0	0	0	0	0
2	*23*	3	11	7	2	0	0	0	0	0
2.5	*15*	0	3	10	1	1	0	0	0	0
3	*35*	6	3	16	9	1	0	0	0	0
3.5	*10*	0	1	7	0	1	1	0	0	0
4	*20*	0	1	7	2	8	2	0	0	0
4.5	*1*	0	0	0	0	1	0	0	0	0
5	*10*	0	0	3	2	4	1	0	0	0

4.5.7. Length-at-age analysis

Thirty-three brown and 34 countershaded cod from this research were aged and used in length-at-age analysis (Appendix 2). Ages of brown cod ranged from 3-10 years (mean 5 years) (Appendix 3) and ages of countershaded cod ranged from 3-6 (mean 4 years) (Appendix 3). Lengths of cod are discussed under section 4.3.2.

Differences in length-at-age relationships between countershaded (n=34) and brown cod (n=33) collected for this research were not significant (ANCOVA $p<0.001$) (Figure 4.8). Length-at-age data collected for all fish (n=67) were pooled and compared to length-at-age data of cod sampled in Gilbert Bay in 1996/97 (n=158) (Appendix 2). Again, no significant differences were observed (ANCOVA $p<0.001$) (Figure 4.8). Data from fish collected in Gilbert Bay in 1996/97 and 2001 were then pooled and compared to length-at-age data from cod sampled in NAFO division 2J between 1978 and 1995 (n=177) (Appendix 2). Cod from NAFO division 2J were found to have significantly longer lengths-at-age than cod from Gilbert Bay (ANCOVA $p<0.0001$).

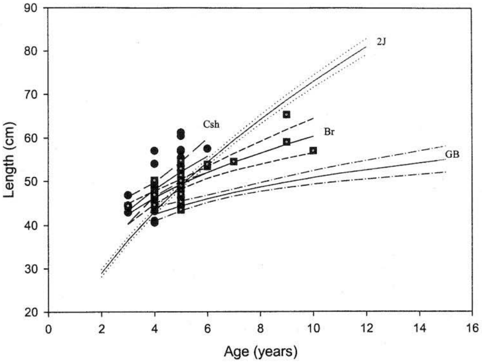

Figure 4.8 Length-at-age relationships of countershaded (Csh ●) (n=34) and brown (Br ■) (n=31) Atlantic cod (*Gadus morhua*) sampled in October 2001 compared to cod caught in Gilbert Bay (GB) in 1996/97 (n=159) (from Smedbol et al. 1999) and to research vessel surveys in NAFO division 2J (2J) between 1978 and 1995 (n=177) (from Shelton et al. 1996). For each sample, the solid curve is the regression relationship and the dashed curves are the upper and lower 95% confidence intervals for the population.

4.5.8. Analysis of environmental conditions

4.5.8.1. Temperature

Temperature at approximately 4.5m depth was recorded continuously in Captain Jack's Cove over a period of 57 days from 25 August to 20 October. Temperature ranged from 10.2 °C on 26 August to 0.2 °C on 19 October (Figure 4.9). The low temperature observed on 19 October provides evidence that the pens were hauled up and the fish poached before researchers arrived just days later. Slight increases in temperatures of approximately 1-2 °C were experienced between 4 and 11 September and between 19 and 25 September. In general, however, temperature at the bottom of the fish pens decreased over time (Figure 4.9).

Temperature profiles were collected in Captain Jack's Cove for all weeks between 25 July and 28 September, except for the week of 29 July. Profiles were slightly distorted due to the length of time for the temperature probe to adjust to the surrounding temperature. Results, however, do provide a general idea of surface temperatures throughout the study period. Surface temperatures generally increased from 7.5 °C on 25 July to a maximum of 16 °C on 15 August (Figure 4.10). Temperature remained around 12-13 °C between 22 August and 18 September, until dropping to 8.4 °C on 28 September (Figure 4.10).

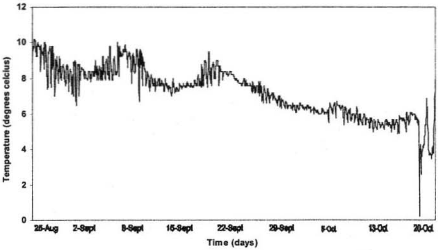

Figure 4.9 Water temperature at 4.5m depth in Captain Jack's Cove, Labrador, from 25 August to 21 October 2001.

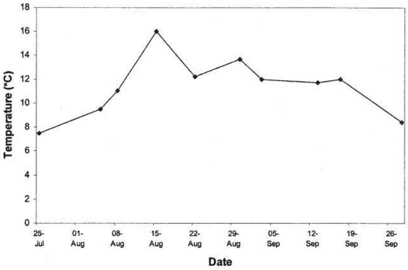

Figure 4.10 Surface water temperatures in Captain Jack's Cove, Labrador, based on weekly vertical temperature profiles collected from 25 July to 28 September 2001.

4.5.8.2. Turbidity

Water turbidity in Captain Jack's Cove was surveyed on 4 days in August. The average depth at which the Secchi disk could no longer be seen decreased from 10 m on 3 August to 3 m on 28 August. Readings between these dates were 7.5 m on 10 August and 8m on 17 August.

4.5.8.3. Pen biofouling

Within one week of being placed in the water, both pens were covered in "slub." "Slub" samples were collected on 12 days between 6 August and 2 October. Samples from the 6 and 22 August, 1 and 21 September, and 2 October were analyzed. The biofouling was comprised of two species of filamentous algae, *Ectocarpus siliculosus* and *Pilayella littoralis*, common throughout Newfoundland and Labrador on rocks and as epiphytes. Both species are also considered common fouling organisms on nets and other substrates. *E. siliculosus* was found in August samples and the sample collected on 1 September. On 21 September, only *P. littoralis* was identified. Both species were found together on the 2 October.

4.6. Discussion

Colouration changes in fish may result from morphological or physiological colour changes (as discussed in Chapter 2). Morphological colour changes involve an increase or decrease in the total concentration of pigment in cells. Physiological colour changes involve a redistribution of pigment in cells, usually in response to changes in background colouration. The relative influences of morphological and physiological colour changes on the colouration of cod will be discussed separately.

4.6.1. Carotenoids, diet and morphological colour changes

Red, yellow, and orange pigments (carotenoids) are synthesized by plants and passed through the food chain. Thus, a fish acquires its carotenoids through food – the only way they can obtain them (Fox and Vevers 1960; Weedon 1971; Bagnara and Hadley 1973). Though little research has focused in this area, it is generally accepted that a diet rich in carotenoid containing invertebrates increases the total amount of carotenoid pigment in chromatophores, resulting in an increased red to reddish-brown colouration in fish species (Derek Burton, Memorial University, pers. comm.). Once the carotenoid source stops, concentrations should decrease, though there is no detailed account of this metabolism in the scientific literature (Derek Burton, Memorial University, pers. comm.).

Cod feed inshore on amphipods, copepods, barnacle larvae and other small crustaceans (Scott and Scott 1988). Juveniles and young adult cod consume euphausiids, mysids, shrimps, small lobsters, crabs (Scott and Scott 1988), annelids, and molluscs (Keats and Steele 1992 as cited in Steele and Lilly 1999). With increasing size, cod become increasingly piscivorous (Scott and Scott 1988; Steele and Lilly 1999). At lengths ranging from approximately 40-70 cm, cod feed predominately on capelin and sand lance (Turuk 1968; Lilly and Flemming 1981 as cited in Steele and Lilly 1999).

Cod in Gilbert Bay eat a wide variety of benthic organisms, with fish comprising only a small portion of the diet (Morris 2000). Adult cod feed predominantly on benthic invertebrates such as shrimp, mysids, amphipods and various crab species, with individuals tending to specialize on certain food items (Morris 2000). Wild cod caught in Gilbert Bay in November 2001 were feeding almost exclusively on mysids, limpets, shrimp, or scallops/clams (Joe Wroblewski, Memorial University, pers. comm.). Cod caught in June were feeding on both invertebrate crustaceans and small fish.

Unique colourations observed in some cod may be accounted for by a diet consisting of predominately invertebrates. The reddish-brown colouration of Gilbert Bay cod is believed to result from a diet rich in carotenoid-containing invertebrate species (Wroblewski 2000; this research). The golden hues of some cod from Gilbert Bay may result when reddish carotenoid pigments overlay naturally occurring crystalline guanine found in guanophores (Fox and Vevers 1960). The reddish-brown colouration of juvenile Atlantic cod (Methven and McGowan 1998) can similarly be accounted for by their diet of carotenoid rich invertebrates. Norwegian coastal cod also exhibit a unique reddish colouration, believed to arise from astaxanthin, an abundant carotenoid of animals, obtained from their diet of shore crab (Fox and Vevers 1960).

The relationship of diet to colouration has been shown for several other fish species. Pacific killifish (*Fundulus* sp.) fed a piscivorous diet experienced a decrease in concentrations of xanthophyll (Fox 1976). Sumner (1937) stated that the "xanthophyll must be rapidly lost from [such] fishes if it is not present in sufficient amounts in their diet" (as cited in Parker 1948). In another study, Garibaldi (*Hypsypops rubicunda*) were shown to lose their yellow-brown to orange colouration when placed on a piscivorous carotenoid free diet for periods from 3.5 to 11 months (Fox 1976).

In the colouration change experiment, fish were held in net pens and fed a piscivorous diet of capelin and herring. Fish were held within the same environment they would have encountered in the wild during the same period. The obvious loss of red to reddish-golden-brown colouration from experimental fish confirms the role of diet in the colouration of cod in Gilbert Bay. Whether or not this observed loss of red colouration, however, is due to a total loss of pigment, an aggregation of pigment, or a combination of both remains an open question. Similarly, whether a countershaded cod would turn red/brown when fed a traditional bay diet of crustaceans and other carotenoid-rich invertebrates cannot be determined on the basis of this research.

4.6.2. Background habitat and physiological colour changes

A fundamental feature of melanophores is that melanins, unlike carotenoids, are synthesized directly within melanophores (Bagnara and Hadley 1973). Thus, fish can produce (or redistribute) melanins when placed on dark backgrounds. A number of studies have shown that fish acquire more melanophores and more melanin when kept on a dark background and lose melanophores and melanin when kept on a light background (Fox and Vevers 1960). Atlantic cod in this research were held in net pens with dark "walls" of filamentous algal species. On this dark background melanins would be expected to be dispersed, and cod become darker in colouration. Results of this research showed, however, that cod lost both brown and red pigmentation (and turned white on their bellies) when held in such an environment.

This response, opposite to what was expected, may be representative of a "resting" condition. Flatfish, when held in a black chamber, all adopt an intermediate grey colouration that is hypothesized to be a "resting" or baseline colouration (though it is noted that it could be a combination of many factors) (Derek Burton, Memorial University, pers. comm.). Nonetheless, that cod in this research lost their colouration when placed on a dark background indicates that diet is the prominent factor influencing cod colouration.

4.6.3. Colouration and stock structure

Previous research has shown that cod from Gilbert Bay are slower growing than cod from offshore in NAFO division 2J (Smedbol 1999; Ruzzante et al. 2000) and significant differences exist in length-at-age relationships between such groups. Countershaded and brown cod used in the colouration change experiment, believed to be offshore and inshore cod respectively, were not found to have significant differences in length-at-age relationships. Fish used in this analysis ranged in length from 40-65 cm, with the majority less than 50 cm. The data collected may be inadequate to resolve length-at-age differences. Genetic analysis would be necessary to determine whether the brown and countershaded cod used in this study are/are not from the same population.

Even without genetic confirmation that countershaded and brown cod used in this research were distinct groups, what remains is the fact that an individual cod has the ability to change colouration and a brown to reddish-golden-brown coloured cod will lose its colouration within 78 days when held in a bay environment and fed a piscivorous diet. As such, it can be argued that colouration can be used to deduce the length of time cod have been feeding on available carotenoid rich invertebrates in shallow water inshore environments. Seventy-six Atlantic cod in this study were a distinct brown to reddish-golden-brown colouration when placed in holding pens in August. It is assumed that prior to capture these fish were freely feeding on inshore invertebrates such as shrimp, mysids and amphipods (Morris 2000). When placed in holding pens in a shallow water environment and fed a traditional offshore diet (Lilly and Botta 1984), 75% of these cod completely lost their pigmentation. Thus, a brown to reddish-golden-brown colouration acts as a *dietary time tag*, indicating that an individual has been feeding on shallow water benthic invertebrates for some unknown length of time.

Despite the information available on fish colouration, there is no known scientific literature investigating colouration as an indicator of stock structure in Newfoundland cod. This research suggests two interpretations of results:

1) brown cod represent offshore cod that come into the bays in spring/summer, feed on carotenoid-rich invertebrates, and turn brown.

2) brown cod represent cod that remain in the bays year round, feeding predominantly on carotenoid rich benthic invertebrates.

The paradigm surrounding the behaviour and migration of northern cod (i.e. offshore cod migrate inshore guided by migrating capelin on which the cod feed) (Lear and Green 1984) does not support the first hypothesis. Research in Bonavista Bay has shown that offshore cod migrating inshore in the spring feed intensively and almost exclusively on capelin (Lilly and Botta 1984). This suggests that an offshore cod migrating inshore and acquiring a reddish-brown colouration is possible but unlikely due to the preference for a piscivorous diet.

4.7. Summary

Results of this research demonstrated that if inshore cod from Gilbert Bay are fed a typical offshore piscivorous diet, their unique brown to reddish-golden-brown colouration is lost in less than 78 days. The absence of carotenoids in the diets of cod held in net pens in Gilbert Bay is concluded to be the main factor contributing to this loss of pigmentation. The variability of colouration, however, allows us only to make general conclusions regarding the duration of cod in the inshore environment through its diet of benthic invertebrates. Thus colouration is a useful, but not-conclusive indicator of cod stock structure. Colouration, in combination with other scientific research (i.e. genetics, sonic tagging/tracking, and behaviour studies), can provide a more complete understanding of stock structure to be used in the identification of local inshore populations of cod that may exist or may have existed in the past.

Overall, a brown colouration suggests that cod are of the inshore group rather than the offshore group. As such, brown cod are of concern to management.

5. Fish harvesters' and scientific knowledge of brown cod and bay stocks

5.1. Comparing fish harvesters' and scientific knowledge of colouration and inshore stocks of cod

Harvesters' observations of a complex and diverse array of colourations of cod are consistent with scientific investigation of cod colouration in Gilbert Bay. Harvesters reported many gradations of colourations between brown, red and countershaded. Angling and photographing of individual fish in Gilbert Bay confirmed and documented this complexity. Many fish harvesters described the presence of red to reddish-brown coloured cod that were generally observed in shallow water areas both inside and outside of bays where "kelp," "red moss," and/or crabs were present. Fishermen attributed the red colouration to lying on the "kelp"/"red moss," feeding on a diet of mainly "kelp"/"red moss" and invertebrate crustaceans, or a combination of the two. Cod in Gilbert Bay traditionally feed on carotenoid-rich prey items such as crab, amphipods and mysids (Morris 2000) and have a distinct reddish to golden-brown colouration. The results of the colouration change experiment have show that when these fish are fed a traditional offshore diet devoid of carotenoids, their reddish to golden-brown colouration is lost. These results confirm harvesters' beliefs that diet plays a role in the colouration of Gilbert Bay cod and likely such colourations of cod reported in other areas throughout Newfoundland and Labrador. Several fish harvesters also reported that the red to reddish brown cod were smaller than the offshore countershaded cod. This description fits with scientific knowledge of such coloured cod in Gilbert Bay. Gilbert Bay cod are slower growing and have a shorter length at age than their offshore counterparts (Ruzzante et al. 2000).

Several harvesters held the belief that offshore countershaded cod migrate inshore in the spring and early summer and turn brown to reddish-golden-brown before migrating back offshore in the fall. This colouration change is generally associated with an inshore habitat (i.e. fresh or shallow water, presence of red algal species, and/or a diet of crab, algae, etc). Results of the colouration change experiment confirm harvesters' belief that cod have the ability to change colouration and suggest that the reddish-brown colouration results from feeding on invertebrates. Whether a countershaded cod would turn brown if fed a traditional bay diet of shallow-water invertebrates, however, has not yet been determined.

For most harvesters interviewed, cod colouration reflected a particular season (red cod late in the fall), diet (feeding on crab, kelp, etc.), and/or habitat (shallow or fresh water). Harvesters based their conclusions as to whether cod were "native" to an area on a combination of factors including colouration, season of capture and food availability. Thus, colouration alone did not reflect bay residency for interviewed harvesters. In the same way, this research concludes that colouration must be combined with other sources of information (sonic tagging/tracking, genetics, etc.) to identify local stocks of cod.

Using a combination of observations of colouration, behaviour, diet, food availability, and season of capture, fish harvesters believe in the existence of cod that remain year-round in bays, and distinguish them from offshore cod that migrate to the coast to feed in the summer. In agreement with harvesters' beliefs, scientific study of the genetics, life history, and migration and spawning behaviour of northern cod suggests that the Newfoundland and Labrador cod stock complex is composed of relatively independent subpopulations in the inshore and offshore environments (Taggart et al. 1998 and references therein; Smedbol 1998).

Fish harvesters and scientists represent two very different knowledge systems often with two very different dialogues. For researchers of this project, the term "bay cod" was defined by the presence of cod that overwinter and spawn in the bay (see Table 2.1). Though some harvesters used this term to refer to cod that were believed to remain year-round in the bay, they generally based their definition of "bay cod" on the presence of cod inshore during the winter. Similar issues arose surrounding the term "spawning." Harvesters often used this term to refer to cod that have eggs/"milk" in them. Scientists, however, would use this term to refer to cod that are releasing eggs/milt.

Fish harvesters and scientists often have differing opinions as well. In this research, fish harvesters reported cod resident in many inshore areas throughout Newfoundland and Labrador (Table 3.1 and Figure 3.5) and some harvesters believed that cod were actually increasing in numbers. Science, however, has only documented three such areas that support inshore populations of cod – Trinity, Placentia, and Gilbert Bays – and recent studies in 2001 have concluded that inshore stocks of cod continue to decline (DFO 2002).

5.2. Assessing the role of colouration as an indicator of cod stock structure

The ability of an individual cod to change colouration has shown that colouration cannot be used in isolation to identify inshore stocks of cod. This raises the question: "given the plasticity, is it valuable to even ask about colouration?"

Even though colouration is not definitive of stock structure, this research has established the role of diet in brown to reddish-golden-brown colourations observed in Gilbert Bay cod. Thus, results of this research have shown that colouration acts as a *time-dependant dietary index* and can be used to deduce recent feeding histories of individuals or groups of fish. The absence of brown to reddish-golden brown cod in the inshore environment does not mean that a resident population of cod does not exist (note that cod resident in the deep waters of Trinity Bay are countershaded in colouration) (Table 2.1), however their presence inshore does indicate that they have likely been inshore, feeding on shallow-water carotenoid-rich invertebrates for some unknown period of time. Through this relationship, colouration acts as a general indicator of inshore groups of cod and a cost-efficient guide for future research attempting to identify probable locations of resident coastal cod stocks. Fish harvesters' knowledge of uniquely coloured cod throughout Newfoundland and Labrador, as revealed through this research, provides a valuable base line of information on which to plan more formal scientific studies. Specifically, sonic tagging/tracking and genetic studies could be conducted in bays where there were indications of overwintering cod to test the hypothesis that these bays support a resident population of cod. Results of such studies could assist in answering the question "Are Gilbert Bay, Trinity Bay, and Placentia Bay unique, or are there other bays in Newfoundland and Labrador where resident populations of cod exist?"

5.3. Closing the loop

Combining fish harvesters' and scientific knowledge allowed for improved understanding of cod colouration, research methodologies required to study colouration, and issues that need to be addressed in future studies that seek to combine the two knowledge systems.

Through the scientific colouration change experiment, the information necessary to understand the mechanisms of colouration change was provided. Many harvesters expressed the belief that countershaded cod change colouration upon migration into shallow inshore waters. Their opinions influenced the design of the colouration change experiment. This researcher had also initially believed that water depth governed the colouration of cod (i.e. cod in deep water are countershaded and cod in shallow water are brown). The colouration change experiment, however, has shown that diet is the key factor controlling the reddish-brown colouration of cod in Gilbert Bay. Though two harvesters interviewed for this research believed that diet played an important role in cod colouration, the issue of diet and cod colouration was not discussed in any detail throughout interviews. Thus, from results of the colouration change experiment harvesters' have not only gained an understanding of factors controlling cod colouration, but scientists have learned the importance of harvesters' observations of cod diets as an area of discussion in future interviews.

Through the combination of interviews with fish harvesters and results of the colouration change experiment, it became apparent that a variety of colourations of cod exists in the inshore/coastal environment. Using photographs of golden-brown cod from Gilbert Bay, reddish-brown cod from Norway (Figure 3.2), and a drawing of a countershaded cod to stimulate discussions of inshore cod limited ones' ability to understand the colourations harvesters were describing. As a direct result of this research, researchers at Memorial University have changed procedures used in recent interviews with fish harvesters. Interviews now include photographs showing a broad range of cod colourations and harvesters are asked to select which photographs of cod are similar to cod observed in their area.

In addition, several significant questions have arisen that may not have been considered if scientific field studies were conducted in isolation from fish harvesters. These include: What role, if any, does the "red moss" or "kelp" described by harvesters play as habitat for localized stocks of cod? Do cod obtain their carotenoids in these areas from a crustacean diet or are cod able to obtain carotenoids from feeding on "red moss" and "kelp?" How do harvesters' observations of cod in the nearshore environment relate to Templeman's (1966; 1979) description of coastal cod (cod that overwinter in the deep waters along the headlands) (Table 1.1)? Finally, of most significance to this research: Do bay populations of cod exist in the areas identified by harvesters where scientific research has not been carried out?

5.4. Summary

Commercial cod fishers use their experience and observations to explain patterns of fish ecology and trends in the fishery. The detailed observations related to fish colouration, spawning, and migration they acquire are valuable to science. The knowledge of fish harvesters, documented through interviews as a part of this research, contributed to our understanding of inshore stocks of cod. This knowledge, however, was tested by scientific research that closed the induction-deduction loop, providing a more complete understanding of nature. Conversely, such tests also improved the quality of our interactions with fish harvesters and on our ability to interpret their responses correctly.

Fish harvesters' observations of different colourations of cod can play an important role in the identification of local stocks of Atlantic cod in the future. Results from the colouration change experiment demonstrated that a brown cod will lose its colouration in a period of several months when feeding on a piscivorous diet – something never before documented to this authors' knowledge. The variability of colouration, however, allows us only to make general conclusions regarding the duration of cod in the inshore environment. Harvesters' observations of brown cod, therefore, are indicative of cod that were at the time of the observation, or in the recent past, feeding on invertebrates in the inshore environment. Whether cod remain year-round inshore cannot be determined on the basis of brown colouration alone. However, a brown colouration *suggests* that cod are of the inshore group rather than the offshore group. As such, brown cod are of concern to a management system that has historically placed little importance on inshore stocks in the overall management of northern cod (Lilly 1996).

I conclude that further scientific research is needed to identify the location and status of inshore populations of cod, specifically in locations identified by fish harvesters during interviews. New management strategies that preserve these fish populations, such as the establishment of marine protected areas, may be necessary.

5.5. Future considerations

Future interviews with fish harvesters should be based on some of the methodological lessons learned. The following is a list of specific recommendations for use in future interviews with fish harvesters to obtain information on colouration and stock structure of Atlantic cod:

1. Use several pictures of cod during interviews, showing a series of colourations (i.e. brown, black/dark, yellow-brown, reddish-brown, red, countershaded, etc). If possible, photographs of different colourations of cod should be taken in each bay under study and used in subsequent interviews in the surrounding communities. Label/number each picture and speak each number out loud when tape-recording interviews for identification when analyzing transcribed interviews.

2. Record the terms harvesters use to describe each picture of cod (e.g. brown, golden, red, black, foxy, etc). This would allow researchers to determine, for instance, whether "foxy" is a term used in all areas for red cod and whether different harvesters use "foxy" to describe different colourations.
3. Avoid using the terms "brown" or "red" in questions surrounding cod colouration, unless used by the interviewee.
4. Avoid asking questions about "spawning" cod. Ask questions that distinguish between cod that were observed to be running with spawn and those that were ripe, seedy, or full of "milk"/eggs. Pictures of gonads at different stages of maturity may be a useful tool to shed light on this issue.
5. Ask specific questions surrounding the terms "bay cod," "bay stock" and "bay fish." Do harvesters associate these terms with cod that are inshore year-round (i.e. overwinter, spawn and feed inshore) or cod that migrate into the bays in the summer time, feed, and migrate back offshore in the fall?
6. Ask harvesters questions about the prevalence of males or females in their catches during the spawning season. The prevalence of males in spawning condition may indicate spawning areas (Morgan and Trippel 1996).
7. Throughout interviews for this research, each area referred to by an individual was given a unique identification number. In the future, when tape-recording interviews, frequently repeat out loud this number. This will allow for easier and more accurate analysis of transcripts.
8. Combine future interviews with participatory research. Researchers should spend time on the water, talking with and learning from fish harvesters, and observe

themselves the colourations of cod harvesters describe. This allows for a more detailed, more effective, assessment of fish harvesters' knowledge of localized stocks of cod.

Future scientific studies should further investigate, both in the field and in the laboratory, the roles of diet and environment in cod colouration as well as the relative abundance of carotenoids obtained through diet. Specifically, I suggest five future studies:

1. Hold two groups of countershaded cod (from NAFO division 2J) in net pens in an area where Gilbert Bay cod are known to overwinter (i.e. the Shinneys) (Morris 2000). Feed one group a carotenoid-rich diet and the other a diet of capelin and herring. This will determine i) whether a countershaded cod has the ability to change colouration when fed a traditional bay cod diet, and ii) whether a change from an offshore to an inshore location has an effect on offshore cod colouration.
2. Hold brown to reddish-golden-brown cod in net pens in Gilbert Bay, in an area such as the Shinneys, and feed them a piscivorous diet. Monitor colouration changes on a weekly basis, using the devised colouration scale. This will determine more accurately the length of time it takes for cod to lose their pigmentation.
3. Capture live fish from Gilbert Bay, Labrador and hold them on dark and light backgrounds in a laboratory setting. Feed both groups a diet rich in carotenoids. This will determine whether background has any influence on the brown

colouration observed in cod from Gilbert Bay. A concurrent study could involve feeding such fish a piscivorous diet or using cod from an offshore location, such as NAFO Division 2J.

4. Analyze skin samples from brown, red, and countershaded cod to determine the relative abundance of carotenoids present. Taking skin samples before and after holding fish in pens, in either experiment 1 or 2 above, would allow one to determine i) whether xanthophylls are present after a fish loses its red/brown colouration and/or ii) whether xanthophylls increase in concentration in countershaded cod after being fed a carotenoid rich diet and/or iii) the relative abundance of xanthophylls present in red versus brown cod.
5. Capture live fish from Gilbert Bay, Labrador and hold them on a constant background colouration in a laboratory setting. Feed fish a diet of different carotenoid concentrations. This will provide information on the levels of carotenoids in the diet needed to maintain a reddish-brown colouration.

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Appendix 1: Interview questions used to gather fish harvesters' knowledge of Atlantic cod (*Gadus morhua*) in November and December 2000.

Fish Harvester ID #:
Chart #:
Date:
Location:

<u>Demographics</u>

1. Age:
2. Sex:
3. Where born:
4. Where currently living:
5. Marital status:
6. Spouse's occupation:
7. Education level:
8. Training in fisheries:

<u>Fishing Experience</u>

1. Year when started fishing: Age:
2. Last season fished:
3. Gaps in fishing career? When? How long? Why?
4. Number of generations family has been in the fishery:
5. Always in this community/region?
6. Sectors has fished in:

Inshore	*Crew:*	*Skipper:*	*Years at each?*
Longliner	*Crew:*	*Skipper:*	*Years at each?*

7. Areas where has fished:
8. Who taught you how to fish?

Scientific name	Known local names	Other names	Observed locally?	Fished/hunted-commercial, food (human, livestock, dogs), fertilizer, bait
Gadus morhua	Cod, tomcod, rounder, foxy tom cod, herring cod, sun burnt or black backed cod, loder, seal-headed cod, pot bellies, mother fish			
Gadus ogac (stubbier, darker than cod)	Greenland cod, rock cod			
Melanogrammus aeglefinus (sharp fin, mark on side)	Haddock			
Boreogadus saida	Arctic cod			
Urophycis tenuis (pointed fin)	White hake, ling			
Pollachius virens	Pollock			
Tautogolabrus adspersus	Cunner, conner			
Cyclopterus lumpus	Lumpfish			
Salmo salar	Salmon			
Salvelinus alpinus	Arctic char			
Oncorhynchus mykiss (Salmo gairdneri) (white fins)	Rainbow trout, steelhead			
Salvelinus frontinalis	Brook trout			
Fundulus diaphanus	Banded killifish, swimp, minnow, freshwater killifish, killie			
Gasterosteus aculeatus	Threespine stickleback, barnystickle, thornback, prickley			
Mallotus villosus	Capelin, white fish, whale bait			
Ammodytes americanus (silvery, pencil shaped, wiggly)	Sand lance, lance			
Osmerus mordax	Smelt, white fish			
Clupea harengus harengus	Herring, midge herring, (juveniles) herring brit			
Alosa pseudoharengus	Alewife, gasperau			
Alosa sapidissima (golden colored)	American shad			

Appendix 2. Data used for length at age analysis of northern Atlantic cod (*Gadus morhua*) sampled in Gilbert Bay, Labrador, during August and October 2001 (n=121), in Gilbert Bay during 1996 and 1997 (n=159) (from Smedbol 1999) and during the Department of Fisheries and Oceans research vessel survey in NAFO division 2J from 1978-1995 (n=177) (from Shelton et al. 1996).

Countershaded		Brown		Gilbert Bay (Smedbol 1999)		2J (Shelton et al. 1996)	
Age	Length (cm)	Age	Length (cm)	Age	Length (cm)	Age	Length (cm)
3	42.9	3	44.4	4	43	2	29
3	44.5	4	46.4	4	38.5	2	30
3	46.8	4	47.6	4	42	2	31
3	44.4	4	46.9	4	42	2	30
4	46.9	4	50.2	4	42.5	2	30
4	57	4	44.6	4	39	2	26
4	47.1	5	47.4	5	46	2	27
4	50	5	54.8	5	42	2	27
4	48.9	5	45	5	63.5	2	28
4	46.7	5	50	5	46.5	2	29
4	47.7	5	52.9	5	49.5	2	31
4	54	5	50.1	5	41	2	28
4	49.6	5	51.8	5	39	2	27
4	45.2	5	47.8	5	41	2	28
4	40.6	5	47.1	5	38.5	2	26
4	48.4	5	49	5	52.5	2	26
4	46	5	51.6	5	39	2	26
4	43.2	5	51.9	5	38	2	27
4	46.4	5	51.4	5	48.5	3	38
4	41	5	47.8	5	51.5	3	41
4	48.7	5	47.1	5	43.5	3	39
5	60.4	5	43.8	5	43.5	3	39
5	53.5	5	47.1	5	39.5	3	38
5	61.2	5	45.4	5	44	3	39
5	46.3	5	43.5	5	42.5	3	34
5	52.5	6	53.4	5	52.5	3	34
5	44.3	6	53.9	5	42.5	3	36
5	48.6	7	54.5	5	46.5	3	36
5	57.2	9	65.3	5	42.5	3	37
5	49.4	9	59	5	45.5	3	38
5	56.9	10	57	5	42	3	35
5	55.4			5	51	3	34
5	48.5			5	43.5	3	34
6	57.5			5	42	3	62
				5	53.5	3	36
				5	52	3	33

Countershaded		Brown		Gilbert Bay (Smedbol 1999)		2J (Shelton et al. 1996)	
Age	Length (cm)	Age	Length (cm)	Age	Length (cm)	Age	Length (cm)
				5	41.5	4	46
				5	47	4	48
				6	41	4	50
				6	41	4	47
				6	47.5	4	47
				6	45	4	46
				6	51	4	44
				6	45.5	4	40
				6	57.5	4	41
				6	39.5	4	43
				6	44.5	4	44
				6	50.5	4	44
				6	44	4	42
				6	50	4	39
				6	49	4	39
				6	46	4	41
				6	40	4	42
				6	48.5	4	42
				6	46	5	54
				6	49.5	5	56
				6	66	5	54
				6	44	5	55
				6	43	5	53
				6	48	5	54
				6	53	5	51
				6	48	5	49
				6	42.5	5	48
				6	44.5	5	49
				6	41	5	48
				6	44.5	5	50
				6	49.5	5	47
				6	43	5	44
				6	42	5	42
				6	46.5	5	44
				6	41.5	5	47
				6	44	5	47
				6	45	6	60
				6	42	6	61
				6	47	6	61
				6	47.5	6	58
				6	44	6	59
				6	45.5	6	60
				6	48	6	57

Countershaded		Brown		Gilbert Bay (Smedbol 1999)		2J (Shelton et al. 1996)	
Age	Length (cm)	Age	Length (cm)	Age	Length (cm)	Age	Length (cm)
				6	46	6	53
				6	43	6	53
				6	47.5	6	52
				6	43	6	53
				6	48	6	54
				6	41.5	6	53
				6	48	6	52
				7	47	6	46
				7	51	6	48
				7	50.5	6	56
				7	49	6	56
				7	47.5	7	66
				7	53.5	7	68
				7	51.5	7	64
				7	58	7	63
				7	47.5	7	61
				7	44.5	7	63
				7	43	7	63
				7	47	7	58
				7	45.5	7	57
				7	47.5	7	57
				7	46.5	7	56
				8	51.5	7	57
				8	46	7	56
				8	45	7	57
				8	46	7	60
				8	52.5	7	46
				8	48.5	7	56
				8	41	8	69
				8	38.5	8	74
				8	44.5	8	70
				8	43	8	67
				8	51.5	8	64
				8	42	8	65
				8	49.5	8	66
				8	44	8	64
				8	47.5	8	60
				8	43	8	59
				8	46.5	8	60
				8	48.5	8	59
				8	52.5	8	59
				8	51	8	59
				9	50	9	79

Countershaded		Brown		Gilbert Bay (Smedbol 1999)		2J (Shelton et al. 1996)	
Age	Length (cm)	Age	Length (cm)	Age	Length (cm)	Age	Length (cm)
				9	41	9	69
				9	40	9	82
				9	63.5	9	73
				9	51	9	69
				9	60	9	69
				9	45	9	67
				9	51	9	67
				9	50.5	9	68
				9	51	9	61
				9	56.5	9	63
				9	54	9	61
				9	44	9	61
				9	48.5	9	63
				9	49	10	80
				9	50	10	77
				9	50	10	83
				9	54	10	84
				9	42.5	10	77
				9	51	10	74
				9	43.5	10	72
				9	47	10	70
				9	50	10	68
				10	69.5	10	68
				10	44	10	66
				10	51.5	10	61
				10	47	10	61
				10	46	10	65
				10	66	11	87
				10	42	11	87
				10	49.5	11	86
				10	56.5	11	90
				11	53	11	86
				11	54.5	11	75
				11	67.5	11	78
				11	55.5	11	73
				15	52.5	11	72
						11	77
						11	74
						11	69
						11	71
						11	74
						12	90
						12	86

Countershaded		Brown		Gilbert Bay (Smedbol 1999)		2J (Shelton et al. 1996)	
Age	Length (cm)	Age	Length (cm)	Age	Length (cm)	Age	Length (cm)
						12	87
						12	89
						12	95
						12	95
						12	83
						12	76
						12	77
						12	75
						12	80
						12	67
						12	70
						12	65

Appendix 3. Data from northern Atlantic cod (*Gadus morhua*) sampled within the bay and along the headlands of Gilbert Bay, Labrador, during August and October 2001 (n=121). Locations are shown in Figure 4.1.

Tag	Location of Capture	Age (years)	Spawning Age (years)	Length (cm) Jul./Aug.	Length (cm) Oct.	Weight (kg) Jul./Aug.	Weight (kg) Oct.	Color Aug.	Color Oct.
j42820	Pipers Tickle			17.2	21.4	<0.10	0.11	3	2.5
j42770	Pipers Tickle			19.2	23.8	0.11	0.11	3	2
j42937	Merchants Hr.			21.6	28.5	0.11	0.11	2.5	2
j42755	Pipers Tickle			22.5	28	0.11	0.23	3	2
j42788	Merchants Hr.			22.5	26.9	0.11	0.23	3.5	2
j42987	Pipers Tickle			22.5	27.6	0.11	0.11	3	2
j42787	Merchants Hr.			22.9	28.6	0.11	0.23	2.5	2
j42932	Merchants Hr.			23	29.8	0.11	0.23	2	1.5
j42880	Merchants Hr.			23.4	29.5	0.11	0.23	3	1
j42793	Merchants Hr.			23.7	29.4	0.11	0.23	3.5	3
j42933	Merchants Hr.			24	28.5	0.11	0.11	4	2
j42796	Merchants Hr.			24.2	29.8	0.11	0.23	3.5	2
j42947	Merchants Hr.			24.6	32.5	0.23	0.34	4	2
j42744	Merchants Hr.			24.7	30.5	0.11	0.23	3	2
j42984	Merchants Hr.			24.9	31.2	0.23	0.11	3	2
j42679	Merchants Hr.			25	32.6	0.23	0.34	3	2
j42785	Merchants Hr.			25.2	32.6	0.11	0.34	4	1.5
j42781	Merchants Hr.			25.4	30.5	0.23	0.23	3.5	2
j42942	Merchants Hr.			26.1	33.7	0.23	0.46	3	2
j42906	Pipers Tickle			26.2	31.4	0.11	0.34	2.5	2
j42769	Pipers Tickle			26.3	32.3	0.11	0.23	3	2
j42961	Merchants Hr.			26.3	33.3	0.11	0.46	4	2
j42879	Merchants Hr.			26.4	33	0.23	0.34	3	2.5
j42792	Merchants Hr.			26.5	33.3	0.11	0.46	3	1

Tag	Location of Capture	Age (years)	Spawning Age (years)	Length (cm) Jul./Aug.	Length (cm) Oct.	Weight (kg) Jul./Aug.	Weight (kg) Oct.	Color Aug.	Color Oct.
j42753	Pipers Tickle			26.6	32.8	0.23	0.34	3	2
j42869	Merchants Hr.			26.9	34.4	0.23	-	4	2
j42809	Pipers Tickle			27.1	32.5	0.23	0.34	3	2
j42784	Merchants Hr.			27.4	34.6	0.23	0.46	3.5	2
j42940	Merchants Hr.			27.4	34	0.23	0.46	5	2
j42795	Merchants Hr.			27.5	33.4	0.23	0.46	3	2
j42782	Merchants Hr.			27.7	35.5	0.23	0.46	3.5	2
j42798	Merchants Hr.			27.8	35.2	0.23	0.46	2	2
j42751	Pipers Tickle			28	34.3	0.46	0.46	3	2.5
j42740	Merchants Hr.			28.1	33.9	0.23	0.46	3	1.5
j42966	Pipers Tickle			28.5	36.3	0.23	0.46	3	2
j42695	Pipers Tickle			29	34.4	0.23	0.34	3	1.5
j42738	Merchants Hr.			29.3	36.3	0.23	0.57	3	2.5
j42965	Merchants Hr.			29.6	36.3	0.23	0.46	3	1
j42821	Pipers Tickle			30.3	35.5	0.23	0.46	3	2
j42766	Pipers Tickle			30.5	35.6	0.23	0.46	2	1.5
j42939	Merchants Hr.			30.6	35.8	0.34	0.46	2	1.5
j42677	Merchants Hr.			31.1	38.4	0.34	0.46	3.5	2
j42774	Pipers Tickle			32	36.4	0.34	0.46	2.5	2
j42765	Pipers Tickle			32.2	37.2	0.34	0.46	3	1
j42780	Merchants Hr.			32.2	40.3	0.34	0.46	3.5	1.5
j42986	copper island			32.2	36.6	0.23	0.46	4	2
j42699	Pipers Tickle			32.4	38.5	0.34	0.57	3	2
j42741	Merchants Hr.			32.7	38.6	0.34	0.34	3	2.5
j42938	Merchants Hr.			32.8	29.5	0.11	0.11	4	2.5
j42732	Merchants Hr.			33.4	39.2	0.34	0.57	3	1
j42810	Pipers Tickle			33.4	40	0.11	0.57	3	1
j42878	Merchants Hr.			33.8	36.6	0.34	0.46	2.5	2

Tag	Location of Capture	Age (years)	Spawning Age (years)	Length (cm) Jul./Aug.	Length (cm) Oct.	Weight (kg) Jul./Aug.	Weight (kg) Oct.	Color Aug.	Color Oct.
j42684	Merchants Hr.			34.1	41.5	0.34	0.68	2.5	2
j42831	Pipers Tickle			34.3	38.6	0.46	0.46	2	1
j42971	Captain Jacks Tickle			34.9	42.5	0.46	0.91	5	2
j42686	Merchants Hr.	3		36.3	42.9	-	0.91	2	2.5
j42913	Pipers Tickle	4		37	41	0.46	0.80	2.5	2
J042764	Pipers Tickle	4		37.4	40.6	0.46	0.57	2.5	1.5
j42999	Airport	5	4	37.6	43.5	0.57	1.02	5	3
j42890	Pipers Tickle	3		38.1	44.4	0.46	0.91	3	2
j42996	Airport	5		38.1	45	0.57	0.91	3	2.5
j42903	Pipers Tickle	3		38.2	44.4	0.57	0.91	2	1.5
j42724	Kelly's Pt.	5	5	38.5	43.8	0.46	1.02	5	3
j42803	Pipers Tickle	4		38.5	44.6	0.46	0.91	5	2
j42730	Merchants Hr.	3		39.5	44.5	0.57	0.91	2	1.5
j42756	Pipers Tickle	5		39.5	44.3	0.57	0.91	2	2
j42968	Captain Jacks Tickle	5	5	39.6	47.1	0.57	1.71	4.5	3
j42877	Merchants Hr.	4		40	46.4	0.57	1.02	2.5	1.5
j42779	Merchants Hr.	4		40.5	46	0.68	0.91	2.5	2
j42826	Pipers Tickle	3		40.5	46.8	0.68	0.91	2	1.5
j42985	Airport	5		40.8	45.4	0.91	0.91	5	3
j42837	Pipers Tickle	4		41.2	43.2	0.46	0.68	2.5	2.5
j42919	Pipers Tickle	4	4	41.2	47.1	0.68	0.91	1.5	1
j42706	Airport	5		41.3	47.6	0.80	1.02	5	3.5
j42888	Pipers Tickle	4		41.3	47.7	0.68	1.02	2	2
j42832	Pipers Tickle	4		41.5	46.4	0.57	0.91	3	2.5
j42759	Pipers Tickle	4		41.5	46.7	0.68	0.91	2	1.5
j42954	Near Peckhams Cove	5		41.6	47.1	0.68	1.02	4	3
j42715	Airport	5		41.7	47.8	0.80	1.02	4	2

Tag	Location of Capture	Age (years)	Spawning Age (years)	Length (cm) Jul./Aug.	Length (cm) Oct.	Weight (kg) Jul./Aug.	Weight (kg) Oct.	Color Aug.	Color Oct.
j042702	Airport	5	5	41.9	47.4	0.91	1.36	3	2.5
j42915	Pipers Tickle	4	4	42.3	46.9	0.68	0.68	4	2
j42950	Merchants Hr.	4		42.3	45.2	0.80	0.91	2	2.5
j42726	Merchants Hr.	5		42.4	46.3	0.68	0.91	2	1.5
j42991	Airport	5		42.5	47.8	0.80	1.36	4	3
j42713	Williams hr. run	4		43.1	46.9	0.80	1.02	1.5	2
j42926	Merchants Hr.	4		43.2	48.7	0.68	0.80	2.5	2
j42688	Pipers Tickle	4		43.3	48.9	0.57	1.02	2	1
j42956	Airport	5	5	43.5	49	0.91	1.02	4	3.5
j42776	Merchants Hr.	4		43.5	48.4	0.91	1.36	2.5	3
j42804	Pipers Tickle	5		43.5	48.5	0.91	1.02	2.5	1.5
j42917	Pipers Tickle	4		44	49.6	0.68	1.36	2	1.5
j42836	Pipers Tickle	4		44.5	47.6	0.68	1.02	3	1.5
j42976	Airport	5	5	44.5	50.1	1.02	1.82	3.5	3.5
j42969	Captain Jacks Tickle	5		44.6	47.1	0.91	1.48	5	3
j42712	Airport	5	5	45	51.8	0.91	1.25	4	2.5
j42835	Pipers Tickle	5	5	45.4	49.4	0.80	1.02	2	2
j42721	Rexton's Cove Pt.	4		45.5	50.2	0.80	1.48	5	2.5
j42967	Captain Jacks Tickle	5	4	45.5	51.6	1.02	1.71	4	3
j42924	Pipers Tickle	4	4	45.5	50	0.91	1.25	1.5	1.5
j42990	Airport	5		45.6	51.4	1.25	1.82	4	3
j42777	Merchants Hr.	5		45.6	48.6	0.80	0.91	2	1.5
j42978	Airport	5		45.8	51.9	0.91	1.48	4	3
j42997	Airport	5		47.5	50	1.02	1.36	3	4
j42703	Airport	5		47.8	52.9	1.02	1.48	3.5	2
j42746	Pipers Tickle	5	5	48	52.5	0.91	1.48	2	1
j42716	Airport	6	5	48.6	53.4	1.14	1.48	4	3

Tag	Location of Capture	Age (years)	Spawning Age (years)	Length (cm) Jul./Aug.	Length (cm) Oct.	Weight (kg) Jul./Aug.	Weight (kg) Oct.	Color Aug.	Color Oct.
j42989	Airport	5		48.8	54.8	1.36	1.82	3	2
j42901	Pipers Tickle	4		49.2	54	0.91	1.36	2	2
j42993	Airport	7	5	49.6	54.5	1.36	1.82	5	2.5
j42972	Captain Jacks Tickle	6	5	50.1	53.9	1.36	1.93	4	3
j42876	Merchants Hr.	5		50.5	53.5	1.25	1.36	1.5	1.5
j42957	Airport	9	5	50.6	59	1.48	1.93	4	3
j42833	Pipers Tickle	5		51.9	57.2	1.25	1.48	2	2
j42687	Pipers Tickle	5		52	55.4	1.25	1.59	2.5	2
j42801	Pipers Tickle	4	4	52.4	57	1.36	1.93	1.5	1.5
j42918	Pipers Tickle	5	5	53	56.9	1.14	1.82	2	2
j42953	Near Peckham's Cove	10	6	53.9	57	1.71	2.73	4	3.5
j42806	Pipers Tickle	5	5	54	60.4	1.36	1.82	1.5	1.5
j42737	Merchants Hr.	6	6	54.3	57.5	1.36	1.59	2	1.5
j42911	Pipers Tickle	5		58	61.2	2.16	2.84	1.5	1.5
j42994	Airport	9	5	60.8	65.3	2.05	1.82	3	2.5
Total		66	23	121	121	120	120	121	121
Mean		5	5	36.9	42.3	0.59	0.87	3	2
Median		5	5	38.1	43.8	0.46	0.46	3	2
Range		3-10	4-6	17.2-60.8	21.4-65.3	<0.10-2.16	1.14-2.84	2-5	1-4