Life History Characteristics of Freshwater Fishes Occurring in Newfoundland and Labrador, with Major Emphasis on Lake Habitat Requirements

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April 1999

Canadian Manuscript Report of
Fisheries and Aquatic Sciences
No. 2485

Fisheries and Oceans   Pêches et Océans

Canada

CANADIAN MANUSCRIPT REPORT

OF FISHERIES AND AQUATIC SCIENCES 2485

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WITH MAJOR EMPHASIS ON

LAKE HABITAT REQUIREMENTS

by

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Minister of Supply and Services Canada 1999
Cat. No. FS97-4/2485 ISSN 070-6473

Correct citation of this publication:
Bradbury, C., M.M. Roberge and C.K. Minns. 1999. Life History Characteristics of Freshwater Fishes Occurring in Newfoundland and Labrador, with Major Emphasis on Lake Habitat Characteristics. Can. MS Rep. Fish. Aquat. Sci. 2485:vii+150p.

ABSTRACT

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An extensive literature review was performed to compile information on habitat use among various life stages of freshwater and anadromous/catadromous fishes occurring throughout Newfoundland and Labrador. The major emphasis was placed on the use of lake habitats by species for some portion of their life cycle. Preferences for the main physical habitat features water depth, substrate type, and cover (i.e. structural complexity) were rated as nil, low, medium, or high. Habitat preference tables were assembled for 26 of 31 species. In some instances, separate tables were compiled for different morphotypes or life history patterns within species. In addition, text synopses were prepared for each species noting additional life history and habitat preference data. The additional information highlights the habitat use flexibility species may show in different ecosystems. Within the lentic environment, there are often seasonal and temporal shifts in habitat use by various species. Fish distributions and abundance are often related to early life history requirements, food availability, spawning requirements and the likelihood of overwintering survival which results in seasonal and/or size-related changes in habitat use. Furthermore, intra- and inter-specific competition, predation risk and various environmental variables may also cause shifts in habitat utilization.

RESUME

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Nous avons effectué une analyse documentaire exhaustive afin de recueillir de l’information sur l’utilisation de l’habitat pour différents stades biologiques de poissons dulcicoles et anadromes/catadromes des eaux de Terre-Neuve et du Labrador. L’analyse s’est principalement concentrée sur l’utilisation des habitats lacustres, par espèce, pour une période spécifique du cycle biologique. Les préférences quant aux caractéristiques physiques principales de l’habitat, c’est-à-dire la profondeur de l’eau, le type de substrat et le couvert (par exemple, la complexité de la surface), ont été évaluées comme nulles, faibles, moyennes et fortes. Des tables de préférence de l’habitat ont été établies pour 26 des 31 espèces. Dans certains cas, des tables séparées ont été calculées pour différents morphotypes ou patrons de cycle biologique chez une même espèce. De plus, nous avons préparé un court narratif pour chaque espèce, en notant les données supplémentaires sur les cycles biologiques et les préférences en matière d’habitat. Cette information additionnelle met en relief la flexibilité de l’utilisation de l’habitat dont font preuve les espèces selon l’écosystème. Dans l’environnement lentique, il y a souvent des changements saisonniers et temporels dans l’utilisation de l’habitat par les différentes espèces. La distribution et l’abondance des poissons sont souvent reliées aux besoins du début du cycle biologique, à la disponibilité de la nourriture, aux exigences de la fraye et à la probabilité de survie hiémale, ce qui produit des changements liés à la saison et/ou à la taille dans l’utilisation de l’habitat. En outre, la compétition intra et interspécifique, le risque de prédation et différentes variables environnementales peuvent aussi causer des changements dans l’utilisation de l’habitat.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

Information on the diversity and complexity of habitat use by various life stages of fish is necessary for the effective management of fish and their habitat. This knowledge is particularly important when assessing potential impacts on fish and fish habitat resulting from various development activities. It is believed that one of the main causes of the continuing decline of freshwater fishes in Canada is the destruction and degradation of fish habitat (Beamish et al. 1986; Pearse 1988). Although physical habitat features such as water depth, substrate type and cover are important to the growth, survival, distribution and abundance of various fish species, habitat use is not solely dependant on attributes of the physical environment. Spatial and temporal variations in prey availability (Werner and Mittlebach 1981; Werner et al. 1983a), predation risk (Werner et al. 1983b), intra- or inter-specific competition and various environmental variables such as water quality may cause shifts in habitat utilization within lacustrine systems. For instance, the location of fish within the water column can be greatly influenced by water temperature, especially in thermally stratified lakes. Spawning requirements and overwintering survival also influence the distribution and movements of many fish species.

Most fish species undergo ontogenetic, or size-related, shifts in habitat use. This often results in the selection of different habitat types by different-sized individuals which is based on trade-offs between costs (i.e., predation risk, competition) and benefits (i.e., increased foraging). These ontogenetic niche shifts often reduce intraspecific competition among various life stages and may also reduce encounters with potential predators. Consequently, predator avoidance and competitive interactions between species may result in the movement of younger and smaller fish to less preferred habitats (i.e., areas with fewer competitors/predators and more refuge sites, but less prey abundance). In lake ecosystems, the littoral zone is considered to be a highly productive area, providing spawning, rearing and/or feeding habitat for most freshwater fish species during at least one stage of their life cycle. The structural complexity of the littoral zone (e.g. vegetation, woody debris, rocky substrate, etc.), provides shelter for younger and smaller fish against predators and competitors (Orth et al. 1984), while the unstructured pelagic zone can be a more risky habitat (Sandlund et al. 1992b; L'Abee-Lund et al. 1993).

Many fish species have specific substrate preferences during particular stages of their life histories. Apart from species that broadcast their eggs, fish usually have very specific spawning substrate requirements. However, even broadcast spawners may prefer certain depths or substrate types since the type and quality of substrate on which eggs are deposited is often crucial to reproductive success. Spawning is typically the most intensively studied aspect in the life history of fish mainly because adults of many species move into nearshore areas of lakes to spawn so that individuals are often concentrated in relatively small areas, making them readily observable and more susceptible to capture. Despite the disproportionate amount of attention spawning habitat has received, relative to other life stages, descriptions of spawning habitat for some species still remain vague. Documentation dealing specifically with nursery habitats is also quite limited for many species. According to Casselman and Lewis (1996), this is partly because young-of-the-year (YOY) are often difficult to catch and usually require specialized sampling techniques or gear (e.g. electrofishing or plexiglass traps).

This document represents a summary of physical lake habitat requirements of various life history stages of freshwater and anadromous/catadromous fishes occurring throughout Newfoundland and Labrador. Although certain conclusions regarding lacustrine habitat utilization can be drawn from the information compiled in this report, its limitations must be noted. First, and probably most importantly, although the Newfoundland and Labrador studies reviewed reported information on life history characteristics such as growth, age, fecundity and feeding, they rarely contained specific information on habitat utilization or basic habitat requirements. Consequently, much of the data compiled in this report was supplemented by studies from similar geographical areas in Canada, the United States and other countries in north temperate locations. Several investigators have suggested that juvenile Atlantic salmon are able to make widespread use of lacustrine habitats in Newfoundland mainly due to a relative lack of predators or competitors of the families Esocidae, Cyprinidae and Percidae (Scott and Crossman 1964; O'Connell and Ash 1989, 1993; Gibson 1993). It is likely that this general statement applies to all species of insular Newfoundland. Therefore, some of the literature cited in this report may only be generally applicable for species in this region and until similar findings have been reported for Newfoundland populations, one should be cautious about making extrapolations based on information where these species are more prevalent.

Secondly, the authors acknowledge that a lot of 'grey' literature (i.e., consultant reports and unpublished records) exists which generally have a very limited distribution. These reports rarely occur in major libraries and almost never appear in standard abstracts. There was no efficient way of finding this material and consequently, much of this information may have been overlooked. Thirdly, our assessment of the relative significance of particular habitats to individual species was necessarily subjective. Much of the information was derived from studies that sampled specific habitats, rather than a range of habitats. Undoubtedly, some habitats (e.g. predominantly boulder habitats) which are difficult to sample with traditional gear have received less attention than those for which the sampling equipment is better suited. Depth of occurrence also poses a problem, as water temperature often plays a critical role in depth selection which may vary depending on the size of the lake, season and activity levels. These limitations notwithstanding, the data summarized in this report are useful in assessing the relative significance of different lake habitats to various life stages of freshwater fishes occurring in Newfoundland and Labrador.

METHODS

This report includes all species of fishes reported to occur in the fresh waters of Newfoundland and/or Labrador. An extensive literature search was carried out to obtain information on lake habitat use among various life stages of freshwater fish species occurring in Newfoundland and Labrador. Databases searched included:

- various reference texts including Scott and Crossman 1964, 1973; Leim and Scott 1966; McPhail and Lindsey 1970; Burgess 1978; Morrow 1980; Becker 1983; and Scott and Scott 1988;
- DFO Underwater World Factsheets;
- DFO (Newfoundland Region) publications and scientific reports;

- reference list compiled on the Lower Churchill River, Labrador by D. Sooley and B. Moriarity, MEHM, DFO Newfoundland Region;
- various environmental reports submitted to DFO during provincial/federal environmental assessment processes;
- research theses at Memorial University of Newfoundland, St. John's, NF;
- Fisheries and Aquatic Sciences Abstracts (1970-present); and
- various Habitat Suitability Index (HSI) Models and Species Profiles published by the U.S. Fish and Wildlife, Biological Services.

The major life history characteristics of all freshwater and anadromous/catadromous fishes occurring in Newfoundland and Labrador is summarized, with the major emphasis on species utilizing lake habitats for at least a portion of their life cycle. Four distinct life stages have been identified; i) spawning, ii) YOY, iii) juveniles and iv) adults. Habitat requirements were reported on the basis of three physical habitat features: i) water depth, ii) substrate type, including pelagic (i.e. open-water areas, not directly influenced by the shore or the bottom) and iii) structure/cover.

<u>Water Depth</u>
A total of five water depth categories were employed; 0-1, 1-2, 2-5, 5-10 and >10 m.

<u>Substrate Type</u>

Substrate composition was reported exactly as stated in the reference, however, if particle size was provided, substrate type was classified according to Scruton et al. (1992).

<u>Cover</u>
Cover is defined as features within the aquatic environment that may be used by fish for protection (or refuge) from predators, competitors and adverse environmental conditions. Recruitment of many fish species has also been shown to be associated with availability of nearshore cover (Wright 1990). In addition cover may provide spawning habitat for some fish species (e.g. pike) as well as substrate for potential prey.

The following categories were used to define cover:

- submergent vegetation - aquatic plants that grow entirely below the water's surface (e.g. elodea, pondweeds, bladderwort, pipewort) and includes numerous mosses and macroalgae;
- emergent vegetation - aquatic plants which grow on water-saturated or submerged soils and extend their stems and leaves above the surface of the water (e.g. cattails, grasses, sedges and rushes);
- overhead - riparian cover overhanging the littoral zone, undercut banks and woody debris at the surface of the water;
- *in situ* - rocks and boulders on a sand/gravel substrate, submerged woody debris, etc.; and
- other which included any type of cover not defined in the above categories.

The strength of association with these habitat features was reported in tabular format using a rating system as follows; high (species is nearly always associated), medium (species is frequently associated), low (species is infrequently associated), nil (species is not associated) and cases where no information was found to indicate that a species utilizes a particular habitat feature were left blank (Tables 2-30). Where there was no available information on specific lake habitat utilization, a rating was made based on known habitat requirements of similar life stages, information on diet/feeding, and on occasion extrapolations were made regarding the use of cover in lotic environments; these ratings appear in the tables in italics. All references cited in the Comments and Observations section of Tables 2-31 are listed in alphabetical order in the Common Reference List on p. 118. Only those references containing specific information on species utilization of water depth, substrate type and cover were assigned a numeric value for ease of representation. The non-numeric references are listed in the Reference list on p. 45.

RESULTS

A total of 31 species, three introduced (or exotic) and 28 native (or indigenous), are reported to occur throughout the fresh waters of either Newfoundland or Labrador. Several hybrids have also been reported including; splake (lake trout x brook trout) (R. Burton, DFO, pers. comm.) and tiger trout (brown trout x brook trout), as well as crosses between brown trout and Atlantic salmon, and Arctic charr with several species including brook trout, Atlantic salmon and lake trout (Hammar et al. 1989). For a complete listing of these species (excluding hybrids) and their distribution refer to Table 1; the list is presented in alphabetical order by common names (i.e., family and species). The common and scientific names of fish species cited in this report generally follows Robbins et al. (1991). A map of Newfoundland and Labrador, highlighting reference locations quoted throughout the report, is shown in Fig. 1. Of the 31 species, 24 enter lakes for at least a portion of their life cycle, while there is evidence that two, although very rarely, (e.g. Atlantic tomcod and mummichog) occur as landlocked populations and one (e.g. longnose dace) has been reported as being typically a stream inhabitant but has been found in lakes in other areas throughout its geographical range. Four species have not been reported to enter lake habitats during any stage of their life cycle (e.g. American shad, Atlantic sturgeon, pink salmon and blackspotted stickleback).

The time periods provided throughout this report on critical periods for fish in Newfoundland and Labrador are only approximate and are intended as a rough guideline. Environmental factors such as temperature, photoperiod and variable stream discharges ultimately determine the actual timing of critical events such as spawning migration, incubation period and hatching. Consequently, the timing of these activities may vary from year to year and from one locality to another.

The following is a summary of the major life history stages of all species (excluding hybrids) including their habitat requirements, with major emphasis on lake inhabitance.

Cod (Gadidae)

Atlantic tomcod (*Microgadus tomcod*)

In eastern North America, the Atlantic tomcod is mainly distributed in coastal and brackish waters along the Atlantic coast from the Hamilton Inlet-Lake Melville region of southern Labrador to North Carolina (Scott and Scott 1988). Tomcod are generally found at the high tide mark of saltmarshes and mudflats in eelgrass (*Zostera* sp.) beds and occur to a maximum depth of approximately 6 m in bays, estuaries and coastal waters never ranging far from shore (Bigelow and Schroeder 1953; Stewart and Auster 1987). Atlantic tomcod, however, have been reported to ascend rivers well beyond the farthest point of seaward intrusion (Bigelow and Schroeder 1953; Leim and Scott 1966) and totally landlocked populations have been reported in Newfoundland (Seabrook 1962; Scott and Crossman 1973) and eastern Quebec (Legendre and Lagueux 1948).

Spawning typically occurs in early to mid-winter, usually beneath the ice and although tomcod may spawn in saltwater, they apparently prefer to spawn in shallow waters of estuaries or stream mouths in brackish or fresh water (Frost 1938b; Dew and Hecht 1976; Able 1978; Scott and Scott 1988). During spawning, females release somewhat adhesive eggs over sand or gravel substrates to which the eggs readily attach (Scott and Crossman 1973; Scott and Scott 1988). Upon hatching, larvae drift downstream to estuarial waters where they typically remain throughout the summer months (Frost 1938b; Bigelow and Schroeder 1953; Peterson et al. 1980; Stewart and Auster 1987; Scott and Scott 1988).

Burbot (*Lota lota*)

Burbot occur throughout southern Labrador, except for the southeastern corner (Black et al. 1986), but have not been reported in insular Newfoundland (Scott and Crossman 1973). The burbot is the only true freshwater representative of an otherwise marine family (the cods, Gadidae). It is also one of the few freshwater fishes that spawn under the ice in winter, usually between January and March (McCrimmon and Devitt 1954; Lawler 1963; Faber 1970; Sorokin 1971; Scott and Crossman 1973; Bruce 1974; Morrow 1980; Mansfield et al. 1983; Breeser et al. 1988; Boag 1989; Ford et al. 1995). Burbot have been observed spawning in both lakes (Boag 1989; Ghan and Sprules 1991) and rivers over clean sand, gravel or cobble/rubble substrates (McCrimmon and Devitt 1954; Sorokin 1971; Scott and Crossman 1973; Bruce 1974; Morrow 1980; Mansfield et al. 1983; Breeser et al. 1988; Evenson 1993; Ford et al. 1995). In lakes, spawning occurs in areas with little accumulation of silt or detritus, usually at depths of 0.3-3.0 m, but has been reported at depths of 18-20 m (McCrimmon and Devitt 1954; McPhail and Lindsey 1970; Sorokin 1971; Scott and Crossman 1973; Morrow 1980; Mansfield et al. 1983; Boag 1989; Ford et al. 1995).

During spawning, eggs are broadcast into the water column well above the substrate (Fabricius 1954). They are semi-buoyant when first laid, but become demersal within a few days and settle into interstices in the substrate (Sorokin 1971; Morrow 1980; Ford et al. 1995). Eggs incubate for 3-4 months and upon hatching, larvae are pelagic (Clady 1976; Mansfield et al. 1983; Ghan and Sprules 1991; Ryder and Pesendorfer 1992). At about 30 mm, which is generally attained by early summer, larval burbot undergo a habitat shift from pelagic to a mainly benthic existence (McPhail 1997). YOY are typically found in the littoral regions of lakes over gravel, cobble or rubble bottoms (Lawler 1963; Faber 1970; Ford et al. 1995) where they have been observed in shallow water (0.5-3.0 m) during the day, sheltering under rocks and debris and are mainly active at night (Lawler 1963; Boag 1989; Ryder and Pesendorfer 1992). Juveniles have been shown to occupy essentially the same habitat as YOY and feed mainly on benthic invertebrates (McPhail 1997). In streams, young typically use undercut banks, submerged logs and vegetation for cover in sandy areas if rocky habitat is limited (Scott and Crossman 1973; Hanson and Qadri 1980). Throughout its geographical range in Canada, burbot generally reach sexual maturity between 2-8 years of age (McCrimmon and Devitt 1954; Scott and Crossman 1973; Ryan 1980; Ford et al. 1995) and have been shown to mature at 5-6 years of age in Labrador (Ryan 1980).

In lakes, both adults and juveniles congregate in areas with gravel, cobble or rubble substrate (Scott and Crossman 1973; Morrow 1980; Ford et al. 1995). As water temperatures increase during the summer, adult burbot tend to move offshore to deeper waters (i.e. hypolimnion zone) and return to littoral regions during the autumnal decline in water temperatures (Lawler 1963; Scott and Crossman 1973; Bruce 1974; Morrow 1980; Kirillov 1988a and b; Carl 1992; Edsall et al. 1993; Ford et al. 1995). In shallow water, especially where the bottom is brightly illuminated, burbot may seek overhead cover during the day and are sometimes found amongst aquatic plants (Edsall et al. 1993). The loft habitat provided by the tops of boulders is also a preferred resting area for adults (Edsall et al. 1993). Although adult burbot are mainly piscivorous (McCrimmon and Devitt 1954; Lawler 1963; Bruce 1974; Parsons 1975; Bruce and Parsons 1979; Ryan 1980), they have been found to consume large quantities of benthic invertebrates during the summer and fall (Lawler 1963; Bailey 1972; Ryan 1980).

Eels (Anguillidae)

American eel (*Anguilla rostrata*)

American eels are common inhabitants of inland waters along the Atlantic coast and have been reported throughout Newfoundland and the southeastern coast of Labrador as far north as the Churchill River (Backus 1957; Scott and Crossman 1973; Black et al. 1986; Scott and Scott 1988). The American eel is catadromous spending most of its life in freshwater and estuaries but migrating to sea to spawn. Eels typically begin their spawning migration in late summer and fall throughout much of eastern Canada (Burgess 1978; Jessop 1984, 1987, 1996; Scruton et al. 1997), although migration from lakes that are far inland may begin earlier (Facey and Van Den Avyle 1987). Peak migratory activity often occurs in September-October (Jessop 1987) during the last quarter of the moon (Jessop 1984) and is enhanced by dark, stormy nights and rising water levels (Templeman 1966; Jessop 1984).

Eels spawn in the Sargasso Sea, with peak spawning occurring in mid-winter between January and March (Frost 1939; Jessop 1984; Helfman et al. 1987; McCleave et al. 1987), but may extend as late as May or June according to Vladykov and March (1975). Although the depth at which spawning occurs is not known, evidence suggests that eels spawn in the upper few hundred meters of the water column (Kleckner et al. 1983; McCleave and Kleckner 1985). Adult eels presumably die after spawning (Frost 1939; Jessop 1984; Scott and Scott 1988; Jessop 1996).

After hatching, larvae drift in the surface ocean currents, remaining at sea for approximately one year before undergoing metamorphosis and assuming the adult form (Frost 1939; Templeman 1966; Facey and Van Den Avyle 1987; Helfman et al. 1987; Jessop 1996). In late spring or early summer, young approach freshwater (Smith and Saunders 1955; Leim and Scott 1966; Templeman 1966; Scott and Crossman 1973) and in most areas of insular Newfoundland, begin their upstream migration in early June to mid-August, always entering freshwater at night and on a rising tide (Hudson 1974; McCleave and Kleckner 1980; McCleave and Wippelhauser 1987; Scruton et al. 1997).

During the freshwater phase of their life history, eels move into streams, rivers and muddy or silt-bottomed lakes (Frost 1939; Scott and Crossman 1973; Scott and Scott 1988), generally following the bank of the river in very shallow water (Becker 1983). Eels can be very mobile and may gain access to ponds and lakes, which appear unavailable to them, by using very small watercourses or by moving overland through wet grass (Frost 1939; Scott and Scott 1988). Eels, being nocturnal, usually spend the day hiding under rocks and logs or buried in the mud (Scott and Crossman 1973; Becker 1983; Helfman et al. 1983; Jessop 1984). In Lake Champlain, Vermont, American eels were generally found in weedy areas at depths <10 m, over a mainly sandy bottom with some mud (LaBar and Facey 1983). Investigations on diet composition of juvenile eels suggest that American eels rely heavily on benthic organisms and demersal fishes as food sources (Hudson 1974; Facey and LaBar 1981).

There are indications that a proportion of eels remain in brackish estuaries and do not enter freshwater at all (Leim and Scott 1966; Jessop 1984), and in certain areas of Newfoundland, eel densities may be higher in brackish than in freshwater habitats (Gray 1969). Gray and Andrews (1971) found that eels in brackish waters were generally older and larger than eels captured in freshwater habitats. Eels generally hibernate at temperatures $<4^{0}$C (Tesch 1977), in the muddy bottoms of lakes and rivers over winter (Frost 1939; Vladykov 1955; Scott and Crossman 1973; Scott and Scott 1988). American eels may remain in freshwater for 5-20 years or longer before attaining sexual maturity and undergoing seaward migration to spawn (Jessop 1984, 1996). In Newfoundland, Gray and Andrews (1971) found that most eels migrate to sea after spending 12 to 13 years in freshwater.

Herring (Clupeidae)

Alewife (*Alosa pseudoharengus*)

Alewives have been reported in Newfoundland (Winters et al. 1973) and southern Labrador (Hare and Murphy 1974; Anderson 1985; Scott and Scott 1988; Communications Directorate 1993) where they occur in either anadromous or landlocked forms. Anadromous alewives utilize brackish or freshwater areas for spawning but spend most of their life at sea (Mullen et al. 1986), whereas landlocked alewives spend their entire life in freshwater (Scott and Crossman 1973; Scott and Scott 1988; Jessop 1990). Several studies have described alewives spawning in freshwater ponds that have an open connection with the ocean (Havey 1973; Kissil 1974). Spawning occurs along shallow beaches of lakes or in slow moving sections of rivers above tidal influence, typically over a sand/gravel substrate (Leim and Scott 1966; Scott and Crossman 1973; Kissil 1974; Burgess 1978; Nigro and Ney 1982; Loesch 1987; Scott and Scott 1988). During spawning, demersal eggs are broadcast at random and are essentially nonadhesive (Scott and Crossman 1973; Jessop 1990).

Anadromous

Upstream spawning migration may extend from April to early June (Burgess 1978; Durbin et al. 1979; Jessop 1990) with spawning typically commencing in mid-May or June, once water temperatures reach 9-12^{0}C (Lackey 1970; Scott and Scott 1988; Jessop 1990). Adults leave inshore waters shortly after spawning, most migrating to deep water sometime in late August (Scott and Crossman 1973; Kissil 1974; Loesch 1987; Jessop 1990). This seasonal migration appears to be triggered by increasing water levels (Mullen et al. 1986).

Young remain on spawning grounds until at least the late larval stage before migrating to sea in late summer or fall during their first year of life (Leim and Scott 1966; Kissil 1974; Richkus 1975; Durbin et al. 1979; Scott and Scott 1988; Jessop 1990). There is evidence, however, that some young remain in inshore waters for one or two years before migrating offshore to deeper, colder waters (Bozeman and Van Den Avyle 1989; Jessop 1990). Seaward migration by juveniles is usually initiated by high water levels and sharp drops in water temperature (Kissil 1974; Richkus 1974; Mullen et al. 1986). In freshwater habitats, juveniles are typically concentrated near the bottom during the day and move up into the water column at night (Loesch 1987). Young alewives generally remain at sea 4-5 years before maturing and returning to freshwater to spawn (Jessop 1990). At times, however, immature alewives (mostly 2 years of age) have been observed migrating into lakes during the latter part of the spawning run from mid- to late June (Jessop 1990). Although it has been reported that few alewives live beyond 5 to 6 years of age (Threinen 1958), alewives 9 and 10 years old have been captured in North Carolina (Street et al. 1975; Johnson et al. 1977) and Nova Scotia (O'Neill 1980), respectively.

Freshwater resident

Landlocked alewives typically move into shallow inshore areas to spawn, returning to deeper areas of the lake once spawning is complete (Lackey 1970; Lindenberg 1976; Jessop 1990). YOY remain in shallow, nearshore spawning sites during July and August (Reckahn 1970) and generally move into deeper waters as they grow and mature (Jessop 1990). Juveniles have been shown to exhibit significant diel movements, occupying areas close to the bottom during the day and moving up towards the surface at night (Lindenberg 1976). Adults generally occupy open water areas throughout most of the year, occurring at depths ranging from 1-14 m (Lackey 1970; Reckahn 1970; Scott and Crossman 1973; Lindenberg 1976). During summer and early fall, adults are commonly found near the bottom in offshore waters during the day and occur up in the water column in nearshore regions of the lake at night (Scott and Crossman 1973; Janssen and Brandt 1980). It has been suggested that this migration within the water column is in response to alewives following the vertical migration of mysids (Janssen and Brandt 1980). During late fall and winter, alewives are mainly pelagic, avoiding both surface and bottom waters (Lindenberg 1976).

American shad (*Alosa sapidissima*)

The American shad is the largest member of the herring family, Clupeidae (Dadswell 1986). Although American shad occur in freshwaters of Newfoundland (Scott and Crossman 1964; Hodder 1966; Chadwick et al. 1978; Chadwick 1981) and Labrador (Hare and Murphy 1974; Dempson et al. 1983; Anderson 1985), they are not abundant in these areas and probably represent stray occurrences rather than self-sustaining populations (Dempson et al. 1983). American shad is an anadromous fish which spends 2-6 years at sea before maturing and returning to its natal river to spawn (Leggett 1976; Leggett and Carscadden 1978; Morrow 1980; Steir and Crance 1985; Dadswell 1986; Melvin et al. 1986; Weiss-Glanz et al. 1986). In Canadian waters, adults may spawn up to 7 times and live to be 13 years of age (Dadswell 1986).

In eastern Canada, spawning runs of shad enter rivers between late April and late June (Dadswell 1986) with few, if any, entering rivers before water temperatures reach at least 4^0C (Leggett 1976). Spawning normally occurs in May and June, but may occur as late as July (Leim and Scott 1966; Steir and Crance 1985; Scott and Scott 1988) at water temperatures ranging from 13-20^0C (Weiss-Glanz et al. 1986; Dadswell 1986; Scott and Scott 1988). Unlike the alewife, shad spawn in rivers or brackish estuarine waters, seldom if ever in lakes (Leim and Scott 1966; Scott and Crossman 1973; Scott and Scott 1988). River spawning usually takes place in moderate to strong flowing water (Marcy 1972; Dadswell 1986; Scott and Scott 1988; Ross et al. 1993a and b), generally where there is sufficient velocity to eliminate silt deposits (Steir and Crance 1985) and at the same time, far enough upstream for eggs to drift and hatch before reaching saltwater (Steir and Crance 1985; Weiss-Glanz et al. 1986). It is generally thought that substrate is unimportant to shad since spawning occurs in the water column and eggs are carried downstream by the current. Leggett (1976) observed shad spawning over sand, silt, muck, gravel and boulder substrate, whereas Morrow (1980) and Steir and Crance (1985) found shad preferably spawning over sand or gravel substrate. Water depth does not appear to be a critical factor for spawning either, since shad have been found to spawn at depths ranging from 0.2 to 12 m (Steir and Crance 1985; Weiss-Glanz et al. 1986; Ross et al. 1993a).

During spawning, nonadhesive eggs are released into open water where they are carried along by currents, and being slightly heavier than water, gradually sink to the bottom (Scott and Crossman 1973; Morrow 1980; Steir and Crance 1985; Dadswell 1986; Weiss-Glanz et al. 1986; Scott and Scott 1988). Upon hatching (8-12 days at temperatures between 11-15^0C) (Dadswell 1986), larvae are planktonic and do not metamorphose into juveniles for 4-5 weeks (Steir and Crance 1985; Weiss-Glanz et al. 1986). Juveniles gradually move downstream to brackish water (Leim and Scott 1966; Steir and Crance 1985; Weiss-Glanz et al. 1986) and by fall, when water temperatures fall below 15^0C, all have left freshwater (Scott and Crossman 1973; Morrow 1980; Dadswell 1986). Some juveniles spend their first year in estuarine waters, while others migrate directly to sea (Steir and Crance 1985).

Adult shad return to sea shortly after spawning (Leim and Scott 1966; Scott and Crossman 1973; Leggett 1976; Morrow 1980; Dadswell 1986) or in the fall, usually in October or November, to overwinter at sea (Scott and Scott 1988). At sea, shad exhibit an extensive northward migration during the summer, some moving as far north as Nain, Labrador (Dempson et al. 1983) before returning to southern regions of their oceanic range in winter (Dadswell 1986). Dadswell (1986) suggested that by undertaking this migratory pattern, shad are able to maintain themselves in the 13-18^{0}C ocean isotherm, their preferred temperature range. It should be noted that there is a discrepancy in the literature concerning the preferred temperature range of American shad; Leggett and Whitney (1972) and Dadswell (1986) report a temperature preference between 13-18^{0}C, while Neves and Depres (1979) report a temperature preference between 3-15^{0}C.

Killifishes (Cyprinodontidae)

Banded killifish (*Fundulus diaphanus*)

Although the banded killifish is widely distributed throughout the Atlantic provinces, it has an extremely limited distribution in Newfoundland (Scott and Crossman 1973; Gibson et al. 1984; Houston 1990). Temperatures of 21-23^{0}C appear to be necessary for killifish reproduction (Carlander 1969; Houston 1990). It has been suggested that the cooler waters of Newfoundland may limit their distribution and further immigration to the island is unlikely due to either a lack of suitable habitat or thermal barriers to dispersion (Houston 1990). Gibson et al. (1984) also suggested that a lack of suitable habitat along the coast and the steep gradient of the rivers may constitute barriers to immigration to sites further inland. Although the banded killifish is euryhaline, it usually inhabits freshwater streams and lakes, rarely being found in brackish or marine waters (Leim and Scott 1966; Fritz and Garside 1974, 1975; Scott and Scott 1988; Houston 1990). Killifish are most abundant in very shallow waters and have a preference for clear, glacial lakes with sluggish waters and abundant aquatic vegetation (Scott and Crossman 1973; Cooper 1983; Scott and Scott 1988; Houston 1990).

According to Gibson et al. (1984), spawning probably occurs in mid- or late summer in Newfoundland. Spawning generally occurs in quiet shallows of weedy lakes and ponds at which time clusters of eggs are released that attach to aquatic vegetation (Scott and Crossman 1973; Burgess 1978; Houston 1990). Individuals typically reach sexual maturity at an age of 1+ years and a total length of about 6 cm (Carlander 1969). Banded killifish are a schooling fish usually found in shallow water over sand, gravel or detritus-covered bottoms near patches of submerged aquatic plants (Scott and Crossman 1973; Keast et al. 1978; Rozas and Odum 1987; Killgore et al. 1989). In southeastern Newfoundland, Gibson et al. (1984) reported capturing killifish over a sand/cobble substrate. Within these areas, killifish are found to utilize all levels of the water column (Keast and Webb 1966; Scott and Crossman 1973; Houston 1990).

Mummichog (*Fundulus heteroclitus*)

The mummichog occurs throughout brackish shore waters of all the Atlantic provinces extending to Port au Port Bay (Scott and Crossman 1973) and the Bay of Islands (Dickinson 1974) region of southwestern Newfoundland. In particular, the mummichog is an inhabitant of estuaries, marshy areas and brackish-water ponds, preferring regions where there is submergent and emergent vegetation (Scott and Crossman 1973; Scott and Scott 1988). Mummichog are a mainly schooling fish, living close to the surface in shallow water (Scott and Crossman 1973). It may live in situations where it is likely to be trapped by tidal movement or drying up of small ponds and is very tolerant of low oxygen conditions, surviving in stagnant water for long periods (Leim and Scott 1966; Scott and Scott 1988). There is also evidence that landlocked mummichog may occur in some freshwater ponds and lakes (Klawe 1957).

During spawning, which occurs in shallow water from April to August (Leim and Scott 1966; Scott and Crossman 1973; Taylor et al. 1977; Burgess 1978; Scott and Scott 1988), adhesive eggs are deposited in clutches on aquatic plants, algal mats or in sand/mud substrates (Leim and Scott 1966; Scott and Crossman 1973; Taylor et al. 1977; Able 1984; Scott and Scott 1988). Able and Castagna (1975) also documented eggs being deposited into empty mussel shells in the intertidal zone during six consecutive summers. Eggs may be exposed at low tide and therefore have a capacity for delayed hatching (Taylor et al. 1977).

On the west coast of Newfoundland, large concentrations of mummichog were found in a semi-stagnant backwater area of an estuary at depths of 1 m, over a mainly mud bottom which was practically devoid of vegetation (Dickinson 1974). Mummichog were also reported from a small lagoon comprised of a mainly soft mud bottom and supporting dense growth of *Zostera* sp. (Dickinson 1974). In winter, mummichog have been found in holes in tidal streams and buried in mud (Leim and Scott 1966; Scott and Scott 1988).

Competition with banded killifish, where the two are sympatric, seems to be minimized by differences in diet and foraging patterns (Baker-Dittus 1978; Weisberg 1986).

Lampreys (Petromyzontidae)

Sea lamprey (*Petromyzon marinus*)

The sea lamprey occurs off the Atlantic coast of North America from southwest Greenland to northern Florida (Bigelow and Schroeder 1948) and rare occurrences have been reported in inshore areas of Newfoundland (Scott and Scott 1988; Dempson and Porter 1993) and Labrador (Low 1895; Murphy 1972; Anderson 1985). Although sea lamprey are common in the Atlantic provinces (Scott and Crossman 1973), in Newfoundland, spawning populations have only been reported from the Terra Nova River system (Dempson and Porter 1993). Sea lamprey normally live in saltwater and migrate into freshwater to spawn (Beamish 1980; Dees 1980; Downs 1982; Scott and Scott 1988; Halliday 1991). It can, however, live its entire life in freshwater, and often resides in lakes where it leads a parasitic or predatory existence, feeding on other fishes (Dees 1980; Downs 1982; Scott and Scott 1988).

At the time when spawning migration starts, lamprey cease feeding and begin maturing sexually, so only from that time is it reasonable to refer to them adults. Spawning usually occurs in streams in spring and early summer in moderate to fast flowing water over a mixture of sand, gravel and rubble substrate (Wadden 1968; Hardisty and Potter 1971b; Hardisty 1979; Downs

1982; Scott and Scott 1988). Both breeding adults build a nest usually in shallow water at depths of 25-50 cm (Wadden 1968; Downs 1982; Scott and Scott 1988). In Newfoundland, Dempson and Porter (1993) observed lamprey spawning in July in the Terra Nova River at depths of 25 cm to 1 m over a mainly gravel/cobble substrate. During spawning, adhesive eggs are deposited into a nest where they lodge in the spaces among stones (Dees 1980) and hatch in 2-3 weeks (Wadden 1968; Dees 1980; Downs 1982). Both males and females spawn only once and die shortly after reproduction, either within a few hours (Wadden 1968; Dees 1980; Scott and Scott 1988) or a few days of spawning (Scott and Crossman 1973; Downs 1982).

Within several weeks of hatching, ammocete larvae are carried downstream to quiet pools, where they construct burrows in areas of sand, silt and mud (Hardisty and Potter 1971a; Hardisty 1979; Beamish 1980; Dees 1980; Downs 1982; Scott and Scott 1988). Dempson and Porter (1993) found larvae up to 5 km downstream of the observed spawning area and noted that there was a general decrease in larval density with increasing distance from the spawning area. Although larvae may leave their burrows to engage in free swimming activity, they normally only do so at night (Wadden 1968; Hardisty and Potter 1971a; Hardisty 1979). Ammocete larvae may remain in burrows for 3-17 years feeding on microscopic plants and animals carried to them by water currents (Wadden 1968; Beamish 1980; Dees 1980; Downs 1982; Scott and Scott 1988). In mid-July, larvae begin a transformation to the adult phase (i.e., they undergo metamorphosis) which is usually complete by mid-October (Potter et al. 1978; Downs 1982). In the fall or the following spring, usually during periods of fluctuating stream flow, young either migrate downstream to the ocean (Beamish 1980; Scott and Scott 1988) or enter lakes (Wadden 1968; Morman 1979; Dees 1980; Smith and Tibbles 1980; Downs 1982; Scott and Scott 1988).

Little is known about the habits of parasitic lamprey in lakes except that there appears to be no limit to their depth distribution (Johnson and Anderson 1980); they may be found wherever host fishes occur. There is a general trend however, of sea lamprey inhabiting deeper waters of the lake during the summer and moving into shallow water during the fall, where they apparently remain throughout the winter (Wadden 1968; Scott and Crossman 1973; Johnson and Anderson 1980; Morman et al. 1980; Downs 1982). Further evidence of this inshore movement stems from observations of sea lamprey attacking lake trout and lake whitefish as they move into shallow water to spawn in the fall (Christie and Kolenosky 1980; Downs 1982). Sea lamprey can remain attached to its prey for hours, days or even weeks, feeding until it is satiated or the victim dies (Dees 1980; Downs 1982). The duration of the parasitic phase is unknown, but has been shown to last for 12-18 months in open lake areas (Downs 1982) or 2-3 years at sea (Potter and Beamish 1977). Thereafter, lamprey move into a suitable stream and the cycle begins again.

Minnows (Cyprinidae)

Lake chub (*Couesius plumbeus*)

Lake chub occur throughout the Churchill River system in Labrador (Backus 1951; Black et al. 1986), but are apparently absent from rivers in southern Labrador (Black et al. 1986) and insular Newfoundland. In northwestern Canada and Alaska, the lake chub has been found in both clear and turbid waters of lakes and streams (McPhail and Lindsey 1970), while in Labrador they have been reported to occur mostly in streams and lake-like expansions of rivers (Backus 1951, 1957). In central Canada, lake chub appear to be common in tributary streams only during spring spawning migrations, returning to the lake once water temperatures exceed 16^0C (Brown et al. 1970).

Lake chub usually undergo spawning migrations from lakes to tributary streams in May or June, shortly after ice-out (Brown et al. 1970; McPhail and Lindsey 1970; Scott and Crossman 1973; Bruce and Parsons 1976; Burgess 1978; Morrow 1980). In rivers and small streams, spawning has been observed in shallow water over rocky or gravel bottoms as well as amongst large rocks (McPhail and Lindsey 1970; Morrow 1980). In lakes, spawning typically takes place along shallow rocky shores and may be observed over a variety of substrates including silt, leaves, gravel, cobble and rubble (Brown et al. 1970). Males do not appear to build a nest or guard eggs, although they typically remain on the spawning grounds longer than females (Brown et al. 1970; Scott and Crossman 1973). In Labrador, lake chub generally mature at 2-3 years of age (Bruce and Parsons 1976).

McPhail and Lindsey (1970) reported that lake chub typically remain close to the bottom of lakes. Along shores, lake chub have been observed over a mainly sand bottom interspersed with large boulders (Becker 1983). Although it is essentially a shallow-water species (Becker 1983), lake chub have been reported to move into deeper and cooler regions of lakes during thermal summer stratification (Scott and Crossman 1973; Burgess 1978; Morrow 1980). In Labrador, lake chub were found to feed mainly on benthic invertebrates (Ryan 1980).

Longnose dace (*Rhinichthys cataractae*)

The longnose dace is widely distributed throughout north-central North America, yet in the Canadian Atlantic provinces, it has only been reported along the Churchill and Naskaupi river systems in southwestern Labrador (Scott and Crossman 1973; Black et al. 1986). Although the longnose dace is typically a stream inhabitant in Labrador (Ryan 1980), it has also been reported in lakes throughout its geographical range (Scott and Crossman 1973). According to Brazo et al. (1978), longnose dace have been shown to grow faster in lakes than in streams. Longnose dace have been studied extensively in stream habitats where it is common (Gibbons and Gee 1972; Hubert and Rahel 1989), however, little is known about lake-dwelling populations.

Although spawning normally occurs in gravel dominated riffles (Bartnik 1970; Brown et al. 1970; McPhail and Lindsey 1970; Scott and Crossman 1973; Ryan 1980), it may also occur in lakes (Gee and Machniak 1972; Brazo et al. 1978). Peak spawning usually occurs in June to early July in both lakes and streams (McPhail and Lindsey 1970; Gee and Machniak 1972; Brazo et al. 1978), however, spawning occurred 5-7 weeks later in Lake Winnipeg than in nearby streams, probably due to lower water temperatures in the lake (Gee and Machniak 1972). In lakes, spawning occurs along wave-swept inshore areas (Brazo et al. 1978) over a cobble/rubble/boulder substrate (Gee and Machniak 1972).

During spawning, demersal and adhesive eggs are deposited in groups among the substrate and although no nest is built, territories are often established, with one parent guarding the eggs

(Bartnik 1970, 1972; McPhail and Lindsey 1970). Young are pelagic upon hatching and occupy still, shallow waters close to shore for approximately their first four months of life (McPhail and Lindsey 1970; Gee and Machniak 1972; Scott and Crossman 1973; Ryan 1980). During this time they generally take refuge under cover of overhanging vegetation (Gee and Machniak 1972) and gravel/cobble substrate (Brazo et al. 1978) and feed primarily on algae, diatoms, zooplankton and fish scales (Edwards et al. 1983). Gee and Machniak (1972) suggested that YOY move to deeper areas of the lake predominated by swift currents, once they attain a size of 30 mm (total length).

In streams, longnose dace typically inhabit shallow (10-20 cm) areas of swift flowing water over gravel or boulder substrates (Smith 1979), moving into very fast water as adults, apparently seeking refuge among rock crevices (Scott and Crossman 1973; McPhail and Lindsey 1970; Mullen and Burton 1995). Longnose dace typically mature at 2 years of age (Bartnik 1970; McPhail and Lindsey 1970; Gibbons and Gee 1972; Brazo et al. 1978; Becker 1983) and rarely live longer than 4 years (Brazo et al. 1978). The oldest reported individual of this species was 5 years old found in eastern United States (Reed and Moulton 1973). In streams, adults seem to prefer areas with aquatic vegetation and overhead cover (Hubert and Rahel 1989) and may exhibit similar preferences in lake habitats. Although adults have been found in turbulent, inshore regions of lakes over boulder or gravel bottoms throughout the summer (Brazo et al. 1978; Smith 1979), they generally move into deeper, cooler waters as water temperatures increase (Scott and Crossman 1973). Brazo et al. (1978) reported that longnose dace feed primarily on terrestrial insects, that are presumably washed into the surge zone of the lake by wind and turbulent wave action, as well as benthic organisms and fish eggs.

Pearl dace (*Margariscus margarita*)

Although pearl dace have been reported in the Churchill River, Labrador, there have been no reported occurrences in insular Newfoundland (Scott and Crossman 1973). In southern Canada, the pearl dace typically inhabits cool, clear headwater streams, while in northern areas it is also found in ponds, small lakes, bog drainage streams and stained, acid waters of beaver ponds (Scott and Crossman 1973; Tallman et al. 1984; Bendell and McNicol 1987). Despite the reported abundance of pearl dace in most streams and lakes in northwestern Ontario (Tallman et al. 1984), they were rarely found in lakes containing northern pike (Beamish et al. 1976), suggesting that pearl dace represent an important forage species in lakes. In southern Canada, pearl dace are reported to prefer cool streams or boggy lakes and tend to avoid sandy habitats (McPhail and Lindsey 1970). In deep lakes (>5 m) exhibiting thermal stratification during the summer, pearl dace tend to move into deeper, cooler waters when water temperatures rise above 20^0C (Tallman et al. 1984).

In many northern lakes, pearl dace spawn in tributary streams or in vegetation on the periphery of lakes in early spring, about the time spring melt and ice-off occurs (Tallman et al. 1984). Spawning in beaver ponds and small lakes is typically over soft organic substrates (Bendell and McNicol 1987), while stream spawning occurs at depths of about 60 cm over a sand or gravel bottom in wide ranging currents (McPhail and Lindsey 1970). Males do not build nests, but appear to defend territories (Scott and Crossman 1973). Investigations on diet composition suggest that pearl dace are omnivorous, consuming invertebrates, plant material and detritus (Carlander 1969; McPhail and Lindsey 1970; Tallman and Gee 1982; Tallman et al. 1984).

Pikes (Esocidae)

Northern pike (*Esox lucius*)

Northern pike are found throughout southern Labrador including the southeastern corner to Sandwich Bay, but have not been found in a large number of areas north of this range (Black et al. 1986). Northern pike have not been reported in insular Newfoundland or other Atlantic provinces (Scott and Crossman 1973). Northern pike migrate to spawning areas immediately after the ice melts in spring (McPhail and Lindsey 1970; Scott and Crossman 1973; Burgess 1978; Casselman and Lewis 1996; Scruton et al. 1997). In Labrador, spawning normally takes place from mid-April to mid-May, shortly after ice-out (Scruton et al. 1997) at temperatures ranging from 6 to14^{0}C (Inskip 1982; Ford et al. 1995; Casselman and Lewis 1996; Craig 1996). Pike generally prefer shallow vegetated areas <4 m deep (Diana et al. 1977; Inskip 1982; Chapman and Mackay 1984a and b; Cook and Bergersen 1988) and are considered to be a mainly sedentary species (Ivanova 1969; Nursall 1973; Diana 1980).

Pike are broadcast spawners which release their adhesive eggs onto aquatic vegetation (McPhail and Lindsey 1970; Inskip 1982; Ford et al. 1995; Craig 1996). The preferred spawning substrate is a moderately dense mat of flooded vegetation in shallow (generally 5-60 cm depth), wind sheltered areas (McCarraher and Thomas 1972; Inskip 1982; Ford et al. 1995; Casselman and Lewis 1996; Craig 1996). Although grasses, sedges and rushes with fine leaves make the best substrate for egg deposition (McCarraher and Thomas 1972; Becker 1983; Casselman and Lewis 1996), the type of vegetation does not appear to be critical (Inskip 1982) providing the vegetative substrate is adequate to entrap eggs and suspend them above the substrate where anoxic conditions can develop (McCarraher and Thomas 1972). The type of bottom over which spawning occurs varies widely, but a soft, silt-filled area with decaying vegetation is common (Machniak 1975b). Inskip (1982) reported that the absence of inundated vegetation can inhibit or delay spawning. Thus, the following characteristics constitute suitable spawning sites for pike; presence of live or decaying vegetation, shallowness, no significant water current and some protection from dominant winds.

Upon hatching, typically in May (Scruton et al. 1997), larvae remain attached to vegetation for 6-10 days (Ford et al. 1995) which helps keep larvae removed from oxygen poor, hydrogen sulfide rich sediments typical of pike spawning grounds (Craig 1996). Young remain in shallow spawning areas for several weeks after hatching (Scott and Crossman 1973; Machniak 1975b; Inskip 1982; Holland and Huston 1984) and although the nursery area is generally contiguous with the spawning area, as young grow their preferred depth range increases. Generally, YOY during their first year of life prefer water 10 cm deep for every 12 mm of body length attained, at least until they reach 150 mm in length (Casselman and Lewis 1996). According to Grimm (1989) survival of 0+ pike in their first winter is determined by the amount of permanent cover, such as remnants of emersed plants, and when permanent cover is both sparse and occupied by larger pike, recruitment of yearling pike is very low. Thus juveniles prefer areas containing submerged vegetation (optimal vegetative densities of 40-90% cover) as it provides refuge from predators, including cannibalism by conspecifics (Grimm 1994), and adverse environmental conditions as well as shelter and food resources for potential prey (Inskip 1982; Ford et al. 1995). Bregazzi and Kennedy (1980) found that juvenile pike were always captured in association with weedbeds or reed. In Labrador, pike generally mature at 3-5 years of age (Bruce and Parsons 1979; Ryan 1980).

Although pike were found to be mainly piscivorous in Labrador, they were also shown to feed on benthic invertebrates (Bruce 1974, 1975b; Parsons 1975; Bruce and Parsons 1979; Ryan 1980). Adult pike engage in an 'ambush' style of foraging which requires cover usually in the form of aquatic vegetation, tree stumps or fallen logs (Inskip 1982). Complete vegetative cover is considered to be sub-optimal for adult pike, especially with respect to foraging efficiency (Savino and Stein 1989; Wright 1990; Ford et al. 1995). In general, foraging efficiency has been shown to decrease with increasing vegetation densities (Savino and Stein 1989). Unlike juveniles, adults prefer areas containing open water interspersed with moderately abundant vegetation comprising approximately 30-70% cover (Inskip 1982; Grimm and Backx 1990; Casselman and Lewis 1996; Randall et al. 1996). Grimm (1981) and Chapman and Mackay (1984a) pointed out that large pike are often found near the interface of vegetation and open water, while small pike are generally restricted to vegetated areas. Typically, large pike inhabit deeper unvegetated waters more often than smaller ones (Grimm 1981; Chapman and Mackay 1984a; Cook and Bergersen 1988). Outside of vegetation, the preferred habitat of large pike is a 'broken bottom' (Grimm 1981). Both juvenile and adult pike have been shown to avoid habitat predominated by sand (Eklov 1997).

There is some evidence of a seasonal shift in depth preference among adults. During the summer, adults are generally found in the shallow (<2 m) littoral zone and move further offshore into slightly deeper water (between 2-4 m) over winter (Diana et al. 1977; Grimm 1981; Cook and Bergersen 1988; Casselman and Lewis 1996). It is believed that ice-cover and die-back of vegetation in winter effectively force pike to use deeper habitats. Furthermore, on sunny days fish were found to occupy deeper waters than on cloudy days (Cook and Bergersen 1988), and on windy days (i.e. during periods of high turbidity), pike tended to move further offshore into pelagic habitats (Cook and Bergersen 1988; Chapman and Mackay 1984b; Vollestad et al. 1986). Thus, although pike have been captured over a wide range of turbidity, it is much more common in clear and only slightly turbid waters, suggesting that an increase in turbidity nearshore would reduce the suitability of this habitat for a mainly visual predator.

Salmonids (Salmonidae)

Arctic charr (*Salvelinus alpinus*)

The Arctic charr has the most northerly distribution of any freshwater fish (Walters 1955) and is one of the few species known to occur naturally in systems where no other fish species are present (Johnson 1980). Although Arctic charr populations often occur in isolation, only one such allopatric population has been documented in Newfoundland; a population of stunted or 'dwarf' charr was reported from Long Pond on the Great Northern Peninsula (Gibbons 1993).

Arctic charr are distributed throughout Newfoundland (Scott and Crossman 1973; Scott and Scott 1988) and the entire Labrador coast (Scott and Crossman 1973; Scott and Scott 1988; Black et al. 1986) and may be classified as either anadromous or resident freshwater populations. Although landlocked forms usually occupy lakes that are inaccessible to the ocean, both landlocked and anadromous forms may sometimes inhabit the same waters (Johnson 1980; Gyselman 1984; Nordeng and Skurdal 1985; Langeland 1995). In Newfoundland, Arctic charr were reported as being rather common and were actually the dominant species in some lakes (Hammar and Filipsson 1985).

Anadromous

Ocean migrations of Arctic charr in northern Labrador are generally of short duration, usually lasting one to three months, in localized coastal areas (Dempson 1987). Adults normally spawn every second or third year, but seldom every year except in southern parts of its range. In some areas, particularly the Northwest Territories, maturing fish do not migrate to sea during the year in which they spawn (Johnson 1980, 1989). However, in northern Labrador, maturing charr have been observed migrating to sea (Dempson 1995), although they appear to restrict their marine movements (Dempson 1987; Dempson and Kristofferson 1987), sometimes remaining in brackish or estuarine waters (Scott and Crossman 1973; Gyselman 1984; Scott and Scott 1988; Communications Directorate 1991a).

Spawning normally occurs between mid-October and mid-November in Newfoundland, but may occur two weeks earlier in Labrador (Scruton et al. 1997). In Labrador, Dempson and Green (1985) observed spawning activities extending over a three week period in October at temperatures of 1-3^{0}C, with peak spawning occurring in mid-October. Although anadromous charr may spawn in either streams or lakes in Labrador (Dempson and Green 1985), it has been suggested that most spawning takes place in streams (Balon 1980). Spawning has been reported over a variety of substrates ranging from fine sand and mud to rubble, however, gravel and cobble appear to be the most favoured spawning substrate (McPhail and Lindsey 1970; Scott and Crossman 1973; Moore 1975a; Johnson 1980; Dempson 1982; Gyselman 1984; Nordeng and Skurdal 1985; Scott and Scott 1988; JWEL 1997). In streams, spawning usually occurs at depths of 1.5-2 m (Dempson and Green 1985) which is sufficient to keep the eggs safe from winter ice (Communications Directorate 1990), but has been observed at depths ranging from 1-11 m (Moore 1975a). Lake-spawning normally occurs adjacent to inlet streams at depths of 0.5-1.5 m (Dempson and Green 1985), but has been observed at depths ranging from 2-6 m (Gyselman 1984; Nordeng and Skurdal 1985). Females dig a nest or redd in the loose gravel where the eggs incubate over winter at temperatures of 0-2^{0}C (Scott and Crossman 1973; Scott and Scott 1988; Communications Directorate 1991a).

Upon hatching (early April to mid-May in Newfoundland and from mid-April to mid-June in Labrador; Scruton et al. 1997) alevins remain in the gravel until the yolk sac is absorbed, which occurs about the same time as ice breakup (Scott and Crossman 1973; Scott and Scott 1988; Communications Directorate 1991a). In Newfoundland and Labrador, Arctic charr usually mature at 4-5 years of age (Dempson 1982) and although charr in the western Canadian Arctic commonly move seaward for the first time at 3-4 years of age, some individuals migrate to sea as early as age 1 or 2 (McCart 1980). In Labrador, most charr first migrate to sea after their second or third year (Coady and Best 1976; Bouillon and Dempson 1989; Dempson 1993; Radtke et al. 1998), although some may undergo periodic excursions into salt water charr as young as 1+ (Bouillon and Dempson 1989; Radtke et al. 1998), while others may remain in freshwater for 4 years or more before migrating to sea (Radtke et al. 1998). Thus, the age at first seaward migration can vary widely among Arctic charr populations (Randall et al. 1987). Gyselman (1984) reported that first-time migrants to sea generally stay for only 2 or 3 days before returning to fresh water. Seaward migrations usually occur in the spring and generally coincide with the period of spring runoff and ice breakup in coastal rivers (Andrews and Lear 1956; Morrow 1980; Dempson 1982; Communications Directorate 1991a). Scruton et al. (1997) have suggested that this period may range from early May to early June in Newfoundland and from mid-May to the end of June in Labrador. Some adults overwintering in lakes, however, have been observed migrating downstream before or during ice breakup (Scott and Crossman 1964; Scott and Crossman 1973; Gyselman 1984; Scott and Scott 1988).

Ocean migrations of Arctic charr are of relatively short duration, ranging from 1 to 4 months in localized coastal areas (Johnson 1980; Dempson and Kristofferson 1987). During a tagging study in Labrador, most Arctic charr remained within 100 km of where they were originally released (Dempson and Kristofferson 1987) and exhibited a high degree of homing to their natal rivers (Moore 1975b). In Newfoundland and Labrador, Arctic charr may return to their natal stream anywhere from early July to mid-September, although in Labrador upstream migrations may extend into the last two weeks of September (Dempson and Green 1985; Scruton et al. 1997). Upstream migrations often occur during periods of elevated water levels and are frequently associated with high tide (Andrews and Lear 1956; Scott and Crossman 1973; Scott and Scott 1988).

Freshwater resident

In Newfoundland, landlocked Arctic charr may spawn in streams or lakes from early October to mid-November (Seabrook 1961; Scruton et al. 1997). Lake-spawning has been observed over a variety of substrates from mud and gravel to boulders and at depths ranging from 0.3-120 m (Kircheis 1976; Jonsson and Hindar 1982; Rubin 1987, 1993; Rubin and Buttiker 1992). Preferred spawning habitat, however, is usually a gravel/cobble substrate at depths of 1-5 m which are sufficient to keep the eggs safe from winter ice (Seabrook 1961; Leim and Scott 1966; McPhail and Lindsey 1970; Scott and Crossman 1973; Morrow 1980; Gyselman 1984; Scott and Scott 1988; Communications Directorate 1991a). It is interesting to note that in the Northwest Territories, anadromous charr were observed spawning at the same time and in the same general areas of lakes as resident charr (Gyselman 1984). Females usually dig a nest or redd in the loose gravel where the eggs incubate over winter at temperatures of 0-2^{0}C (Scott and Crossman 1973; Scott and Scott 1988; Communications Directorate 1991a). In Maine, however, females did not construct redds, but simply released their eggs in exposed areas of the lake over a cobble/rubble/boulder substrate (Kircheis 1976).

Eggs normally hatch from early April to early June (Scruton et al. 1997) and alevins remain in the gravel until the yolk sac is absorbed which occurs around the time of ice breakup (Scott and

Crossman 1973; Scott and Scott 1988; Communications Directorate 1991a). In Arctic and subarctic lakes, YOY have been found in shallow nearshore waters (Johnson 1976; Sparholt 1985; Riget et al. 1986; Sandlund et al. 1988, 1992a and b), although some have been shown to move into the pelagic zone in the fall (Sandlund et al. 1988, 1992a) and possibly migrate into deeper benthic areas. In temperate lakes, YOY usually leave shore regions early in life, probably during their first summer, and have been found occupying profundal or sublittoral habitats (Kircheis 1976; Svardson 1976; Hindar and Jonsson 1982; L'Abee-Lund et al. 1993; Naesje 1995) as well as pelagic areas (Brabrand 1991). These distributions may be related to heavy predation (Klemetsen et al. 1992). YOY often seek cover in structurally complex bottom substrates including cobble, rubble and boulders (Klemetsen et al. 1992; L'Abee-Lund et al. 1993).

In Norway, juveniles are most abundant in the profundal zone (>6 or 7 m) of lakes, but have been observed foraging in the lower stratum of the pelagic zone or sublittoral zone during late summer or fall (Klemetsen et al. 1989, 1992; Naesje 1995; Halvorsen and Jorgensen 1996; Jorgensen et al. 1996; Halvorsen et al. 1997). Littoral and shallow benthic habitats are more productive feeding areas than profundal habitats and are inhabited mainly by larger conspecifics and potential predators thereby making them high risk areas (Klemetsen et al. 1989; Naesje 1995). Therefore, juveniles typically inhabit deeper (>5 m) benthic habitats where they are less vulnerable to agonistic behaviour from larger conspecifics and are less exposed to predators (Johnson 1980; Sandlund et al. 1987; Hegge et al. 1989; Bjoru and Sandland 1995). In benthic habitats, juveniles usually seek cover in structurally complex bottom substrate (i.e. cobble, rubble and boulders) as well as aquatic vegetation (Sandlund et al. 1987; Stenzel and Power 1990; L'Abee-Lund et al. 1993; Halvorsen et al. 1997). In Quebec, although juveniles were observed hiding among bottom substrate during the day, they were found foraging in open-water areas over sand, gravel or bedrock at night (Stenzel and Power 1990). Juveniles typically undergo an ontogenetic habitat shift from benthic to pelagic areas at 3-4 years of age (Johnson 1980; Sandlund et al. 1987; L'Abee-Lund et al. 1993; Bjoru and Sandland 1995; Naesje 1995). In Newfoundland, landlocked Arctic charr have been shown to mature at 2-3 years of age (Seabrook 1961) and probably reach a maximum age of 9 years (Seabrook 1961; O'Connell and Dempson 1996).

In Newfoundland lakes, Arctic charr (age 4+ to 9+) were found predominately in the pelagic zone during June and July, while occupying mainly benthic areas during other times of the year (O'Connell and Dempson 1996). Within lakes, some part of the adult population usually performs a seasonal movement from the benthic (i.e. littoral) to the pelagic zone in response to improved food abundance during late summer in the form of high crustacean zooplankton density (Hindar and Jonsson 1982; Riget et al. 1986; Hegge et al. 1989; L'Abee-Lund et al. 1992, 1993; Jamet 1995; Naesje 1995). Similar findings have been found in stunted Arctic charr populations which also undergo a seasonal niche shift from benthic to pelagic habitats (Hindar and Jonsson 1982; Klemetsen et al. 1989; Bjoru and Sandlund 1995). In Newfoundland, Arctic charr from several distinct localities were found to feed heavily on zooplankton (Pippy 1966; Wiseman 1973; Rombough et al. 1978; Beak Consultants Ltd. 1980) and rainbow smelt (Seabrook 1961; Hammar 1987), suggesting that they too inhabit open lake areas or deeper waters and forage in a pelagic fashion. In Gander Lake (Gander River system), Newfoundland, Arctic charr are reported to move into deeper water as water temperatures increase throughout the summer (J.B. Dempson, pers. comm.). Arctic charr have also been shown to overwinter in spawning areas of lakes (McCart 1980; Naslund 1990).

There have been reports of as many as four morphs of Arctic charr occurring sympatrically in lakes throughout its geographical range (Behnke 1980) which appear to be dependant on lake depth; shallow (1-3 m) lakes are usually inhabited by a single morph, while deeper lakes with a pronounced pelagic zone may contain two or more morphs (Hindar and Jonsson 1982; Kristiansson and Adalsteinsson 1984). Despite the reported occurrence of only single morph populations in Newfoundland and Labrador, the following information is presented in lieu of the possibility that future research may reveal the existence of similar morphs in Newfoundland waters.

Single freshwater resident and/or stunted populations

The epibenthic zone is inhabited by all age classes of Arctic charr throughout the year, with 1-3 year olds generally restricted to deeper (>5 m) benthic or profundal habitats and charr >4 years of age are found mostly at depths <5 m (i.e. littoral zone) and occupy pelagic areas during late summer and fall (Klemetsen et al. 1989; L'Abee-Lund 1993; Bjoru and Sandlund 1995). Jamet (1995) also found that adult charr immigrate from benthic/littoral to pelagic habitats while foraging. In the fall, charr have been shown to return to benthic habitats when food abundance decreases in the pelagic zone (L'Abee-Lund 1993; Bjoru and Sandlund 1995). It has been suggested that this shift from littoral to pelagic zone occurs at ages and sizes equal to those of smoltifying anadromous charr (Klemetsen et al. 1989) and appears to be a result of a trade-off between feeding possibility and risk of predation (L'Abee-Lund et al. 1993).

Populations containing two freshwater resident morphs

The coexistence of two distinct forms (i.e. normal and dwarf) of landlocked Arctic charr have been reported by several investigators (Klemetsen and Grotnes 1975, 1980; Hindar and Jonsson 1982; Jonsson and Hindar 1982; Sparholt 1985; Svendang 1990; Parker and Johnson 1991; Reist et al. 1995). Generally, dwarf charr are restricted to marginal (i.e. littoral or deeper benthic habitats), while normal charr may occupy benthic and/or pelagic areas (Hindar and Jonsson 1982; Sparholt 1985; Parker and Johnson 1991). This habitat segregation only occurs during the summer and usually breaks down during periods of high food abundance (Hindar and Jonsson 1982). Dwarf -sized charr have also been shown to spawn at greater depths over marginal substrates and later in the season than normal-sized charr (Klemetsen and Grotnes 1980; Jonsson and Hindar 1982).

Populations containing three freshwater resident morphs

Several investigators have reported the sympatric occurrence of three distinct forms of landlocked Arctic charr; 1) small-sized, deeper benthic inhabitant, 2) intermediate- or normal-sized charr which occupies benthic areas but may also inhabit the pelagic zone during the summer, and 3) a large-sized predatory form which inhabits benthic and/or pelagic habitats and moves throughout all depth strata (Hindar and Jonsson 1982; Hammar 1984; Riget et al. 1986; Savvaitova 1991).

Populations containing four freshwater resident morphs

In Iceland, Sandlund et al. (1987, 1992a) reported the occurrence of four sympatric landlocked Arctic charr morphs; 1) planktivorous form which occupies pelagic and epibenthic habitats >10 m, 2) small, 3) large benthic charr which occur mainly at depths <10 m in benthic littoral zone, and 4) a piscivorous form which occurs mainly in the epibenthic zone.

Sympatry with other salmonids

The distribution and feeding habits of Arctic charr appear to be highly variable depending on whether or not they occur singly or in sympatric associations with other salmonids. The general trend seems to be that Arctic charr exploit littoral areas, feeding mainly on benthic invertebrates and terrestrial insects on the lake surface, in situations of allopatry and are confined to deeper offshore (i.e., epibenthic and pelagic) habitats where they feed on zooplankton and profundal zoobenthos when in sympatry with brown trout (Svardson 1976; Hindar and Jonsson 1982; Hammar 1984; Jonsson and Gravem 1985; Hegge et al. 1989; Langeland et al. 1991; L'Abee-Lund et al. 1992; Jorgensen et al. 1996). In Red Indian Lake (Exploits River system), Newfoundland, Arctic charr were restricted to profundal and deeper pelagic habitats when in sympatry with ouananiche (Hammar and Filipsson 1985). In Micmac Lake (Exploits River system), Newfoundland, small-sized Arctic charr were also restricted to deep pelagic areas in the presence of brook trout and American eels (Hammar 1987). However, this spatial segregation may break down over time since these observation were based on single point-in-time sampling periods. Similar findings were found in Norway where juvenile Arctic charr were confined to the profundal zone in the presence of juvenile Atlantic salmon (Jorgensen et al. 1996). In Labrador and northern Quebec where Arctic charr are often sympatric with lake trout, the two rarely occupy the same habitats (Johnson 1980) and although adult charr are mainly piscivorous in allopatric populations, they switch to a diet of zooplankton and aquatic insects in the presence of lake trout (Fraser and Power 1989). Similar findings were also reported by McCart (1980) in the western Arctic.

Atlantic salmon (*Salmo salar*)

Atlantic salmon are found throughout Newfoundland and southern Labrador (Scott and Crossman 1973; Scott and Scott 1988) and have been reported in coastal rivers as far north as the Fraser River (Black et al. 1986). Throughout Newfoundland and Labrador, Atlantic salmon occur in both anadromous and landlocked populations (Smith 1988). Anadromous salmon have been captured at sea up to the northern tip of Labrador (Power and Creesman 1975). Landlocked salmon, commonly called ouananiche, are the dominant species in some Newfoundland lakes where they may exist in either normal or dwarf forms (Smith 1988). Although these ouananiche are distributed throughout most areas of Newfoundland, there have been no reports to date of ouananiche from the Great Northern Peninsula (Scott and Crossman 1964). Dwarf populations have been reported from several localities in Newfoundland (Bruce 1976; Barbour et al. 1979).

Habitat usage by normal and dwarf landlocked salmon were assumed to be similar for the purposes of this report since there was no distinction between the two in the literature reviewed regarding differences in their habitat utilization. Ouananiche are also present in western Labrador (Backus 1957; Bruce 1974, 1975b), but are relatively less abundant than in Newfoundland (Ryan 1980).

Anadromous

In insular Newfoundland, there is considerable variation in the timing of the upstream spawning migration which extends from early May to early September (Porter 1975), while in Labrador, upstream migrations are usually restricted to July and August (Scruton et al. 1997). Salmon have been shown to enter rivers during and immediately following a freshet, when there is an increased volume of clean, cool water (Power 1981; Smith 1988). In Newfoundland, sea-run Atlantic salmon normally spawn between mid-October and mid-November and may occur two weeks earlier in Labrador (Scruton et al. 1997). A spawning site is chosen by the female usually in gravel-bottomed riffle sections of streams (Scott and Crossman 1973; Scott and Scott 1988; Smith 1988). Eggs are deposited in the gravel nest or redd where they incubate over winter (Smith 1988). Although some adults return to sea immediately after spawning, others may overwinter in freshwater or estuarine habitats (Gruenefeld 1988; Smith 1988) and migrate to sea the following spring (Scott and Scott 1988; Smith 1988). After hatching, usually between mid-April and early May in Newfoundland (Porter 1975; Scruton et al. 1997) and mid-April to mid-June in Labrador (Scruton et al. 1997), alevins remain in the gravel for a few weeks until their yolk sac is absorbed. In Newfoundland, young typically remain in freshwater for 2-4 years and 2-5 years in Labrador before migrating to sea (Porter 1975). In Newfoundland, migration to the sea occurs in May and June (Porter 1975). Atlantic salmon typically remain at sea for one to three years before returning to their natal river to undergo spawning for the first time (Porter 1975; Scott and Scott 1988).

Although juvenile Atlantic salmon are typically considered to be stream dwellers (Keenleyside 1962; Gibson 1966; Symons and Heland 1978; Wankowski and Thorpe 1979; deGraaf and Bain 1986; Heggenes 1990), in insular Newfoundland juveniles make extensive use of estuarine (Shears 1985; Cunjak et al. 1989; Cunjak 1992) and/or lacustrine habitat (Pepper 1976; Chadwick and Green 1985; Pepper et al. 1985; Hutchings 1986; Ryan 1986, 1993; O'Connell and Ash 1989; O'Connell and Dempson 1990, 1995) for rearing. Lake use by juvenile salmon has also been observed in the northeast Atlantic (Einarsson et al. 1990; Erkinaro et al. 1995; Halvorsen and Jorgensen 1996; Halvorsen and Svenning 1996; Halvorsen et al. 1997; Jorgensen et al. 1996; Matthews et al. 1997). In Newfoundland, the first lakeward migrations of juveniles from streams most often occurs in spring and early summer (Hutchings 1986; Ryan 1990; Erkinaro and Gibson 1997) after the first year of life (Leggett and Power 1969; Pepper 1976; Pepper et al. 1985; Hutchings 1986; Ryan 1993; Erkinaro and Gibson 1997). However, in some areas lake use may occur earlier (O'Connell and Dempson 1990, 1996; Matthews et al. 1997). In Sweden, YOY initially feed on zooplankton and then switch to a diet of mainly benthic invertebrates as they grow larger (Arnemo 1975). Several investigators have provided evidence of parr migrating into lakes in the fall presumably to overwinter (Hutchings 1986; Einarsson et al. 1990; Gibson 1993; Sutton 1994). Others have shown that young may benefit from entering lakes through increased growth and survival (Pepper 1976; Northcote 1978; Pedley and Jones 1978; Godin 1982; Hutchings 1986; Bley 1987; O'Connell and Ash 1989, 1993; Daya 1993; Erkinaro et al. 1995; Dempson et al. 1996; Erkinaro and Gibson 1997), enhanced reproductive success or avoidance of unfavourable environmental conditions such as low water levels, high water temperatures or winter freezing (Porter 1975; Northcote 1978; Godin 1982). Hutchings (1986) also suggested that lake-dwelling juveniles may accrue benefits from more abundant food resources, reduced energy requirements for maintaining position in relation to the lotic environment as well as reduced competition for food and/or space (Hutchings 1986).

In Newfoundland, juvenile salmon (1-2 years of age) have been shown to occupy benthic areas within the shallow (<2-3 m) littoral zone of lakes (Sutton 1994), while larger and older parr occur more frequently in pelagic and deeper benthic areas (Pepper et al. 1985; O'Connell and Dempson 1996). In Norway, although salmon parr were predominantly caught in the shallow (<3 m) littoral zone, few were caught on sandy locations or in the pelagic zone (Halvorsen et al. 1997). In the littoral zone, parr were often concentrated over rocky areas and were also observed among submergent and emergent vegetation (Sutton 1994; Halvorsen and Jorgensen 1996; Halvorsen et al. 1997). Arnemo (1975), on the other hand, reported that salmon parr occurred most frequently in areas devoid of vegetation.

Freshwater resident (Ouananiche)

Ouananiche, remain in freshwater even though there may be no physical obstruction preventing seaward migration (Scott and Scott 1988). The life history of ouananiche is similar to anadromous forms except that adults remain in lakes, migrating to tributary streams to spawn (Scott and Crossman 1964; Havey and Warner 1970; Scott and Crossman 1973; Wiseman 1973; Hutchings 1986; Smith 1988) or spawn along rocky shorelines of lakes (Scott and Crossman 1964; Havey and Warner 1970; Cowan and Baggs 1988; Scruton et al. 1996a, 1997). Similar to sea-run salmon, ouananiche have also been shown to enter spawning streams immediately following a freshet, when there is an increased volume of clean, cool water (Scott and Crossman 1964; Smith 1988). In Newfoundland, spawning typically occurs between late September and early November (Leggett 1965; Lee 1971; Beak Consultants Ltd. 1981; Scruton et al. 1996a, 1997), whereas in Labrador spawning normally occurs between mid-September and October (Wiseman 1972; Scruton et al. 1997). In Newfoundland, lake-spawning has been reported to occur over a gravel substrate (Leggett 1965) at depths of 0.5-1.3 m (Cowan and Baggs 1988). Lake-spawning has also been observed along shorelines (Leggett 1965) as well as near areas of moving water, usually above outlet streams and near the mouths of inlet streams (Leggett 1965; Havey and Warner 1970; Einarsson et al. 1990). Although most stream-spawning ouananiche return to the lake shortly after spawning (Warner and Havey 1985; Scruton et al. 1996a, 1997), others take up residence in pools where they may remain over winter before returning to the lake the following spring (Scott and Crossman 1964; Havey and Warner 1970). In Newfoundland, ouananiche have been shown to utilize both deeper, warm waters in ice-covered lakes as well as fast flowing, open water (no ice cover) at the inlets and outlets of lakes for overwintering (Scruton et al., 1996a and b, 1997).

Young usually hatch between early April and mid-June in Newfoundland and from mid-May to mid-June in Labrador (Scruton et al. 1997). Tributary streams provide good ‘nursery’ areas for young ouananiche (Wiseman 1973) where they may remain for 2-3 years before moving into lakes (Leggett 1965; Leggett and Power 1969; Wiseman 1971; Havey and Warner 1970). Jorgensen et al. (1996) found that juveniles utilized the littoral zone throughout the entire ice-free season with smaller individuals occupying areas closer to the bottom than larger ones (Halvorsen et al. 1996). Ouananiche are usually 2-3 years of age before attaining sexual maturity (Leggett 1965; Lee 1971; Leggett and Power 1969) and may live for up to 10 years in Newfoundland (Leggett 1965).

Adults have been shown to favour open-water areas (i.e. pelagic) away from the lake bottom (Havey and Warner 1970; Lackey 1970; Scott and Crossman 1973; Speirs 1974) and usually occupy deeper, cooler waters as water temperatures increase during the summer (Leggett 1965; Leggett and Power 1969; Lackey 1970; Wiseman 1971,1972; Scott and Crossman 1973). In Newfoundland, ouananiche have been reported to feed heavily on zooplankton when they are smaller and tend to consume a greater proportion of benthos and terrestrial organisms as they grow larger (Wiseman 1973). Leggett (1965) suggested that ouananiche feed heavily on pelagic and surface organisms during June and July, but appear to feed more on benthic organisms in late summer and early fall (Leggett 1965). Several studies have also shown an increasing importance of fish in the diet of ouananiche as they grow larger (Scott and Crossman 1964; Leggett 1965; Pippy 1966; Wiseman 1973; Whelan and Wiseman 1977; Ryan 1980).

Brook trout (*Salvelinus fontinalis*)

The brook trout is widely distributed throughout Newfoundland and Labrador (Scott and Crossman 1973), at least as far north as the Hebron Fiord (Black et al. 1986), where they have been reported to make extensive use of lake habitats (Ryan and Knoechel 1994). Brook trout may be anadromous, spending 1 or 2 months feeding at sea in relatively shallow water, close to their natal stream, while others spend their entire life in freshwater (Scott and Crossman 1964; Morrow 1980; Power 1980; Ryan 1988; Scott and Scott 1988). Beak Consultants Ltd. (1980, 1981) provided evidence to suggest that two forms of brook trout may coexist in some Newfoundland lakes; a primarily benthic feeding population that is relatively slow growing and short lived and a larger, faster growing piscivorous population that is relatively long lived. Although peak seaward migration of brook trout typically occurs in May or June in Newfoundland (O’Connell 1982) and in June or July in Labrador (Scruton et al. 1997), O’Connell (1982) reported that movements between fresh and salt water may occur throughout the year. Based on the literature reviewed, habitat utilization by resident and anadromous brook trout do not appear to differ appreciably, therefore they are treated as similar.

<u>Anadromous and freshwater resident</u>

Upstream spawning migrations have been observed as early as July in some Newfoundland rivers (O’Connell 1982). Spawning normally occurs between late September and early November in Newfoundland (Frost 1940; Wiseman 1969, 1970, 1971, 1972; O’Connell 1982; McCarthy 1996; McCarthy et al. In press) and Labrador (Dempson and Green 1985). Brook trout typically spawn in shallow, gravel-bottomed streams and occasionally in lakes (Wiseman 1970, 1971; Ryan 1988). In lakes, spawning has been observed at depths ranging from 0.1-8.0 m, but occurs most commonly at depths <2 m (Wiseman 1970; Wurtsbaugh et al. 1975; Fraser 1982, 1985; Dempson and Green 1985; Cowan and Baggs 1988; Schofield 1993; Ford et al. 1995; Quinn 1995). Preferred lake spawning substrate is gravel or a sand/gravel/small cobble mixture (McPhail and Lindsey 1970; Scott and Crossman 1973; Wurtsbaugh et al. 1975; Morrow 1980; Raleigh 1982; Dempson and Green 1985; Fraser 1985; Cowan and Baggs 1988; Ford et al. 1995; Quinn 1995; McCarthy 1996) which are usually cleaned of filamentous green algae and debris (Cowan and Baggs 1988). In Petty Harbour Long Pond, Newfoundland, brook trout were observed spawning along the shoreline and in nearby offshore reefs over a rubble/cobble/gravel substrate at depths of 0.2-0.3 m (Wiseman 1970). O'Connell (1982) observed anadromous brook trout spawning in an out-pocketed area off the main river over a substrate predominated by sand and silt with limited gravel. In Copper Lake, a small headwater system of the Corner Brook watershed in Newfoundland, most spawning was observed on small rock outcrops along the shoreline and shoals near the mouths of tributaries (McCarthy et al. In press).

Numerous findings have suggested that lake spawning populations of brook trout are strongly dependent on groundwater seepage for successful reproduction (Wiseman 1970; Wurtsbaugh et al. 1975; Webster and Eiriksdottir 1976; Carline 1980; Morrow 1980; Fraser 1982, 1985; Raleigh 1982; Snucins et al. 1992; Schofield 1993; Curry and Noakes 1995; Curry et al. 1995; Quinn 1995), however, no significant groundwater upwellings were detected over redd sites in several lakes on the Avalon Peninsula, Newfoundland (Cowan and Baggs 1988). Several investigators have observed brook trout spawning on sandy, heavily silted substrates (Webster and Eiriksdottir 1976; Carline and Brynildson 1977; Chisholm et al. 1987; Gloss et al. 1989) as well as over an aggregation of waterlogged sticks, woodchips and debris overlying soft organic matter (Fraser 1982) providing there was sufficient upwelling of groundwater. Thus, upwelling groundwater appears to take precedence over substrate composition and may be the single most important factor in spawning site selection (Morrow 1980; Schofield 1993). Spawning in association with upwelling groundwater is beneficial, as it carries dissolved oxygen to, and metabolic wastes away from, the developing embryos as well as provides protection from freezing (Reiser and Wesche 1977; Fraser 1982, 1985; Matthess 1982; Curry et al. 1995).

During spawning, the female digs and cleans a shallow nest or redd in which the eggs are deposited (Ryan 1988; Scott and Scott 1988). Eggs incubate in the gravel over winter and hatch between April and mid-June in Newfoundland (Baggs 1988; Scruton et al. 1997) and from mid-May to mid-June in Labrador (Scruton et al. 1997). Adults leave spawning areas shortly after spawning (Fraser 1985). Alevins remain in the nest until the yolk sac is absorbed (Ryan 1988; Scott and Scott 1988) and upon emergence disperse over gravel/cobble substrates in the shallow (<2 m) littoral zone, usually residing within 0.5 m of the bottom (Wurtsbaugh et al. 1975; Pepper et al. 1985; Tremblay and Magnan 1991; Curry et al. 1993; Hosn and Downing 1994; Ford et al. 1995; Venne and Magnan 1995; Halvorsen et al. 1996). It should be noted that although YOY are typically found at depths <2 m, they have been observed at depths up to 7 m (Venne and Magnan 1995; Halvorsen et al. 1996), which may be associated with moving further offshore to deeper, cooler waters during the summer. In a central Ontario lake, some YOY were observed moving into cool outlet streams during the summer (Curry et al. 1993, 1997). The opposite has also been found where young tend to move into lakes from stream habitats as they grow (Scott and Crossman 1964; Ryan and Knoechel 1994; Clarke et al. 1997) especially when water temperatures rise above 20^{0}C (Scott and Crossman 1973; Scott and Scott 1988). In Newfoundland, juvenile brook trout typically move into lakes at 1-3 years of age (Ryan and Knoechel 1994; O'Connell and Dempson 1996; Clarke et al. 1997). In Quebec, availability of lake habitat has been shown to reduce mortality, increase growth and augment production of brook trout populations (Saunders and Power 1970).

Although growth rates are highly variable, in Newfoundland, brook trout usually mature at 2 to 4 years of age (Frost 1938a; Wiseman 1969, 1973; Lee 1971; Bruce 1974, 1979; Parsons 1975; Wheeler 1977; Ryan 1980, 1988; Beak Consultants Ltd. 1981; O'Connell 1982; Baggs 1988) and although they seldom live longer than 5 or 6 years (Wiseman 1972; Whelan and Wiseman 1975; Ryan 1980), brook trout 8 years of age have been reported from several Newfoundland lakes (Beak Consultants Ltd. 1980, 1981). Brook trout of all ages are normally found within 4-10 cm of the bottom (Lackey 1970; Wurtsbaugh et al. 1975; Magnan 1989; Hosn and Downing 1994; Venne and Magnan 1995; O'Connell and Dempson 1996), although in Newfoundland, they have also been captured in pelagic areas during the ice-free season; no brook trout were captured from the pelagic area during winter (O'Connell and Dempson 1996). O'Connell and Dempson (1996) found that brook trout in deeper benthic and pelagic areas were generally larger and older than those inhabiting the littoral area of lakes. Investigations on diet composition provide evidence of brook trout maintaining a mainly benthic existence (Frost 1938a; Lackey 1970; Wiseman 1969, 1970, 1971, 1972, 1973; Bruce 1974; Speirs 1974; Parsons 1975; Wheeler 1977; Whelan and Wiseman 1977; Ryan 1980; O'Connell 1982; Baggs 1989; Magnan 1989; Tremblay and Magnan 1991; Lacasse and Magnan 1992; Venne and Magnan 1995) with fish assuming greater importance in the diet with increased size (Frost 1940; Wiseman 1969, 1973; Whelan and Wiseman 1975, 1977; O'Connell 1982). Both Wiseman (1969) and O'Connell (1982) reported that invertebrates were consumed almost exclusively by trout <20 cm, whereas fish predominated the diet of trout >25-30 cm. Recently, mainly piscivorous brook trout populations have also been reported from Star Lake, part of the Exploits River system (JWEL 1996) as well as several lakes within the Indian Bay Brook watershed (D. Scruton, pers. comm.), Newfoundland.

Brook trout often seek refuge among rocks, aquatic vegetation (both emergent and submergent), woody debris, overhanging logs and undercut banks (McPhail and Lindsey 1970; Wurtsbaugh et al. 1975; Lacasse and Magnan 1992; Noakes 1992; Curry et al. 1993; Hosn and Downing 1994; Ford et al. 1995; Halvorsen et al. 1996) and have been reported to occur at depths up to 11 m (Lackey 1970; O'Connell and Dempson 1990, 1996). As water temperatures increase during the summer, brook trout move further offshore to cooler, deeper waters (Tremblay and Magnan 1991; Venne and Magnan 1995). During the winter some brook trout remain over gravel/rubble/boulder substrates in streams in <5 m of water (Chisholm et al. 1987; Curry et al. 1997), while others remain in shallow water ponds at depths ranging from 0.3-5 m (Chisholm et al. 1987; O'Connell and Dempson 1996).

Several investigators have shown that brook trout (<20 cm) shift their spatial distribution (i.e. littoral to pelagic zone) and feeding habits (i.e. zoobenthos to zooplankton) in the presence of white suckers (Magnan 1988, 1989; Lachance and Magnan 1990; Tremblay and Magnan 1991;

Lacasse and Magnan 1992; Venne and Magnan 1995), however, similar shifts were not found for brook trout > 20 cm (Magnan 1989).

Brown trout (*Salmo trutta*)

Brown trout were first introduced to Newfoundland in 1886 (Andrews 1965) with subsequent introductions in the 1890's and early 1900's (Frost 1938a,1940). Through anadromous migrations, populations have been established throughout much of eastern Newfoundland including the Avalon Peninsula, Burin Peninsula, Trinity Bay, Bonavista Bay and possibly as far north as Notre Dame Bay (Andrews 1965; O'Connell 1982; Gibson and Cunjak 1986). Brown trout, however, are not found in Labrador (Scott and Scott 1988). Sea-run brown trout normally undergo downstream migrations from April to June (O'Connell 1982; Scruton et al. 1997) and while some return to fresh water after spending 2 to 4 months at sea (O'Connell 1982; Jonsson and Gravem 1985; Scott and Scott 1988), others may remain at sea for one or more winters (O'Connell 1982; Ryan 1988). Upon returning to freshwater, brown trout often stray to places other than their river of origin (Ryan 1988).

Brown trout are reported to have habitat requirements similar to those of brook trout (Ryan 1988; Scott and Scott 1988; O'Connell and Dempson 1996). Unlike brook trout, however, they do not appear to prefer areas of upwelling groundwater for spawning (Hansen 1975). They have been found to occupy streams and ponds somewhat warmer and more turbid than those preferred by brook trout (Scott and Crossman 1973; Scott and Scott 1988). In Newfoundland, specifically on the Avalon Peninsula, spawning may occur from early October to late November (Kellett 1965; Liew 1969; O'Connell 1982; Scruton et al. 1997) and may continue into the first week of December (Lee 1971; Wiseman 1972). Brown trout typically spawn in shallow gravel sections of streams (Hansen 1975; Raleigh 1982; Haraldstad and Jonsson 1983; Jonsson 1985; Jonsson and Gravem 1985; Ryan 1988; Scott and Scott 1988; Clapp et al. 1990); however, lake-spawning along rocky shorelines has been observed (Eddy and Surber 1960; Borgeson 1966; Daly 1968; Liew 1969). Matthews et al. (1997) reported spawning over gravel beds near lake outflows. Eggs incubate over winter and young emerge from the substrate, usually between mid-April and mid-May (Ryan 1988; Scruton et al. 1997). In Newfoundland, many stream-spawning adults return to lakes shortly after spawning (Kellett 1965; Wiseman 1972; Liew 1969; Lee 1971; MacKinnon 1998). Tributary streams have been used as 'nursery' areas by juvenile brown trout during their first few years of life before migrating to lakes to mature (Thorpe 1974b; Craig 1982; Jonsson 1985; Haraldstad et al. 1987; Hegge et al. 1993a).

Lakeward migrations of juvenile brown trout may occur as early as their first year of life (Thorpe 1974b; Schei and Jonsson 1989; Matthews et al. 1997). Swales (1986) found juvenile brown trout that migrated to a lake at an early age had better survival and growth. Several investigators have also shown that brown trout have a higher growth rate in lakes than in streams (Stuart 1953; Alm 1959; Ball and Jones 1960). Several investigators have found that small-sized brown trout (1 and 2 years of age) appear to be restricted to the sheltered littoral zone of lakes, while larger-sized individuals utilize both benthic and more exposed pelagic areas (Haraldstad and Jonsson 1983; Jonsson and Gravem 1985; Schei and Jonsson 1989; Hegge et al. 1989, 1993a; Jonsson 1989; L'Abee-Lund et al. 1992; Borgstroem et al. 1993; Jorgensen et al. 1996; O'Connell and

Dempson 1996). It appears that older, larger fish generally shift habitats in accordance with food availability, while smaller fish are restricted to structurally complex littoral habitats where they can seek cover amongst rocks and boulders (Haraldstad and Jonsson 1983; Jonsson and Gravem 1985). Arnemo (1975) found that brown trout occurred most frequently in areas devoid of vegetation. In Norway, a large proportion of brown trout populations (>15 cm in length) may leave the littoral zone during the summer to feed in pelagic areas (Haraldstad and Jonsson 1983; Schei and Jonsson 1989). Similar findings have also been found along the Avalon Peninsula in Newfoundland (Wiseman 1971). Further evidence for a strong benthic association of smaller-sized fish is provided by Hegge et al. (1993a and b) whereby small- and intermediate-sized brown trout were mainly found close to the bottom (i.e. ≤0.5 m above the bottom) over a cobble/rubble/boulder substrate; intermediate-sized fish were also caught in high numbers over sand. Larger individuals, on the other hand, occurred more frequently higher up in the water column and/or in pelagic waters (Jonsson 1981; Schei and Jonsson 1989; Hegge et al. 1993b).

In Newfoundland, brown trout generally mature at 2-6 years of age (Liew 1969; Lee 1971; O'Connell 1982; MacKinnon 1998) and although they seldom live longer than 10 years (Wiseman 1972; Ryan 1988), several anadromous specimens between 11+ to 13+ years of age have been captured on the island (Williams 1963; O'Connell 1982). In Newfoundland, adult brown trout have been shown to feed mainly on fish and benthic organisms (Liew 1969; Wiseman 1971) with fish constituting the bulk of the diet of individuals >35 cm (Liew 1969). Surface and mid-water prey items (i.e. plankton and terrestrial insects) were also of importance in certain areas (Liew 1969).

Most brown trout (stream and lake-dwellers) overwinter in lakes, some remaining in the littoral zone, while others move into deeper offshore areas (Thorpe 1974b; Jonsson 1985; Jonsson and Gravem 1985; Haraldstad et al. 1983, 1987; Hegge et al. 1993a; Schei and Jonsson 1989; Oakland et al. 1996). In Norway, anadromous brown trout were found to occupy shallow (<15m) areas of lakes during winter (November to April), while residents were frequent in deeper (>15m) waters (Oakland et al. 1996). Jonsson and Gravem (1985), on the otherhand, found that most individuals in a Norwegian lake overwintered in the littoral zone and observed anadromous individuals inhabiting deeper waters than juveniles or residents. During spring and early summer, brown trout that overwintered in offshore areas, move back to the shallow littoral zone (Thorpe 1974a). It is also interesting to note that when occurring in sympatry with Arctic charr, brown trout were able to exclude Arctic charr from the shallow littoral zone (Hegge et al. 1989; Langeland et al. 1991; L'Abee-Lund et al. 1992).

Lake trout (*Salvelinus namaycush*)

Lake trout are found throughout southern Labrador, except for the southeastern corner, but do not occur in insular Newfoundland (Scott and Crossman 1973; Black et al. 1986). In the south, lake trout prefer cool (~10^0C), deep lakes, but in the north where temperatures are lower, they may inhabit shallow lakes and large rivers (McPhail and Lindsey 1970; Ryan 1988). The lake trout cannot tolerate a high degree of salinity and, although a few have been observed in the coastal waters of the Northwest Territories, they tend not to migrate to sea (Communications Directorate 1991b).

Lake trout usually spawn in shallow inshore areas of lakes, rarely in streams (Machniak 1975c; Martin and Olver 1980; Ford et al. 1995). In most areas of Canada, spawning occurs in late summer-early fall (Scott and Crossman 1973; Ford et al. 1995), mainly in September or October in Labrador (Scruton et al. 1997). Several investigators have suggested that declining water temperatures and photoperiod coupled with strong on-shore winds are necessary factors triggering spawning (Carlander 1969; Martin and Olver 1980). Lake trout have been reported to spawn over a great variety of depths ranging from 0.5-55 m (Carlander 1969; DeRoche 1969; Morrow 1980; Marcus et al. 1984) greater than 100 m (Thibodeau and Kelso 1990). In larger lakes, spawning typically occurs at depths between 5 and 10 m (Martin and Olver 1980; Thibodeau and Kelso 1990; Ford et al. 1995), while in smaller lakes, spawning has been reported to occur at depths between 0.1-5 m (DeRoche 1969; Normandeau 1969; Martin and Olver 1980; Dumont et al. 1982; Marsden and Krueger 1991). The spawning substrate is usually composed of large gravel (>2 cm in diameter), cobble and rubble interspersed with boulders and is generally free of sand, mud, detritus and vegetation (DeRoche 1969; Normandeau 1969; McPhail and Lindsey 1970; Scott and Crossman 1973; Martin and Olver 1980; Marcus et al. 1984; Cucin and Faber 1985; Thibodeau and Kelso 1990; Marsden and Krueger 1991; Ford et al. 1995). Spawning areas are often exposed to prevailing winds such that wave action and water currents keep the area free of sand, silt and detritus (Normandeau 1969; McPhail and Lindsey 1970; Martin and Olver 1980). Neither DeRoche (1969) nor Martin and Olver (1980) found any evidence of groundwater seepage being important to spawning.

Shortly after release, eggs settle to the bottom and lodge in crevices among rocks where they incubate for 4-5 months over winter (DeRoche 1969; Machniak 1975c; Ryan 1988; Thibodeau and Kelso 1990). Upon hatching, mid-March to April in Labrador (Scruton et al. 1997), alevins remain near the bottom in close association with structurally complex refuge sites (Balon 1980). YOY may remain in spawning areas for several weeks to three months before moving to deeper water (DeRoche 1969; Scott and Crossman 1973; Martin and Olver 1980; Morrow 1980; Peck 1982) which appears to be primarily dependent on water temperature; YOY typically leave inshore areas when water temperatures exceed 15^{0}C (Peck 1982). Juveniles generally remain within 0.3 m of the bottom over a cobble/rubble/boulder substrate and have been observed seeking shelter among boulders and woody debris (Ford et al. 1995). In Labrador, lake trout usually attain sexual maturity in 6-11 years (Bruce 1975b; Bruce and Parsons 1979; Ryan 1980; Bruce 1984; Ryan 1988).

Dispersal of adults from spawning areas begins shortly after spawning (Scott and Crossman 1973; Machniak 1975c; Morrow 1980). As surface waters warm in the spring or early summer, lake trout seek deeper, cooler waters (Riche 1965; Martin and Olver 1980; Olson et al. 1988; Communications Directorate 1991b) where they congregate below the thermocline throughout the summer (Scott and Crossman 1973; Morrow 1980; Sellars et al. 1998). As water temperatures cool down in the fall, lake trout move back into shallower water to spawn (Scott and Crossman 1973; Martin and Olver 1980; Morrow 1980). Although lake trout have been shown to feed mainly on fish and benthic invertebrates in Labrador (Keats 1986), they are quite opportunistic and will feed on almost any food appropriate to their gape (Bruce 1974, 1975b, 1984; Parsons 1975; Bruce and Parsons 1979; Ryan 1980). As a point of interest, natural hybridization between Arctic charr and lake trout has been documented in Labrador by Hammar et al. (1989).

Lake whitefish (*Coregonus clupeaformis*)

Lake whitefish are distributed throughout southern Labrador, except for the southeastern corner (Scott and Crossman 1973; Bruce 1974; Parsons 1975; Black et al. 1986) and are apparently absent from the Fraser River and more northern areas (Bruce et al. 1979; J.B. Dempson, unpublished data). In Labrador, lake whitefish occur as both normal and dwarf-sized populations, although the slow growing, early maturing dwarf form is less common (Bruce 1975b, 1984; Parsons 1975; Bruce and Parsons 1979; Ryan 1980). Since there was no clear distinction in the literature regarding different habitat usage by normal and dwarf-sized populations, for the purpose of this report both forms were assumed to exhibit similar habitat utilization. Lake whitefish were introduced into Newfoundland in 1886 and have only been reported in Hogan's Pond and Murray's Pond on the Avalon Peninsula (Chen 1968).

In Labrador, spawning usually takes place in lakes in mid-September or October (Scruton et al. 1997) at water temperatures >8^{0}C (Ford et al. 1995). Several investigators have found that spawning in small lakes occurs most frequently at depths <5 m (Bryan and Kato 1975; Machniak 1975a; Ayles 1976; Morrow 1980; Cucin and Faber 1985; Ford et al. 1995), while it may occur at depths up to 30 m in larger lakes (Machniak 1975a; Ford et al. 1995). In Labrador, Ryan (1980) reported that spawning occurred at depths <8 m. Preferred spawning substrate appears to be gravel, cobble or boulder, but spawning may occasionally occur over sand (McPhail and Lindsey 1970; Machniak 1975a; Ayles 1976; Morrow 1980; Cucin and Faber 1985; Barnes and Bodaly 1990; Ford et al. 1995). Lake whitefish have been observed spawning in both lakes (Machniak 1975a; Bodaly et al. 1984) and rivers over gravel or rubble substrates at depths < 1 m (McPhail and Lindsey 1970; Machniak 1975a; McCart et al. 1982; Ford et al. 1995). Although Lindstrom (1970) and Machniak (1975a) reported that river spawning generally occurred earlier than lake spawning, M. Roberge (DFO, pers. comm.) found that lake and river spawning occurred at a similar time in the Great Slave Lake system of the Northwest Territories. Mud bottoms are generally avoided by both river and lake spawners (Machniak 1975a), although in the Yukon Territory spawning was reported over silt and emergent vegetation where there was a slight current (Bryan and Kato 1975). Bidgood (1972) also observed spawning in shallow water (<1 m) over a sand-silt substrate in two eutrophic Alberta lakes. Unlike many other species, flowing water is not required for spawning (Bryan and Kato 1975; Ford et al. 1995).

Adhesive eggs are broadcast into the water column and settle in rocky crevices where they remain for 4-6 months at water temperatures of 1-8^{0}C (Cucin and Faber 1985). In Labrador, young typically hatch from mid-May to mid-June (Scruton et al. 1997) and remain within the general vicinity of the spawning area (Machniak 1975a; Ryan 1980; Cucin and Faber 1985) where they are often associated with emergent vegetation and woody debris (Reckahn 1970; Hoagman 1973; Morrow 1980; Ford et al. 1995). YOY are generally found over a gravel, cobble or boulder substrate and typically remain in these shallow inshore areas for 6-8 weeks (Faber 1970; Hoagman 1973; Desjardine 1979; Loftus 1982; Cucin and Faber 1985; Ford et al. 1995). By early summer when water temperatures increase, young move into deeper water (Lindstrom

1970; Reckahn 1970; Scott and Crossman 1973; Machniak 1975a; Morrow 1980; Cucin and Faber 1985). Young were found to feed mainly on plankton in Labrador and depend more on benthic invertebrates as they grow larger (Bruce 1974, 1984; Bruce and Parsons 1979). Lake whitefish have also been shown to feed on fish and fish eggs (Bruce 1974). In Labrador, lake whitefish usually attain sexual maturity in 5-11 years, although some dwarf populations may mature as early as 2 years of age (Bruce 1975b, 1984; Parsons 1975; Bruce and Parsons 1979; Ryan 1980; Chaput and deGraaf 1983).

After spawning, adults return to deeper water (Machniak 1975a; Ford et al. 1995) and have been found at depths of 10-100+ m in the hypolimnion (McPhail and Lindsey 1970). In several lakes in Algonquin Park, Ontario, juvenile and adult lake whitefish were found at all depths down to approximately 43 m (Sandercock 1964). In Labrador, lake whitefish are predominantly bottom dwelling, but may also occur in the pelagic zone, especially larger individuals (Bruce 1975b, 1984). Outside the spawning period, adults appear to show no preference for substrate type (Ford et al. 1995). In several Ontario lakes, whitefish were captured over a variety of substrates ranging from soft clay and organic debris to mainly rocky substrates (Sandercock 1964). In the spring, both juveniles and adults leave their deeper overwintering sites and move into shallower water (Morrow 1980; Bodaly et al. 1984), returning to deeper, cooler depths as water temperature increases throughout the summer (Scott and Crossman 1973; Parsons 1975; Morrow 1980).

Pink salmon (*Oncorhynchus gorbuscha*)

Pacific pink salmon eggs were first introduced into Newfoundland from British Columbia in 1959 (Blair 1968). By 1966, over 15 million eggs had been planted in North Harbour River, St. Mary's Bay (Lear 1975). Despite these efforts a commercially viable population of pink salmon has not been established in Newfoundland. However, it is conceivable that small populations of pink salmon may exist in certain areas of the province (Dempson 1980). At least 10 pink salmon have been recorded along the Labrador coast, three of which were caught in freshwater (Lear 1975; Dempson 1980; Anderson 1985). This has led to the speculation of whether these salmon were strays from North Harbour River or if they could have originated from Russian transplants in the Baltic and White Sea areas (Dempson 1980).

Although spawning generally takes place in freshwater close to the sea or in the intertidal zones (Bonar et al. 1989), some pink salmon may spawn in streams several kilometers upstream form saltwater (Scott and Crossman 1973). Spawning usually occurs in late August through October and although some adults return to their natal streams to spawn (Sheridan 1962), the rate of straying among pink salmon is believed to be much higher than in any other species of salmon (Bonar et al. 1989). Spawning occurs over a mainly sand/gravel/cobble substrate (Lucas 1959; Collings 1974) at water depths of 0.2 to 0.5 m (Collings 1974).

In British Columbia, eggs hatch from late December to February, with peak emergence of fry in April or May (Neave 1966). YOY in stream habitats migrate to the estuarine zone shortly after emerging from the gravel (Lear 1974) and spend most of their lives in saltwater (Bonar et al. 1989). Upon entering the estuarine environment, they feed near the surface, primarily during daylight hours (Godin 1981) and are often found close to shore, near areas dominated by abundant seaweed growth (Lear 1974). Pink salmon generally mature at 2-3 years of age (Bonar et al. 1989).

Rainbow trout (*Oncorhynchus mykiss*)

Rainbow trout were first introduced on the Avalon Peninsula of Newfoundland in 1887 (Frost 1938a) with subsequent introductions in ponds found along the railway in the early 1900's (Andrews 1965). Presently, there are several hatcheries set up on the island including one in Hopeall River, Trinity Bay (Jamieson 1978) and another in Bay D'Espoir, both of which have resulted in escapements into the wild (V. Pepper, DFO, pers. comm.). Although small landlocked populations have been reported from the Avalon Peninsula (Dominey 1965; Lee 1971; Morry 1976; Jamieson 1978), Notre Dame Bay and in small lakes near Corner Brook (Scott and Crossman 1964), rainbow trout are a mainly stream species (Scott and Scott 1988) which seldom migrate to sea even when access is available (Leim and Scott 1966). However, anadromous rainbow trout (referred to as steelhead trout) have been documented along the west coast of Newfoundland and from four streams in Clarenville, Trinity Bay (Porter et al. 1974; Chadwick and Green 1985). According to Ryan (1988), steelhead trout usually migrate from freshwater in the spring, at 1 to 4 years of age (Ryan 1988). Rainbow trout have not been introduced or recorded from any locations in Labrador.

When occupying lakes, adult rainbow trout generally prefer clear, cold deep lakes that are oligotrophic (Raleigh et al. 1984; Ford et al. 1995). Rainbow trout are commonly reported as the least acid resistant of all salmonids; their lower tolerance limit is a pH of 5.5-6.0 (Grande et al. 1978). McCrimmon (1971) has suggested that low pH may be the reason for unsuccessful introductions of rainbow trout in certain parts of North America and Europe (McCrimmon 1971). Thus, it would appear that water quality may be limiting the successful reproduction of this species throughout most of insular Newfoundland.

Unlike other salmonids in Newfoundland, rainbow trout spawn in the spring, usually from mid-April to mid-May (Frost 1938a; Lee 1971; Scruton et al. 1997), although lake-resident trout may spawn as early as late March in certain areas of Newfoundland (Frost 1940). Spawning occurs almost exclusively in shallow, gravel bottomed streams (Scott and Crossman 1964, 1973; Morrow 1980; Raleigh et al. 1984; Ryan 1988; Ford et al. 1995), although successful reproduction in lakes has been reported (Penlington 1983; Raleigh et al. 1984). Penlington (1983) observed rainbow trout spawning in lakes at depths <1.5 m over a gravel substrate, sometimes within continuous beds of vegetation. Upwelling does not appear to be important for spawning of rainbow trout (Carline 1980; Penlington 1983).

Fry emerge from mid-June to mid-August (Scott and Crossman 1973; Morrow 1980; Scott and Scott 1988; Ford et al. 1995). Lake-dwelling rainbow trout normally have nursery areas in small streams and young may emigrate to lakes during their first growing season or remain in their natal streams for 1-3 years (Northcote 1969, 1978; McPhail and Lindsey 1970; Scott and Crossman 1973; Biette et al. 1981; Raleigh et al. 1984; Kwain 1983; Ford et al. 1995). While occupying lakes, juveniles prefer to inhabit lake margins having a depth of 3-6 m (Ford et al. 1995). During the day, juveniles generally inhabit structurally complex habitats (i.e. substrate is usually cobble/boulder and rubble with cover being provided by boulders, cobble and woody debris) and avoid substrates of sand and gravel (Tabor and Wurtsbaugh 1991; Ford et al. 1995) presumably to reduce predation risk. When away from cover during the day, juveniles were usually found in schools of 30 or more fish and were observed within the bottom 2 m of the water column. At night, on the other hand, they were often found in exposed areas such as sand, gravel and cobble where they remained within 10 cm of the bottom (Tabor and Wurtsbaugh 1991). Juveniles normally remain in lakes for 2 to 4 years before undergoing spawning (Ford et al. 1995). In Newfoundland, rainbow trout usually mature at 3-4 years of age (Lee 1971).

In a small Ontario lake, although adult rainbow trout ranged widely throughout the lake, they frequently inhabited nearshore waters <4 m deep throughout the summer and were shown to feed mainly on zooplankton and benthic invertebrates (Betteridge 1985).

Round whitefish (*Prosopium cylindraceum*)

The round whitefish occurs throughout southern Labrador except in areas along the southeastern coast (Scott and Crossman 1973) and have not been reported north of the Fraser River (Bruce et al. 1979; J.B. Dempson, unpublished data). Although round whitefish have commonly been reported in brackish waters throughout its geographical range, Backus (1957) remarked on its absence in brackish water areas of Labrador. The round whitefish is usually found in ponds, rivers and streams in the northerly extent of its distribution and is found mostly in deeper lakes in more southerly parts of its range (McPhail and Lindsey 1970; Scott and Crossman 1973). In Lake Michigan, although round whitefish were commonly found at depths between 7 to 22 m, they were occasionally captured at depths up to 59 m (Becker 1983).

Spawning occurs in November or December at water temperatures of 2-4.5^{0}C in inshore areas of lakes, at river mouths and occasionally in rivers (Normandeau 1969; Scott and Crossman 1973; Bruce 1974; Bryan and Kato 1975; Morrow 1980; Haymes and Kolenosky 1984). Although round whitefish have been observed broadcasting their eggs over a variety of substrates, ranging from silt and emergent vegetation to gravel and boulder (Bryan and Kato 1975), they appear to spawn most commonly over a gravel or rubble bottom (Normandeau 1969; Bryan and Kato 1975; Morrow 1980). Spawning typically occurs in shallow water, <1 m in depth (Normandeau 1969; Bryan and Kato 1975), but may occur at depths ranging from 5-10 m (Haymes and Kolenosky 1984). Water currents also seem to play a role in spawning site selection; in a New Hampshire lake, Normandeau (1969) found that spawning areas were exposed to prevailing winds, keeping them free from silt by wave action and water currents.

Upon hatching, usually in April, young remain on the bottom (Normandeau 1969) and disperse from the spawning area within 2-3 weeks (Morrow 1980). In several lakes in Algonquin Park, Ontario, juvenile and adult round whitefish were found at all depths down to approximately 23 m (Sandercock 1964). Whitefish were found over a mainly rocky substrate in nearshore areas, while they occurred over a mixture of organic debris and soft clay when inhabiting areas >5 m deep (Sandercock 1964). Round whitefish are mainly bottom feeders, ingesting small benthic invertebrates almost exclusively (Bruce 1974, 1975b; Parsons 1975; Armstrong et al. 1977; Ryan 1980).

Sculpins (Cottidae)

Mottled sculpin (*Cottus bairdi*)

In eastern Canada, the mottled sculpin is confined to mainland areas, occurring throughout the Churchill River system of Labrador (Black et al. 1986), north through Ungava Bay, Quebec (Scott and Crossman 1973). Throughout its geographical range in Canada, the mottled sculpin occurs in cool streams and lakes, but do not usually occur as far up headwater streams nor as deep in lakes as the slimy sculpin (Scott and Crossman 1973). Mottled sculpin are intolerant of high water temperatures and appear to occur at an average summer water temperature of approximately 17^0C (Scott and Crossman 1973).

Spawning typically takes place in the spring, around April or mid-May (Scott and Crossman 1973), in the littoral zone (<1 m) of lakes under rocks and logs (Savage 1963; Downhomer and Brown 1979; Ryan 1980; Lyons 1987). During spawning, females deposit adhesive eggs on the ceiling of a rock, ledge or burrowed nesting site while in an inverted position and the male subsequently guards and aerates the eggs (Savage 1963; Scott and Crossman 1973; Downhomer and Brown 1979; Keenleyside 1979).

Studies in eastern Ontario and Wisconsin suggest that mottled sculpin prefer sandy substrates in both lakes and streams (Emery 1973; Scott and Crossman 1973; Becker 1983). A study in the Mad River, Ontario, summarized by Scott and Crossman (1973), documents the occurrence of YOY on a mud bottom at depths of 5-25 cm. Lyons (1987) found that small sculpins were largely associated with cover, being located under rocks and logs in the shallow (<1 m) littoral zone of the lake during the summer and usually remained there through to October. In Ontario lakes, mottled sculpin were observed foraging at night in open, sandy areas (Emery 1973).

Slimy sculpin (*Cottus cognatus*)

In eastern Canada, the slimy sculpin is confined to the mainland, occurring from the Churchill and Fraser River systems of Labrador (Scott and Crossman 1973; Black et al. 1986) through most of Quebec and Ungava Bay (Scott and Crossman 1973). Throughout its extensive North American range, the slimy sculpin often extends farther north than the mottled sculpin (Scott and Crossman 1973). In northwestern Canada and Alaska, the slimy sculpin is typically less common in lakes than in cool streams and rivers, occurring over a rocky or sandy bottom (McPhail and Lindsey 1970). In the Northwest Territories, slimy sculpin have been found in shallow (<10 m) rocky areas of lakes that are exposed to wind and wave action (McPhail and Lindsey 1970). In eastern Canada, the slimy sculpin frequents rocky or gravel streams and lake bottoms, being captured at depths ranging from 0.5-150 m (Scott and Crossman 1973; Wells 1980; Mohr 1984, 1985; Brandt 1986). In the experimental lakes area of northwestern Ontario, the slimy sculpin occurred in lakes with a well developed hypolimnion (Mohr 1984), only occupying shallow waters (0-4 m depth) during thermal mixing in spring and fall and occurred at depths ranging from 4-10 m throughout the summer (Mohr 1985). In thermally stratified lakes, water temperature appears to be the most critical factor determining sculpin distribution and under such conditions they appear to aggregate within the metalimnion (Mohr 1984, 1985).

Spawning occurs in May, shortly after ice breakup over a sand and gravel substrate in shallow sections of streams and lakes (McPhail and Lindsey 1970; Scott and Crossman 1973; Burgess 1978; Morrow 1980; Mohr 1984). The male selects a spawning site under rocks, submerged logs, tree roots or other foreign debris at water depths <1.5 m (Scott and Crossman 1973; Morrow 1980; Ryan 1980; Mohr 1985) and is most common at depths <30 cm (Morrow 1980). Similar to the mottled sculpin, females deposit adhesive eggs onto the ceiling of the chosen nesting site, then leave the male to guard and aerate the eggs (McPhail and Lindsey 1970; Scott and Crossman 1973; Burgess 1978; Morrow 1980).

During their first year, juveniles may be captured in shallow water (0.5-1.5 m) of lakes, over gravel and sand bottoms interspersed with rocks and boulders (Mohr 1984). Generally, as young sculpin grow and mature, they shift from a shallow water habitat and nocturnal feeding to continuous activity in deeper water (Wells 1968; Mohr 1985; Brandt 1986). In Lake Opeongo, Ontario, slimy sculpins were observed resting on the sand at night with parts of their pectoral and pelvic fins covered with bottom materials and have been shown to bury themselves in the loose substrate when disturbed (Emery 1973). Investigations on diet composition suggest that slimy sculpin feed mainly on benthic organisms (Wells 1980; Mohr 1984) and thus commonly inhabit bottom areas of lakes (Scott and Crossman 1973; Wells 1980).

Smelt (Osmeridae)

Rainbow smelt (*Osmerus mordax*)

Rainbow, or American smelt as they are often called, occur in both landlocked and anadromous forms (Scott and Crossman 1964, 1973; Scott and Scott 1988; Communications Directorate 1990). Landlocked populations may exist as either normal- or dwarf-sized forms (Bruce 1975a; Whelan and Wiseman 1975; Nellbring 1989) and have been reported throughout many parts of insular Newfoundland (Bigelow and Schroeder 1963; Scott and Crossman 1964; Murawski and Cole 1978). It is assumed that both forms have similar habitat requirements since there was no information found to distinguish between the two. Anadromous smelt occur along the Atlantic coast from its northern limit at latitude 55^0 N (Black et al. 1986) southward to New Jersey (Scott and Crossman 1973). Although smelt occur infrequently in Labrador, they may be numerous at times along coastal areas of Newfoundland (Pinhorn 1976). Smelt are essentially a schooling fish, inhabiting lakes or inshore coastal waters and migrate into streams or rivers to spawn (Leim and Scott 1966; Scott and Crossman 1973; Murawski and Cole 1978; Scott and Scott 1988).

<u>Anadromous</u>

Shortly after spring ice-out (mid-April to mid-June in Newfoundland and early-May to mid-June in Labrador, Scruton et al. 1997), smelt migrate into freshwater spawning areas (Scott and Crossman 1964, 1973; Nhwani 1973; Morrow 1980; Scott and Scott 1988; Nellbring 1989; Communications Directorate 1990). Anadromous smelt typically spawn in the lower reaches of streams and rivers (Templeman 1966) and have been observed spawning near the mouths of rivers mainly above tidal influence (McKenzie 1964; Scott and Crossman 1964; Nhwani 1973; Murawski and Cole 1978; Morrow 1980; Buckley 1989). Smelt also spawn offshore on gravel shoals before reaching freshwater especially if they encounter stormy weather or physical obstructions (Rupp 1965; Leim and Scott 1966; Scott and Crossman 1973; Morrow 1980; Communications Directorate 1990). Spawning usually occurs at depths of ≤1.3 m in moderate-flowing, gravel-bottomed sections of the river (Elson et al. 1972; Scott and Crossman 1973; Burgess 1978; Buckley 1989; Communications Directorate 1990). However, spawning has been shown to occur over a variety of substrates including very fine gravel, pebbles, cobble, submerged logs as well as vegetation (Scott and Crossman 1964; Nhwani 1973; Morrow 1980) and according to Buckley (1989), it is water velocity rather than depth or substrate which largely influences spawning site selection.

Eggs sink to the bottom immediately after they are released, and become attached to the substrate by a short pedicel (stalk) formed from the outer shell membrane (Rupp 1965) which enables eggs to sway in the water, thereby ensuring good aeration (Scott and Crossman 1973; Morrow 1980; Communications Directorate 1990). Eggs hatch between mid-May and mid-July in Newfoundland (Dyke 1964; Scruton et al. 1997) and from early-June to mid-July in Labrador (Scruton et al. 1997). Upon hatching, larvae begin drifting downstream to the estuary (McKenzie 1964; Leim and Scott 1966; Scott and Crossman 1973; Morrow 1980; Scott and Scott 1988; Communications Directorate 1990). Around mid-August, most young leave the river and occupy nearshore coastal areas along gravel and sand beaches and have been observed in eelgrass beds (Scott and Crossman 1973; Buckley 1989). Young typically form schools when they are 19 mm in length (Buckley 1989).

Adults may remain in the estuary during the summer or occupy relatively shallow (<6 m) nearshore areas, always within 2 km of the coast (Buckley 1989). In the fall, both juveniles and adults return to estuaries where they overwinter (Scott and Scott 1988; Buckley 1989). In Newfoundland, anadromous smelt have been shown to occupy lake habitats shortly after ice break-up in early spring as evidenced by their presence in the diet of ouananiche (Leggett 1965). Smelt normally mature at 2-3 years of age (Dyke 1964; Bruce 1975a; Ryan 1980; Scott and Scott 1988; Communications Directorate 1990).

Freshwater resident

On the Avalon Peninsula of Newfoundland, lake-spawning was observed before ice-out in early- to mid-April, while spawning in tributary streams did not occur until early to mid-May, after the ice had moved out (Bruce 1975a). Landlocked smelt have been shown to spawn in rivers and along the shoreline of lakes (Rupp 1965; Bruce 1975a; Burgess 1978; Ivanova and Polovkova 1972; Morrow 1980; Nellbring 1989). In the Soviet Union, smelt spawning in lakes were typically first time spawners (i.e. age 1+ and 2+), while repeat spawners more commonly used the river (Ivanova and Polovkova 1972). During spawning, eggs are released indiscriminately over a wide variety of substrates including mud, clay, sand, gravel, cobble, rubble and boulders as well as aquatic vegetation and woody debris at depths ranging from 0.1-5 m (Rupp 1965; Ivanova and Polovkova 1972; Bruce 1975a; Burgess 1978; Morrow 1980). In Newfoundland, lake-spawning often occurs near the mouths of inlet streams (Bruce 1975a), while in the Soviet Union, spawning generally takes place in protected areas, with little wind or wave action (Ivanova and Polovkova 1972). Although less common, deepwater lake-spawning has been reported in Quebec (Legault and Delisle 1968) and New York (Plosila 1984).

Evans and Loftus (1987) reported that smelt in inland lakes of the Great Lakes region have a eurythermal life history: they occurred in the nearshore zone (0-60 m) in three temperature strata, with YOY in warm water (i.e. epilimnion zone), yearlings in cool water (i.e. metalimnion) and adults in cold water habitats (i.e. hypolimnion zone). Larvae generally occupy shallow (2-4 m) water areas during the day and move into deeper (<15 m) water at night where they are concentrated 2-3 m above the bottom (Emery 1973; Evans and Loftus 1987). Emery (1973) also found that larvae formed schools during the day but not at night. Adults, on the other hand, occur most frequently in deeper (> 10 m) benthic areas during the day and migrate up into the water column at night (Heist and Swenson 1983; Sandlund et al. 1985; Burczynski et al. 1987; Evans and Loftus 1987). Juveniles typically inhabit mid-water depths (Argyle 1982; Evans and Loftus 1987) and thus are usually found in intermediate positions between YOY and adults. It has been suggested that this behaviour enables smelt to utilize the spatial, thermal and food resources of the entire water column, while minimizing intraspecific interactions (Evans and Loftus 1987). This spatial segregation may breakdown, however, during periods of high food abundance. In Norway, for example, smelt typically inhabit benthic areas throughout much of the year and are abundant in the pelagic zone only during August and November, at times of maximum zooplankton biomass (Sandlund et al. 1985).

Sticklebacks (Gasterosteidae)

Blackspotted stickleback (*Gasterosteus wheatlandi*)

The blackspotted stickleback is found predominantly in coastal waters from northern Newfoundland south to Long Island, New York (Leim and Scott 1966; Burgess 1978; Wootton 1984; Scott and Scott 1988), but has not been reported in Labrador. Blackspotted stickleback have been found to enter brackish water in late spring to spawn (Scott and Crossman 1973; Wootton 1976) and has been reported to spawn slightly later than the threespine stickleback (Coad and Power 1973a; Scott and Crossman 1973). The blackspotted stickleback is often confused with the threespine stickleback, so little is known of its life history or habits (Leim and Scott 1966).

Males build a nest made of thread-like algae and other plant debris in relatively open areas (McInnerey 1969; Burgess 1978). The spawning territories of males occur mainly over a sandy or coarse mud bottom containing abundant rooted aquatic plants, stones or sunken logs (McInnerey 1969). Nesting typically occurs at depths varying from 0.2-0.6 m at low tide (McInnerey 1969; Burgess 1978), although nesting has been observed at depths >6 m (Wootton 1984). Males guard and aerate the eggs through fanning with their pectoral fins (Scott and Crossman 1973; Burgess 1978). Sexual maturity is attained within one year (Coad and Power 1973a) during which time they frequently lead a semi-pelagic existence, swimming near floating seaweed (Leim and Scott 1966; Scott and Crossman 1973).

Fourspine stickleback (*Apeltes quadracus*)

In Newfoundland, the fourspine stickleback is often confined to more southerly locations and has not been found to extend as far north as Labrador (Scott and Scott 1988). Fourspine stickleback, a euryhaline species, is the smallest member of the stickleback family, Gasterosteidae (Courtenay and Keenleyside 1983). Although the fourspine stickleback typically inhabits marine or brackish waters in Newfoundland (Scott and Crossman 1964; Leim and Scott 1966; Garside 1970; Hanek and Threlfall 1970; Van Vliet 1970; Scott and Crossman 1973; Lewis 1978; Scott and Scott 1988; Campbell 1992) it has been noted to occur occasionally in freshwater lakes (Nelson 1968a; Van Vliet 1970; Baker 1971; Dadswell 1972; Coad and Power 1973d; Rombough et al. 1981; Campbell 1992). In Newfoundland, isolated populations of four- and threespine sticklebacks have been reported in a freshwater lagoon in Pt. Verde, Placentia Bay which has no open connection to the ocean (Fitzpatrick 1988). Fully marine populations are rare and tend to occur in sheltered inlets or mudflats where eelgrass is abundant (Blouw and Hagen 1981; Courtenay and Keenleyside 1983; Wootton 1984).

The fourspine stickleback spawns in spring or early summer (May-July) and is commonly associated with dense aquatic vegetation in areas with calm water (Leim and Scott 1966; Baker 1971; Briggs and O'Connor 1971; Wootton 1976, 1984; Burgess 1978; Blouw and Hagen 1981; Courtenay and Keenleyside 1983; Scott and Scott 1988). Males construct a small nest made of aquatic plants and twigs bound together by a glutinous kidney material secreted by the male (Leim and Scott 1966; Scott and Crossman 1973; Wootton 1976; Blouw and Hagen 1981; Courtenay and Keenleyside 1983; Courtenay 1985) which may be constructed anywhere from the base of plants to 33 cm up off the bottom (Wootton 1976, 1984; Courtenay and Keenleyside 1983).

While Courtenay and Keenleyside (1983) found no clear substrate preference for nest building in the estuarine areas they studied (i.e. nests were built over mud and rock bottoms on all vegetation types as well as on rocks and submerged twigs), Blouw and Hagen (1981) found that most nesting occurred at depths of 0.5-0.8 m over a muddy bottom. The reproductive period of fourspine stickleback has been shown to be extended until the end of July when occurring sympatrically with other stickleback species (blackspotted, threespine and ninespine stickleback), all of which had completed their spawning by late June (Worgan and Fitzgerald 1981). Worgan and Fitzgerald (1981) suggested that this was possibly in response to competition for space with other species.

Adhesive eggs are deposited in the nest (Scott and Crossman 1973) which the male aerates by sucking a current of water over them (Reisman 1963; Wootton 1976; Blouw and Hagen 1981), rather than fanning with the pectoral fins, as observed in other gasterosteids. Males have been known to care for as many as four or five clutches of eggs simultaneously. Clutches may be placed in nests, one on top of the other, in a tiered effect (Reisman 1963; Rowland 1974; Wootton 1976) or may be distributed among several nests scattered throughout a male's territory (Courtenay and Keenleyside 1983; Courtenay 1985). Larvae hatch within a week at water temperatures of 16-18^{0}C and remain motionless on the bottom for several days before engaging in free-swimming (Wootton 1976; Blouw and Hagen 1981). Unlike many other sticklebacks, males do not care for their young once they hatch (Wootton 1976).

In marine and brackish water, male fourspine sticklebacks were reported to have a one year lifespan, while females may survive a second winter to spawn the following spring or summer (Scott and Scott 1988). In Pt. Verde, no individuals were found to live past 2 years of age (Fitzpatrick 1988). Studies conducted in Nova Scotia and New Brunswick also suggested that fourspine stickleback live between one and two years (Blouw and Hagen 1981). In Pt. Verde, fourspine stickleback were observed feeding exclusively on invertebrates (Fitzpatrick 1988), while in Nova Scotia and New Brunswick, they were fed on invertebrates as well as some plant material (Blouw and Hagen 1981). Several investigators, however, have reported on the insignificance of plant material in the diet of fourspine stickleback and have suggested that it is probably ingested accidentally while foraging for invertebrates (Hynes 1950; Coad and Power 1973a). In Pt. Verde, fourspine stickleback occurred primarily in areas of dense, emergent vegetation over a predominantly rocky bottom covered in black mud (Fitzpatrick 1988).

Ninespine stickleback (*Pungitius pungitius*)

Ninespine stickleback have been reported from several localities in Newfoundland and southern Labrador (Scott and Crossman 1973; Black et al. 1986). Although ninespine stickleback have a relatively high salinity tolerance, they have only been reported to spawn in freshwater (Nelson 1968a; Scott and Crossman 1973). In most areas throughout its range, spawning occurs in the summer in relatively shallow areas containing dense aquatic vegetation (Scott and Crossman 1964, 1973; McPhail and Lindsey 1970; Morrow 1980; Ryan 1980; Wootton 1984; Scott and Scott 1988). However, spawning has been observed at depths of 5-40 m in some areas (Nelson 1968b; Becker 1983). It is important to note that even though ninespine stickleback prefer areas of heavy vegetation they are not confined to such areas (Wootton 1976) and may move freely into open water (Nelson 1968b; Scott and Crossman 1973) over sand or even gravel beaches and other areas of sparse vegetation (McPhail and Lindsey 1970).

Males construct a nest made of algae and other plant debris (McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1976; Morrow 1980). Typically the nest is positioned on aquatic vegetation 10-15 cm off the bottom, but occasionally is in contact with the bottom or even slightly sunk into it (McPhail and Lindsey 1970; Wootton 1976; Morrow 1980). In some areas, nests have been observed under or between rocks at depths of 25-80 cm on rocky, wave-swept lake shores (McKenzie and Keenleyside 1970) and at the bottom of burrows in soft, organic mud (Griswold and Smith 1972). Generally though, the weedy areas inhabited by ninespine stickleback are dominated by a muddy rock bottom (Scott and Crossman 1964; Griswold and Smith 1972). Males guard the nest and aerate the eggs through fanning with their pectoral fins (McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1976; Burgess 1978; Scott and Scott 1988).

Morrow (1980) found that newly hatched larvae move to the top of the nest where they remain relatively inactive. At this time, the male may construct a ‘nursery’ area (i.e. a loosely constructed aggregation of nest-building materials situated a few cm above the nest) (McPhail and Lindsey 1970; Wootton 1976; Morrow 1980). However, 'nursery' construction appears to occur only in areas where breeding takes place in dense vegetation (Keenleyside 1979). After a few days in the nursery area, young are completely free-swimming (McPhail and Lindsey 1970) and typically remain in the shallow, littoral zone before dispersing to deep waters in the fall (Becker 1983) where they have been found to overwinter (Morrow 1980).

In the St. Lawrence River system, Quebec, Coad and Power (1973c) noted that the longevity of the river form of the ninespine stickleback was 1 year and some months, whereas the lake form lived for more than 2 years. In lakes exhibiting thermal stratification, ninespine stickleback were found in warmer, deep water in early spring and late fall but were evenly distributed at all depths during spring turnover when the waters mix and the water temperatures are the same at all depths (Griswold and Smith 1973).

Threespine stickleback (*Gasterosteus aculeatus*)

The threespine stickleback occurs throughout most of Newfoundland and Labrador (Black et al. 1986) and even though it has been reported as the second most widely distributed fish in Newfoundland's fresh waters, little information exists on its local ecology (Scott and Crossman 1964). It is a euryhaline species being tolerant of marine, brackish and freshwater, occupying mainly shallow waters in still or relatively slow-flowing areas (Scott and Crossman 1964, 1973; Wootton 1984; Scott and Scott 1988) and has been documented in many freshwater lakes within insular Newfoundland (Pepper 1976; Rombough et al. 1978; Ryan 1984; Campbell and Knoechel 1988, 1990, 1991). A freshwater population of threespine stickleback has also been reported in an isolated lagoon in Pt. Verde, Placentia Bay, Newfoundland (Fitzpatrick 1988).

<u>Anadromous</u>

Anadromous populations may spawn in brackish or freshwater (Leim and Scott 1966; Coad and Power 1973a; Morrow 1980; Wootton 1984). Migrations of anadromous stickleback into freshwater usually occurs in late spring (June) with spawning occurring shortly thereafter (McPhail and Lindsey 1970). In marine or estuarine habitats, spawning may occur in a variety of habitats including rock crevices, sheltered eelgrass beds, algal mats and sometimes over sand and silt near vegetation (Black and Wooton 1970; McPhail and Lindsey 1970; Morrow 1980). Upon hatching, young leave the spawning area but remain close to shore in shallow water, seeking shelter in floating seaweed or other debris (Leim and Scott 1966; Morrow 1980; Scott and Scott 1988). Young and adults overwinter in coastal waters, some remaining close to shore, while others may move considerable distances offshore (Morrow 1980; Wootton 1984). However, in offshore areas, sticklebacks generally occur in quite shallow water in association with floating seaweed or other debris (Scott and Scott 1988).

<u>Freshwater resident</u>

Resident freshwater populations of threespine stickleback spawn mainly in mid-summer (during June and July) in Atlantic-zone temperate lakes (Leim and Scott 1966; Coad and Power 1973b; Scott and Crossman 1973; Pepper 1976; Ryan 1984; Jakobsen et al. 1988; Scott and Scott 1988;

Campbell and Knoechel 1991). Spawning in freshwater has been observed in two distinct habitat types within lakes; open-water areas (Black and Wooton 1970; Lewis et al. 1972; Griswold and Smith 1972; Larson 1976; Wootton 1984) or in association with aquatic vegetation (Black and Wooton 1970; McPhail and Lindsey 1970; Larson 1976; Morrow 1980; Sandlund et al. 1992b). It is important to note that although some males build their nests near aquatic plants, the nests are generally more exposed than those of other members of the family Gasterosteidae (McPhail and Lindsey 1970). The male constructs a nest of small twigs, algae or plant debris typically over a sandy or mud bottom (McPhail and Lindsey 1970; Griswold and Smith 1972; Scott and Crossman 1973; Ryan 1980; Scott and Scott 1988). However, nests have been found on a wide variety of substrates including silt, algal tufts and rock (Hagen 1967; Black and Wootton 1970; Wootton 1971; Pepper 1976). It has been suggested that males prefer to build their nests close to other objects such as boulders, rocks and vegetation, thereby increasing the structural complexity of the habitat and reducing the risk of predation (Wooton and Black 1970). Males generally avoid nesting in water shallower than 0.2 m (Lewis et al. 1972; Kynard 1978) and have been observed nesting at depths of up to 40 m (Griswold and Smith 1972). Kynard (1978) suggested that males avoid nesting in very shallow water because of the potential damage caused by wave action during storms.

During spawning, females release adhesive eggs that are deposited in clusters in the nest (Morrow 1980). The male guards and fans the nest (Leim and Scott 1966; McPhail and Lindsey 1970; Scott and Crossman 1973; Scott and Scott 1988) and protects the young for up to 2 weeks after hatching or until they are able to fend for themselves (Wootton 1976; Scott and Scott 1988). Outside the breeding season, sticklebacks normally live in schools (Wootton 1976) and are found mainly in weedy, littoral areas in lakes with well-developed macrophyte beds (Kerfoot 1975; Ryan 1984; Fitzpatrick 1988; Jakobsen et al. 1988) over a predominantly rocky bottom covered in black mud (Fitzpatrick 1988). Sticklebacks have been observed at all depths (<1 m up to 17 m) in lakes along the Avalon Peninsula, Newfoundland (Campbell and Knoechel 1990) and have been shown to feed mainly on pelagic zooplankton (Ryan 1984; Campbell and Knoechel 1988, 1990) and benthic organisms (Ryan 1984; Campbell and Knoechel 1990). In Pt. Verde, Newfoundland, however, threespine sticklebacks fed mainly on plant material (Fitzpatrick 1988). Both juveniles and adults have been shown to overwinter in deeper waters (Wootton 1976; Morrow 1980; Scott and Scott 1988). According to Ryan (1984), threespine stickleback in Newfoundland normally mature in their second or third year and have a maximum lifespan of about two and one-half years. This was further supported by observations in Pt. Verde, where no individuals were found to live past the age of 2 years (Fitzpatrick 1988).

The spatial distribution of sticklebacks in lakes has been shown to vary depending on the presence of other species. For example, sticklebacks were confined to the vegetative littoral zone of lakes in the presence of predators (Jakobsen et al. 1988; Sandlund et al. 1992b), whereas in localities without predators, sticklebacks are commonly observed both in the open-water of the littoral and limnetic (or pelagic) zones (Larson 1976; McPhail 1984; Bentzen et al. 1984). Gaudreault et al. (1986) indicated that competition for food and space with juvenile salmonids of similar size also affects the distribution of adult sticklebacks.

Sturgeons (Acipenseridae)

Atlantic sturgeon (*Acipenser oxyrhynchus*)

Restricted to the Atlantic coast of North America, the Atlantic sturgeon ranges from Hamilton Inlet, Labrador (Backus 1951) to eastern Florida (Scott and Scott 1988). It is an anadromous fish entering freshwater rivers and estuaries to spawn (Dees 1961; Scott and Scott 1988), but attains most of its growth in saltwater (Smith 1985; Scott and Scott 1988). Based on the literature reviewed, it appears that this species does not occur in lake habitats. In Canadian waters, upriver spawning migrations occur from May to July (Smith 1985). Although actual spawning locations are not well known they are believed to occur in running water over hard substrates such as rock, rubble and shale and in pools below waterfalls (Dees 1961; Smith 1985).

Females release highly adhesive, demersal eggs which attach to rocks, gravel and surrounding vegetation within 20 minutes after being broadcasted (Scott and Crossman 1973; Burgess 1978; Smith 1985; Scott and Scott 1988). The yolksac is absorbed 9-10 days after hatching and larvae begin an immediate benthic existence (Smith 1985). Most juveniles remain in slightly brackish water near the mouth of their natal river for a number of months or years (Scott and Crossman 1973; Smith 1985; Scott and Scott 1988; Kieffer and Kynard 1993; Moser and Ross 1995) before moving into coastal waters where they grow and mature (Gilbert 1989). After attaining sexual maturity (7-27 years for females), spawning occurs once every 2-5 years (Smith 1985).

Suckers (Catostomidae)

Longnose sucker (*Catastomus catostomus*)

Longnose sucker have only been found throughout southern Labrador (Bruce et al. 1979; J.B. Dempson, unpublished data) with no reported occurrences in insular Newfoundland (Scott and Crossman 1973). They occur mainly in deeper areas of lakes throughout its southern range of distribution (Scott and Crossman 1973) and are most abundant in cold, oligotrophic lakes (Walton 1980). For the most part, the longnose sucker is generally restricted to lake bottoms or tributary streams, but has also been reported in brackish waters at the mouths of arctic streams (McPhail and Lindsey 1970; Scott and Crossman 1973).

Longnose suckers are typically stream spawners, but may also spawn in shallow regions of lakes (Geen et al. 1966; McPhail and Lindsey 1970; Scott and Crossman 1973; Smith 1979; Morrow 1980; Ryan 1980). Adults enter spawning streams in large numbers shortly after ice-out, or when water temperatures exceed 5^0C (McPhail and Lindsey 1970; Scott and Crossman 1973; Burgess 1978; Ryan 1980). Lake and stream spawning may take place as early as mid-April to mid-May in northwestern Canada (McPhail and Lindsey 1970; Scott and Crossman 1973) or as late as June in Labrador (Ryan 1980). In some regions, the main spawning migration of the longnose sucker may precede that of the white sucker by several days (Geen et al. 1966).

Spawning generally takes place in riffle areas over gravel and cobble substrates (Scott and Crossman 1973; Morrow 1980) or along wave-swept, rocky shorelines of lakes at depths of 15-30 cm (Geen et al. 1966; Walton 1980). However, in some lakes, spawning has been observed over a mainly sandy substrate (Geen et al. 1966; Morrow 1980). During spawning, adhesive eggs are broadcast over a gravel/cobble substrate (McPhail and Lindsey 1970; Scott and Crossman 1973). In streams, newly hatched young remain in the gravel for 1-2 weeks and drift downstream into lakes soon after hatching (Geen et al. 1966; Bailey 1969; McPhail and Lindsey 1970; Scott and Crossman 1973; Ryan 1980). YOY seek food and shelter in shallow, quiet waters with vegetation (Brown and Graham 1953; Edwards 1983) and may also seek cover among boulders or rubble during the day (Edwards 1983). Juveniles have also been shown to frequent shallow, weedy habitats (Edwards 1983) usually in areas with some current (Johnson 1971). Young are chiefly planktonic feeders and shift their diet to mainly benthic invertebrates as they grow larger (Bruce 1974, 1975b; Bruce and Parsons 1979; Morrow 1980; Ryan 1980) and have also been shown to ingest plants, algae and detritus (Brown and Graham 1953; Ryan 1980). In Labrador, longnose suckers were found to mature at 5-6 years of age (Bruce and Parsons 1979; Ryan 1980). Lake-dwelling adults generally only enter rivers to spawn or overwinter (Harris 1962; Walton 1980) and those that move into tributary streams to spawn, typically return to the lake shortly after spawning (Morrow 1980). Adults have been reported at depths up to 30 m (Harris 1962; McPhail and Lindsey 1970; Johnson 1971). Studies in a Maine reservoir, suggest that longnose suckers may be attracted to submerged logs which appear to provide cover as well as a suitable substrate for the benthic invertebrates on which they feed (Moring et al. 1986).

White sucker (*Catostomus commersoni*)

In eastern Canada, the white sucker occurs in New Brunswick and Nova Scotia north through Quebec and southern Labrador (Black et al. 1986), but has not been reported in insular Newfoundland (Scott and Crossman 1973). The white sucker is typically a shallow water inhabitant of lakes and rivers and is able to withstand turbidity, stagnant water and high alkalinity which would kill most other species (Becker 1983). In the southern limit of its range, the white sucker may be widely distributed throughout lakes, but toward its northern limit it is commonly found in warmer, shallow (2-6 m) littoral areas (McPhail and Lindsey 1970; Magnan 1989; Sellars et al. 1998).

In Labrador, spawning usually occurs in June once water temperatures reach 10^0C (Scott and Crossman 1973; Ryan 1980; Curry and Spacie 1984) and the white sucker generally spawns later than the longnose sucker (McPhail and Lindsey 1970). Spawning typically occurs in shallow (<1 m), gravel riffle sections of streams, but may also occur in rapids and along lake margins (Geen et al. 1966; McPhail and Lindsey 1970; Scott and Crossman 1973; Burgess 1978; Ryan 1980; Corbett and Powles 1983; Spacie and Curry 1984). Eggs are released into the water and either adhere to the substrate in the immediate spawning area or drift downstream, adhering to the substrate in quieter areas (Scott and Crossman 1973; Becker 1983). Fry from stream-spawning populations begin their lakeward migration approximately one month after spawning (Geen et al. 1966; Scott and Crossman 1973; Corbett and Powles 1983). Shortly after entering the lake, YOY are typically found in shallow water along the lakeshore, but move into deeper offshore areas in regions where mid-summer water temperatures reach 30^0C (Corbett and Powles 1983). Fry generally feed near the surface on zooplankton and shift to benthic feeding once they attain a size of 16-18 mm (Scott and Crossman 1973; Parsons 1975; Ryan 1980; Corbett and Powles 1983). In Labrador, white suckers generally mature at 4-5 years of age (Ryan 1980).

Adults that move into tributary streams to spawn, generally return to the lake within a week or two after spawning (Scott and Crossman 1973). Adults feed almost exclusively on benthic organisms (McPhail and Lindsey 1970; Parsons 1975; Magnan 1989; Ahlgren 1990), but have been shown to ingest detritus, especially when there is a decline in benthic prey (Ahlgren 1990). Similar to the longnose sucker, white suckers have been shown to have an attraction to submerged logs (Moring et al. 1986). In Wyoming, white suckers were often found around large woody debris in shady sections of streams (Hubert and Rahel 1989).

SUMMARY AND RECOMMENDATIONS

It is evident that a lot of information on specific lake habitat use is not available for many freshwater species in Newfoundland and Labrador. Clearly, there is a need to acquire this information and future research should be aimed at filling these data gaps. However, in the interim it is believed that the information contained in this report will assist in identifying the freshwater habitat requirements of the fish occurring in Newfoundland and Labrador.

ACKNOWLEDGEMENTS

The authors would like to thank K. Clarke, J.B. Dempson, M.F. O'Connell, D.A. Scruton and D. Sooley (DFO, Newfoundland Region) and J.M. Green (Memorial University of Newfoundland) for their review of the document and contribution of information. Thanks are also extended to K. Regular of GDS Inc. for assistance with the map production. Funding for this project was provided from the Great Lakes Laboratory of Fisheries and Aquatic Sciences, DFO, Burlington, Ontario.

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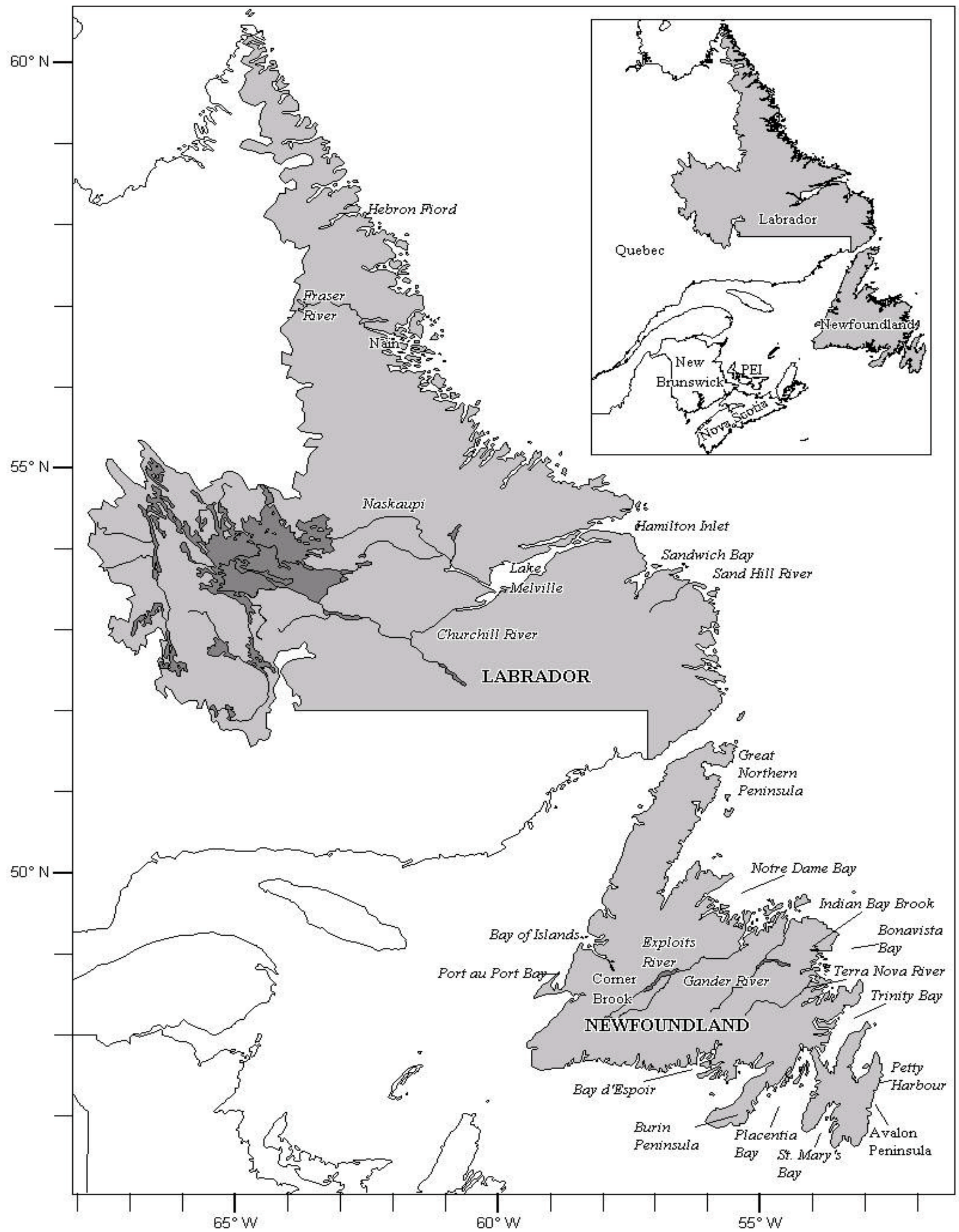

Figure 1. A map of Newfoundland and Labrador highlighting reference locations cited throughout the report.

Table 1: List of fish species occurring in fresh waters of Newfoundland and Labrador.

Common Name	Scientific Name	Newfoundland	Labrador
Cod	Gadidae		
Atlantic tomcod	*Microgadus tomcod* (Walbum, 1792)	X	X
burbot	*Lota lota* (Linnaeus, 1758)		X
Eels	Anguillidae		
American eel	*Anguilla rostrata* (Lesueur, 1817)	X	X
Herring	Clupeidae		
Alewife	*Alosa pseudoharengus* (Wilson, 1811)	X	X
American shad	*Alosa sapidissima* (Wilson, 1811)	X	X
Killifishes	Cyprinodontidae		
Banded killifish	*Fundulus diaphanus* (Lesueur, 1817)	X	
Mummichog	*Fundulus heteroclitus* (Linnaeus, 1766)	X	
Lampreys	Petromyzontidae		
sea lamprey	*Petromyzon marinus* (Linnaeus, 1758)	X	X
Minnows	Cyprinidae		
lake chub	*Couesius plumbeus* (Agassiz, 1850)		X
longnose dace	*Rhinichthys cataractae* (Valenciennes, 1842)		X
pearl dace	*Margariscus margarita* (Cope, 1868)		X
Pikes	Esocidae		
northern pike	*Esox lucius* (Linnaeus, 1758)		X
Salmonids	Salmonidae		
Arctic charr	*Salvelinus alpinus* (Linnaeus, 1758)	X	X
Atlantic salmon	*Salmo salar* (Linnaeus, 1758)	X	X
brook trout	*Salvelinus fontinalis* (Mitchill, 1814)	X	X
brown trout	*Salmo trutta* (Linnaeus, 1758)	X	
lake trout	*Salvelinus namaycush* (Walbaum, 1792)		X
lake whitefish	*Coregonus clupeaformis* (Mitchill, 1818)	X	X
pink salmon	*Oncorhynchus gorbuscha* (Walbaum, 1792)	X	X
rainbow trout	*Salmo gairdneri* (Walbaum, 1792)	X	
round whitefish	*Prosopium cylindraceum* (Pallas, 1784)		X
Sculpins	Cottidae		
mottled sculpin	*Cottus bairdi* (Girard, 1850)		X
slimy sculpin	*Cottus cognatus* (Richardson, 1836)		X
Smelt	Osmeridae		
rainbow smelt	*Osmerus mordax* (Mitchill, 1814)	X	X
Sticklebacks	Gasterosteidae		
blackspotted stickleback	*Gasterosteus wheatlandi* (Putnam, 1867)	X	
fourspine stickleback	*Apeltes quadracus* (Mitchill, 1815)	X	
ninespine stickleback	*Pungitius pungitius* (Linnaeus, 1758)	X	X
threespine stickleback	*Gasterosteus aculeatus* (Linnaeus, 1758)	X	X
Sturgeons	Acipenseridae		
Atlantic sturgeon	*Acipenser oxyrhynchus* (Mitchill, 1814)		X
Suckers	Catostomidae		
longnose sucker	*Catostomus catostomus* (Forster, 1773)		X
white sucker	*Catostomus commersoni* (Lacepede, 1803)		X

Table 2. Lacustrine habitat requirements data for burbot.

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H		4,5,9,12,13,15	4,5,8,15	5,8,15	
1-2 meters	H	H	H		4,5,9,10,12,13,15	4,5,8,15	5,8,15	
2-5 meters	L	H	H	L	4,5,10,13,15	4,5,8,15	5,8,15	*8,* 15
5-10 meters	L	L	*L*	L	4,*13*,*15*	4,*5*	*5*	*5,8,* 15
10+ meters	L	*L*	*L*	H	12,13,15	*5*	*5*	3,*5*,8,13,15
Substrate:								
Bedrock				H				3
Boulder		H	H	H		5,8,15	5,8,15	3,5
Rubble	L	H	H	H	9	5,8,15	5,8,15	3,5
Cobble	H	H	H	H	5,9,10,13,16	5,8,15	5,8,15	5
Gravel	H	H	H	H	1,5,9,10,13,15,16	5,8	5,8	5
Sand	H	*L*	L	*L*	5,9,13,15,16	*7,15*	15	*3*
Silt	Nil			*L*	5,13,16			*3*
Muck(detritus)	Nil				5,13,16			
Clay(mud)	Nil				5,13,16			
Pelagic		L				2,6,9,14		
Cover:								
None								
Submergents		M	M	M		5,*7*,11,*15*	5,11,*15*	3
Emergents		M	M	M		11	11	3
Overhead		M	M	M		5,*7*	5	3
In situ		M	M	M		5,*7*,11	5,11	3
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
YOY and juveniles are typically found in the littoral regions of lakes over rocky bottoms (3,4,6,11) and have been shown to use rocks, weeds or debris as cover (11). In streams, however, young have been shown to use undercut banks, submerged logs and vegetation for cover in sandy areas if rocky habitat is limited (5).
When in shallow water during the day, adults are often found in areas of overhead cover and are sometimes found amongst aquatic plants as well as resting underneath the loft microhabitat provided by large boulders (2).

Table 3. Lacustrine habitat requirements data for American eel.

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters			*H*	H			*3*	3
1-2 meters			*H*	H			*3,7*	3,7
2-5 meters			*H*	H			*3*	3
5-10 meters			*H*	H			*3*	3
10+ meters								
Substrate:								
Bedrock								
Boulder			*H*	H			*1*	1,7
Rubble			*H*	H			*1*	1,7
Cobble								
Gravel								
Sand				H				3
Silt			H				5,6	
Muck(detritus)								
Clay(mud)			H	H			1,2,5,6	1,3,5
Pelagic								
Cover:								
None								
Submergents			*L*	H			*4*	3
Emergents				H				3
Overhead								
In situ			H	H			1	1
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Spawning occurs at sea where young typically spend their first year of life before returning to freshwater (Frost 1939; Templeman 1966; Facey and Van Den Avyle 1987; Helfman et al. 1987; McCleave et al. 1987; Jessop 1996), therefore there are no lake habitat requirements for spawning or YOY.
Since there was no information available in the literature reviewed on depth distribution of juvenile eels, it was assumed that juveniles occupy the same depths as adults.
Eels being nocturnal, usually spend the day hiding under rocks and logs or buried in mud (1,2,6).
During winter, juveniles have been found hibernating in muddy bottoms of lakes and rivers (2,4,5).

Table 4. Lacustrine habitat requirements data for alewife (anadromous).

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters								
1-2 meters								
2-5 meters								
5-10 meters								
10+ meters								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	M				3			
Sand	M				1,3			
Silt	*H*				*1*			
Muck(detritus)	H				1			
Clay(mud)	H				1			
Pelagic		M	M			2	2	
Cover:								
None								
Submergents	M				1			
Emergents								
Overhead								
In situ								
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Adults spend most of their lives at sea, entering fresh water to spawn (3).
Spawning occurs along shallow beaches in lakes, streams and in brackish tidal waters (1,2,3).
Alewives have been shown to spawn over detritus-covered bottoms with attached vegetation,
sticks or other organic matter and occassionally over a hard sand bottom (1).
Juvenile alewives are concentrated near the bottom during the day and move up into the water
column at night (2).

Table 4. Lacustrine habitat requirements data for alewife (anadromous).

Habitat Features:	**Ratings**[1]				**Sources**[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters								
1-2 meters								
2-5 meters								
5-10 meters								
10+ meters								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	M				3			
Sand	M				1,3			
Silt	*H*				*1*			
Muck(detritus)	H				1			
Clay(mud)	H				1			
Pelagic		M	M			2	2	
Cover:								
None								
Submergents	M				1			
Emergents								
Overhead								
In situ								
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Adults spend most of their lives at sea, entering fresh water to spawn (3).
Spawning occurs along shallow beaches in lakes, streams and in brackish tidal waters (1,2,3).
Alewives have been shown to spawn over detritus-covered bottoms with attached vegetation,
sticks or other organic matter and occassionally over a hard sand bottom (1).
Juvenile alewives are concentrated near the bottom during the day and move up into the water
column at night (2).

Table 6. Lacustrine habitat requirements data for banded killifish.

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	H	3	3,5,8	3,5,8	3,5,8
1-2 meters	H	H	H	H	3	3,5,8	3,5,8	3,5,8
2-5 meters								
5-10 meters								
10+ meters								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble			M	M			2	2
Gravel		L	L	L		8	*2*,8	*2*,8
Sand	H	H	H	H	8	5,8	2,5,8	2,5,8
Silt	*H*	*H*	*H*	*H*	*1,3,8*	*3,5,6,7,8,9*	*3,5,6,7,8,9*	*3,5,6,8,9*
Muck(detritus)	*H*	H	H	H	*1,3,8*	5,8	5,8	5,8
Clay(mud)		H	H	H		5	5	5
Pelagic		L	L	L		3	3,4,7	3,4,7
Cover:								
None								
Submergents	H	H	H	H	1,3,8	3,*5*,6,7,8,9	3,*5*,6,7,8,9	3,5,6,8,9
Emergents	H	H	H	H	1,3,8	3,5,6,8,9	3,5,6,8,9	3,5,6,8,9
Overhead								
In situ								
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
During spawning, eggs are released in clusters and have filaments for attaching to aquatic
vegetation (1,8).
Killifish are most abundant in very shallow waters and have a preference for clear, glacial lakes
with sluggish waters and abundant aquatic vegetation (3,8,9). Within these areas killifish are
found to utilize all levels of the water column (3,4,8).
Banded killifish generally reach sexual maturity at one year of age (Carlander 1969).

Table 7. Lacustrine habitat requirements data for mummichog.

Habitat Features:	**Ratings**[1]				**Sources**[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	H	4,7	6	3,6	3,6
1-2 meters	H	H	H	H	4,7	6	3,6	3,6
2-5 meters								
5-10 meters								
10+ meters								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel								
Sand	H				1,7			
Silt	*H*	*H*	*H*	*H*	*1,7,8*	*4,5*	*4,5*	*4,5*
Muck(detritus)	*H*	*H*	*H*	*H*	*1,7*	*4,5*	*4,5*	*4,5*
Clay(mud)	H	H	H	H	1,7	4,5,7	3,4,5,7	3,4,5,7
Pelagic		M	M	M		6	6	6
Cover:								
None								
Submergents	H	H	H	H	*1 ,7,8*	5,6,7	3,5,6,7	3,5,6,7
Emergents	H	H	H	H	7,8	6,7	3,6,7	3,6,7
Overhead								
In situ								
Other-mussels	L				2			

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Mummichog generally inhabit brackish water ponds, preferring regions of aquatic vegetation
(3,6,7); however, there is some evidence that landlocked populations may occur in freshwater
ponds and lakes (Klawe 1957).
Mummichog are a mainly schooling fish which live close to the surface in shallow water (6).
Eggs have been deposited on aquatic vegetation, algal mats, sand, mud and even empty mussel
shells (1,2,5,6,7,8).

Table 8. Lacustrine habitat requirements data for sea lamprey.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters			H				1,2,3,4,5,6	
1-2 meters			H				1,2,3,4,5,6	
2-5 meters			H				1,2,3,4,5,6	
5-10 meters			H				1,2,3,4,5,6	
10+ meters			H				1,2,3,4,5,6	
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel								
Sand								
Silt								
Muck(detritus)								
Clay(mud)								
Pelagic			H				1,2	
Cover:								
None			*H*				*1,2*	
Submergents								
Emergents								
Overhead								
In situ								
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Once lamprey begin migrating to streams they cease feeding and begin sexual maturation, so only from that time is it reasonable to call them adults. Since spawning has only been reported in stream habitats (2; Dees 1980; Scott and Scott 1988; 6), there is no lake habitat component for spawning or adult phases.
Larvae may remain in streams for 3-17 years before undergoing metamorphosis and entering streams.
Juveniles lead a parasitic or predatory existence, feeding on other fishes (2; Dees 1980; Scott and Scott 1988) and as a result there is no limit to the depth distribution of lampreys; they may be found wherever suitable host fishes occur (3). By default then, it can be assumed that parasitic juveniles maintain a mainly pelagic existence when occupying lake habitats.
Lamprey have been found to inhabit deep water throughout the summer and move into shallow water during fall and winter (1,2,3,4,5,6).

Table 9. Lacustrine habitat requirements data for lake chub.

Habitat Features:	**Ratings**[1]				**Sources**[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	*H*	*H*	H	2,5,6	*2,5,6*	*4,5*	1,4,5,6
1-2 meters	H	*H*	*H*	H	2,5,6	*2,5,6*	*4,5*	1,4,5,6
2-5 meters			*H*	H			*4,5*	1,4,5,6
5-10 meters			*M*	M			*4,5*	1,4,5,6
10+ meters			*M*	M			*4,5*	1,3,4,5,6
Substrate:								
Bedrock								
Boulder				H				1
Rubble	H	*H*			2,3,4,5,6	*2,3,4,5,6*		
Cobble	H	*H*			2,3,4,5,6	*2,3,4,5,6*		
Gravel	H	*H*			2,4	*2,4*		
Sand	*M*	*M*		M	*2*	*2*		1
Silt	M	*M*			2	*2*		
Muck(detritus)	M	*M*			2	*2*		
Clay(mud)								
Pelagic								4
Cover:								
None								
Submergents								
Emergents								
Overhead								
In situ								
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
In thermally stratified lakes, lake chub move to deeper, cooler water as temperatures increase during the summer (3,5,6).
Lake chub were found to occupy areas close to the bottom regardless of depth (4).
There was no information available in the literature reviewed on habitat requirements of YOY, therefore it was assumed that YOY remain in spawning areas for at least a portion of their first year of life.
There was no information available in the literature reviewed on whether lake chub use cover during any stage of its life cycle.

Table 10. Lacustrine habitat requirements data for longnose dace.

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	H	1,3	*5,6*	6	6
1-2 meters	H	H	H	H	1,3	*5,6*	6	6
2-5 meters		M	M	M		*5,6*	6	6
5-10 meters		M	M	M		*5,6*	6	6
10+ meters								
Substrate:								
Bedrock								
Boulder	H	H	H	H	3	6	6	1,6
Rubble	H	H	H	H	3	*6*	*6*	*6*
Cobble	H	H	H	H	3	1,6	*6*	*6*
Gravel		H	H	M		1,6	6	1,6
Sand		*H*				*6*		
Silt								
Muck(detritus)								
Clay(mud)								
Pelagic		M	M	M		2,5,6	1	1
Cover:								
None								
Submergents				*M*				*4*
Emergents				*M*				*4*
Overhead		H		*M*		3		*4*
In situ		H				1		
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Longnose dace typically spawn in gravel-bottomed riffle sections of streams (Bartnik 1970; 5; Brown et al. 1970; 6; Ryan 1980) or wave-swept inshore areas of lakes (1) over a cobble, rubble or boulder substrate (3).
Longnose dace inhabit inshore areas of lakes over gravel, cobble, rubble or boulder bottoms and sometimes move into deeper, cooler water during the summer (6).
Since Hubert and Rahel (1989) observed a preference for aquatic vegetation and overhead cover by adults in streams, it was assumed that there may be a similar preference in lake habitats.

Table 11. Lacustrine habitat requirements data for pearl dace.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	*H*			2,4	*3*		
1-2 meters		*H*	*H*			*3*	*3*	
2-5 meters		*M*	*H*	*H*		*3*	*3*	*3*
5-10 meters			H	H			4	4
10+ meters								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	*H*				*2*			
Sand	*H*				*2*			
Silt	*H*	*H*	*H*	*H*	*1,4*	*3*	*3*	*3*
Muck(detritus)	H	*H*	*H*	*H*	1,4	*3*	*3*	*3*
Clay(mud)	*H*	*H*	*H*	*H*	*1,4*	*3*	*3*	*3*
Pelagic								
Cover:								
None								
Submergents	H	*H*	*H*	*H*	4	3	3	3
Emergents	H				4			
Overhead								
In situ								
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Pearl dace generally spawn in vegetation over soft organic substrates along the periphery of
lakes (4).
In deep lakes that exhibit thermal stratification, pearl dace tend to move into deeper, cooler
waters as temperatures increase during the summer (4).

Table 12. Lacustrine habitat requirements data for northern pike.

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	H	2,6,9,13,14,15,17	2,9,11,*12*,13	9,13	4,6,7,9,13
1-2 meters	L	H	H	H	14	2,*5*,9,11,*12*,13	*2*,*5*,9,13	2,4,5,6,7,9,13
2-5 meters	L	L	L	H	6,14,16	5	*2*,*5*	2,4,5,6,7,9
5-10 meters	L			M	6,14,16		*2*,*5*	2,5,7
10+ meters				L				3,7,18
Substrate:								
Bedrock								
Boulder								
Rubble	L				14			
Cobble								
Gravel								
Sand	L	L	Nil	Nil	12	12	8	8
Silt	H	H	H	H	12,*13*,14,*17*	9,12,*13*	9	9
Muck(detritus)	H	H	H	H	2,6,12,13,*14*,*17*	2,3,6,9,12,13	*1*,2,3,6,9	2,4,6,7,9
Clay(mud)	H	H	H	H	2,6	2,3,6,9	*1*,2,3,6,9	9
Pelagic				H				3,4,5,6,9,18,19
Cover:								
None								
Submergents	H	H	H	M	2,6,9,13,15,17,18	2,3,6,9,10,11,12,13	1,2,3,6,9,13	2,4,5,6,7,9,13,16
Emergents	H	H	H	M	2,6,13,17	2,3,6,9,12	1,2,3,6,9	7
Overhead								
In situ				L				13
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Adults have been observed using aquatic vegetation, tree stumps and fallen logs for cover (12).
Spawning generally occurs in sheltered, highly vegetated areas (2,6,9,13,15,17,18).
Grasses, sedges and rushes have been reported as the preferred vegetation for spawning (2,15).
Both juvenile and adult pike were shown to avoid habitat predominated by sand (8).
Although adults mainly occupy relatively shallow littoral areas, they tend to move farther offshore into open-water areas during periods of increased turbidity (3,4,18).

Table 13. Lacustrine habitat requirements data for Arctic char (freshwater resident-normal).

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	L	L	L	H	9,19,26	25,26,27,28	12,27	5,6,8,16,24,26,27
1-2 meters	*L*	L	L	H	*9* ,19,*26*	10,27	12,27	5,6,8,16,24,26,27
2-5 meters	H	L	L	H	2,7,17,19	10,27	12,27	5,6,8,16,18,24,26,27
5-10 meters	H	L	H	H	7,17	10,27	3,8,27	5,6,8,16,18,24,26,27
10+ meters	H	H	H	H	7,22,23,24	9,16,25,26	3,8,10,26	5,6,8,11,16,18,19,24
Substrate:								
Bedrock			L	L			29	
Boulder	L	H	H	H	9	10,12,*27*	12,24,*26,* 27,29	18,*26,27*
Rubble	L	H	H	H	9	10,12,27	12,24,26,27,29	18,26,27
Cobble	H	H	H	H	2,7,9,21,22	10,12,27	12,24,26,27,29	25,26
Gravel	H		L	L	2,7,14,15,17,19,21,22,23		29	
Sand			L	L			29	
Silt					9			
Muck(detritus)								
Clay(mud)	L				7,17			
Pelagic	L	L	H	H	1,25	25	1,10,12,16	1,4,5,11,13,16,18,19,20,24,28
Cover:								
None								
Submergents	L		H		2		3,24	
Emergents			H				3,24	
Overhead								
In situ		H	H			10,12	12,24	
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
In Maine, females did not construct redds, but simply released their eggs in exposed areas of the lake over a cobble/rubble/boulder substrate (9).
Unlike brook trout, there was no upwelling groundwater detected near Arctic char spawning grounds (23).
Juveniles typically seek cover in structurally complex bottom substrates as well as aquatic vegetation during the day (3,12,24,29), but have been observed foraging in open-water areas over sand, gravel or bedrock at night (29).

Table 13. Lacustrine habitat requirements data for Arctic char (freshwater resident-normal).

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	L	L	L	H	9,19,26	25,26,27,28	12,27	5,6,8,16,24,26,27
1-2 meters	*L*	L	L	H	*9*,19,*26*	10,27	12,27	5,6,8,16,24,26,27
2-5 meters	H	L	L	H	2,7,17,19	10,27	12,27	5,6,8,16,18,24,26,27
5-10 meters	H	L	H	H	7,17	10,27	3,8,27	5,6,8,16,18,24,26,27
10+ meters	H	H	H	H	7,22,23,24	9,16,25,26	3,8,10,26	5,6,8,11,16,18,19,24
Substrate:								
Bedrock			L	L			29	
Boulder	L	H	H	H	9	10,12,*27*	12,24,*26,* 27,29	18,*26,27*
Rubble	L	H	H	H	9	10,12,27	12,24,26,27,29	18,26,27
Cobble	H	H	H	H	2,7,9,21,22	10,12,27	12,24,26,27,29	25,26
Gravel	H		L	L	2,7,14,15,17,19,21,22,23		29	
Sand			L	L			29	
Silt					9			
Muck(detritus)								
Clay(mud)	L				7,17			
Pelagic	L	L	H	H	1,25	25	1,10,12,16	1,4,5,11,13,16,18,19,20,24,28
Cover:								
None								
Submergents	L		H		2		3,24	
Emergents			H				3,24	
Overhead								
In situ		H	H			10,12	12,24	
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
In Maine, females did not construct redds, but simply released their eggs in exposed areas of the lake over a cobble/rubble/boulder substrate (9).
Unlike brook trout, there was no upwelling groundwater detected near Arctic char spawning grounds (23).
Juveniles typically seek cover in structurally complex bottom substrates as well as aquatic vegetation during the day (3,12,24,29), but have been observed foraging in open-water areas over sand, gravel or bedrock at night (29).

Table 15. Lacustrine habitat requirements data for Atlantic salmon (anadromous).

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters		H	H			6,8,9	3,4,7,9,10,11	
1-2 meters		H	H			8	2,3,4,7,9,10,11	
2-5 meters		H	M			8	2,3,4,7,9,10	
5-10 meters			L				4,5,7,9	
10+ meters			L				5,8	
Substrate:								
Bedrock								
Boulder		H	H			6,8,9	3,4,6,8,9,10	
Rubble		H	H			6,8,9	3,4,6,8,9,10	
Cobble		H	H			6,8,9	3,4,6,8,9,10,11	
Gravel		L	M			8	8,11	
Sand		L	L			8	4,8	
Silt		L				8		
Muck(detritus)								
Clay(mud)								
Pelagic			L-M				2,7,8,10	
Cover:								
None								
Submergents			L				1,3,4,11	
Emergents			L				1,3,4,11	
Overhead								
In situ			H				3,4	
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Spawning generally occurs in gravel-bottomed riffle sections of streams (Scott and Crossman 1973; Scott and Scott 1988; Smith 1988).
In the literature reviewed, there was no mention of adults utilizing lake habitat.
Although YOY have been reported in lake habitats, numbers were generally low with most immigration into lakes occurring at 1-2 years of age (4,7,10,11).
In Newfoundland, although YOY were observed in lakes sampled by O'Connell and Dempson (1990, 1996), there were no YOY captured in lakes sampled by Pepper (1976) and Pepper et al. (1985).

Table 15. Lacustrine habitat requirements data for Atlantic salmon (anadromous).

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters		H	H			6,8,9	3,4,7,9,10,11	
1-2 meters		H	H			8	2,3,4,7,9,10,11	
2-5 meters		H	M			8	2,3,4,7,9,10	
5-10 meters			L				4,5,7,9	
10+ meters			L				5,8	
Substrate:								
Bedrock								
Boulder		H	H			6,8,9	3,4,6,8,9,10	
Rubble		H	H			6,8,9	3,4,6,8,9,10	
Cobble		H	H			6,8,9	3,4,6,8,9,10,11	
Gravel		L	M			8	8,11	
Sand		L	L			8	4,8	
Silt		L				8		
Muck(detritus)								
Clay(mud)								
Pelagic			L-M				2,7,8,10	
Cover:								
None								
Submergents			L				1,3,4,11	
Emergents			L				1,3,4,11	
Overhead								
In situ			H				3,4	
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Spawning generally occurs in gravel-bottomed riffle sections of streams (Scott and Crossman 1973; Scott and Scott 1988; Smith 1988).
In the literature reviewed, there was no mention of adults utilizing lake habitat.
Although YOY have been reported in lake habitats, numbers were generally low with most immigration into lakes occurring at 1-2 years of age (4,7,10,11).
In Newfoundland, although YOY were observed in lakes sampled by O'Connell and Dempson (1990, 1996), there were no YOY captured in lakes sampled by Pepper (1976) and Pepper et al. (1985).

Table 17. Lacustrine habitat requirements data for brook trout.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	H	4,*5*,*7*,9,10,11,25,*27*,29,32,33	6,*12*,31,34	13,17,22,23,31	3,16,22
1-2 meters	H	H	H	H	4,*5*,*7*,8,25,*27*,32	*12*,31,34	13,17,22,23,31	16,22,31
2-5 meters	L	H	H	H	25,34	*12*,31	13,17,22,31	13,16,22,23,31
5-10 meters	L	L	M	M	34	*12*,31	13,17,22,31	13,16,22,23,31
10+ meters			M	M			22	22,24
Substrate:								
Bedrock								
Boulder		*H*	*H*			*14*	*14*	
Rubble	L	H	H		33	14	14	
Cobble	M	H	H	H	11,18,26,33	9,14	9,14	9
Gravel	H	H	H	H	4,8,9,11,18,19,21,28,26,25,29,33,34	9	9	9
Sand	M			L	1,2,8,9,11,12,19,21,30,32			3
Silt	L			L	11,12,21,26,30,32			3
Muck(detritus)	L				10			
Clay(mud)	L				10			
Pelagic			L	L			13,22	13,22,24,31
Cover:								
None								
Submergents		H	H			13,14,20,34	13,14	15
Emergents		H	H	H		13,14,20,34	13,14	15
Overhead				H				9,18
In situ	L	H	H	H	10	6,9,14,20,34	9,14	9,15,18
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Anadromous and resident brook trout appear to be similar in terms of their habitat utilization, therefore the habitat requirements listed above apply to both populations.
Spawning sites are generally chosen near areas of upwelling groundwater (1,5,7,9,10,11,18,19, 25,26,27,28,30,32,Schofield 1993).
Brook trout have been shown to spawn on an aggregation of waterlogged sticks, wood chips and debris overlying soft organic matter (10).
While Ryan and Knoechel (1994) observed juveniles moving into lakes from tributary streams at 1-2 years of age, Clarke et al. (1997) found lakeward movement to be more common at 2-3 years of age.

Table 18. Lacustrine habitat requirements data for brown trout (freshwater resident).

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	L	4,11	*1*,2,*9*,*10*	*1*,2,5,6,7,8,9,10,13	5,10,13,14
1-2 meters	H	H	H	L	4,11	*1*,2,*9*,*10*	*1*,2,5,6,7,8,9,10,13	5,10,13,14
2-5 meters		L	H	L		3,*9*,10	5,6,7,8,9,10,13	5,10,13,14
5-10 meters		L	M	H		3	8,9,10	5,14
10+ meters		L	L	H		3	8,9	5,14
Substrate:								
Bedrock								
Boulder		H	H	H		7	5,7,13	13
Rubble	H	H	H	H	3,4,11	7	5,7,13	13
Cobble	H	H	H		3,4,11	1,2,7	1,2,5,7	
Gravel	H	*M*	*M*		4,11,12	*7*	*2,5,7*	
Sand		*M*	M			*7*	7	
Silt				M				5
Muck(detritus)				*M*				*5*
Clay(mud)				M				5
Pelagic			L	M			9,*13*	5,6,7,8,9,13,14
Cover:								
None								
Submergents		*L*	L			*9*	1,9	
Emergents			L				1	
Overhead								
In situ		*H*	H			*9*	5,9	
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Several investigators have reported that brown trout appear to have similar habitat requirements as brook trout with the exception that they do not appear to select areas of upwelling groundwater for spawning (Hansen 1975; Ryan 1988; Scott and Scott 1988).
Tributary streams often serve as 'nursery' areas for YOY (3,7, Thorpe 1974b; Craig 1982; Jonsson 1985; Haraldstad et al.1987; Hegge et al. 1993a).
Although based on a small number of specimens (n=9) captured from a Newfoundland pond, highest catch rates of brown trout aged 2+ to 5+ occurred in shallow (<5 m) benthic areas (13).
In Norway, although adults were most abundant at depths of 0-15 m, they have been found at depths >60 m in spring and late fall (14).

Table 19. Lacustrine habitat requirements data for lake trout.

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	L	L		2,3,5,6,7,8,10,11,13,15	8,10,13	4	
1-2 meters	H	M	M	M	2,5,6,7,10,13,15	10,13	4	10
2-5 meters	H	H	H	M	5,6,7,10,13,15	10,12,13	4	*8* ,10,14
5-10 meters	H	H	H	M	4,6,10,13,15	*2* ,4,10,12,13	4	*8* ,10,14
10+ meters	H	H	H	H	4,6,10,13,15	2,5,12,13	4,13	*4,5,8* ,10,13,14
Substrate:								
Bedrock				*H*				*4*
Boulder	H	H	H	*H*	2,4,5,8,13	4	4	*4*
Rubble	H	H	H	*H*	2,3,4,5,6,7,8,9,11,13,15	1,4	4	*4*
Cobble	H	H	H	*H*	2,4,5,6,7,8,9,11,15	1,4	4	*4*
Gravel	H			*H*	2,4,5,6,9,11			*4*
Sand	Nil			*H*	4,5,7,8,9,11,*15*			*4*
Silt	Nil			*H*	4,6,7,*8* ,*9* ,11,*15*			*4*
Muck(detritus)	Nil			*H*	4,5,6,8,*9* ,*15*			*4*
Clay(mud)	Nil			*H*	4,5,8,9			*4*
Pelagic				L				4,13,14
Cover:								
None	H			H	5,8			4
Submergents								
Emergents								
Overhead								
In situ		H	H			1,4,5	4	
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Although no groundwater seepage was found near spawning sites (2,8), spawning areas are often exposed to prevailing winds such that wave action and water currents keep areas free from sand and silt (8,9,11).
Males typically arrive on the spawning grounds before females and have been observed clearing loose sand and mud from spawning areas (9).
Cover for juveniles is usually in the form of boulders or woody debris (4).
YOY typically move into deeper water within 1-3 months after hatching (2,10,12,13).
Outside spawning period, adults have no apparent preference for substrate or depth except that they occupy deeper, cooler waters during the spring or early summer in thermally stratified lakes (Riche 1965; 4,5,8; Olson et al. 1988).

Table 20. Lacustrine habitat requirements data for lake whitefish.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	L	L	H	H	2,9,13	5,7,8,9,10,11,13	13	13
1-2 meters	H	M	H	H	1,6,9,10,12,13	4,5,6,7,9,10,12,13	13	13
2-5 meters	H	M	H	H	1,3,4,6,9,10,12,13	1	13	13
5-10 meters	M	H	H	H	1,6,9,12,13	4,5,6,9,*11*,12,13	13	13
10+ meters	M	M	M	H	6,9	4,6,*9*,11,*12*,13	6,13	6,13
Substrate:								
Bedrock								
Boulder	H	H	H		1,4,6	4,5,6,7,8	6	
Rubble	H	H	H	H	1,4,6,9,10,*12*,13	4,5,6,7	6,13	13
Cobble	H	H	H	H	1,4,6,9,10,*12*,13	4,5,6,7	6,13	13
Gravel	H	H	H		1,4,6,9,10,*12*,13	4,5,6,*7*	6	
Sand	M				1,2,6,9,13	7		
Silt	L				2,3			
Muck(detritus)			H	H			13	13
Clay(mud)			H	H	6,9		13	13
Pelagic		H	H	M		7,8,11	8	6,10
Cover:								
None								
Submergents								
Emergents	L	H	H		3	6,7,10,11	6	
Overhead								
In situ		L	L			6	6	
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Outside the spawning period, adults show no apparent preference for substrate type (6, McPhail and Lindsey 1970) and have been captured over a variety of substrates ranging from soft clay and organic debris to mainly rocky substrates (13).
After 6-8 weeks, YOY behave similarly to adults with respect to movements between shallow and deeper areas of the lake, but YOY are more closely associated with cover (6).
Unlike many other species, flowing water is not required for spawning (3,6).

Table 21. Lacustrine habitat requirements data for rainbow trout.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	H	2,3	4,5	4	1
1-2 meters	H	H	H	H	2,3	4,5	4	1
2-5 meters	L	H	H	H	2	2	2	1
5-10 meters		L	L			2	2	
10+ meters								
Substrate:								
Bedrock								
Boulder		H	H	H		2,4	2,4	2
Rubble		H	H	H		2,4	2,4	2
Cobble		H	H	H		2,4	2,4	2
Gravel	H	L	L		2,3	4	4	
Sand		L	L			4	4	
Silt								
Muck(detritus)								
Clay(mud)								
Pelagic		M				4,5		
Cover:								
None								
Submergents	L	L	L		3	4	4	
Emergents	L	L	L		3	4	4	
Overhead								
In situ		H	H	H		2,4	2,4	2
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Juveniles rely heavily on boulders and woody debris for cover in lake habitats (2,4) and are usually in schools of more than 30 fish when away from cover (4).
Juveniles are often found in exposed areas at night over sand, gravel and cobble substrates (4).
Although, rainbow trout are primarily considered a stream species in Newfoundland (Scott and Scott 1988), small landlocked populations have been reported from the Avalon Peninsula (Dominey 1965; Lee 1971; Morry 1976; Jamieson 1978), Notre Dame Bay and in small lakes near Corner Brook (Scott and Crossman 1964).
Generally, adults will stay at depths below the 18^{0}C isotherm and avoid areas where dissolved oxygen concentrations are below 3 mg/l if possible (Raleigh et al. 1984).

Table 22. Lacustrine habitat requirements data for round whitefish.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	H	2,5,6,8	4	4,7	4,7
1-2 meters	M	H	H	H	*2,8*	4	4,7	4,7
2-5 meters	L		H	H	*2*		7	7
5-10 meters	L		H	H	3		7	1,7
10+ meters			H	H			7	1,7
Substrate:								
Bedrock								
Boulder	L	*L*	*L*	*L*	*2*	*6*	*6*	*6*
Rubble	M	H	H	H	2,6	6	*7*	*7*
Cobble	M	*H*	H	H	2,5,6,6	*5,8*	*7*	*7*
Gravel	H	*H*			2,5,6,6	*5,8*		
Sand					2,6			
Silt	L				*2*			
Muck(detritus)			H	H			7	7
Clay(mud)			H	H			7	7
Pelagic								
Cover:								
None								
Submergents								
Emergents	*L*				*2*			
Overhead								
In situ								
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Round whitefish are mainly bottom feeders (Bruce 1974, 1975; Parsons 1975; Armstrong et al. 1977; Ryan 1980) and have been observed over a variety of substrates ranging from soft clay and organic debris to mainly rocky substrates (7).
In a New Hampshire lake, spawning areas were exposed to prevailing winds, keeping them free from silt by wave action and water currents (6).
Although spawning occurs mainly in lakes, it has been occasionally reported in streams (2,4,5,8).

Table 23. Lacustrine habitat requirements data for mottled sculpin.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	H	5	5,7	5	5
1-2 meters								
2-5 meters								
5-10 meters								
10+ meters								
Substrate:								
Bedrock								
Boulder	H	*H*	*H*	*H*	2,4,5,6,7	*5*	*5*	*5*
Rubble	H	*H*	*H*	*H*	2,4,5,6,7	*5*	*5*	*5*
Cobble								
Gravel								
Sand	H	*H*	*H*	H	4	*3,7*	*1,3,7*	1,3,7
Silt	H				4			
Muck(detritus)								
Clay(mud)		H				7		
Pelagic								
Cover:								
None								
Submergents								
Emergents								
Overhead								
In situ	H	*H*	H	H	2,5	*5*	5	5
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Since females have been reported to deposit adhesive eggs on the ceilings of nests while upside down (4,7), any reporting of females spawning under rocks was assumed to be rocks of boulder or rubble size.
Mottled sculpin often use submerged logs for cover which may also serve as spawning sites (5).

Table 24. Lacustrine habitat requirements data for slimy sculpin.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H	H	4,5,6	*1,3*,4	*3*,4,5	3,5
1-2 meters	H	H	H	H	4,5	*1,3*,4	*3*,4,5	3,5
2-5 meters		H	H	H		*1*,*3*, 8	*3*,4,5	3,4,5
5-10 meters		H	H	H		*1,3*, 8	*3*,4,5,*7*	3,4,5,7
10+ meters		H	H	H		*1*,8	1,*7*,9	1,7,9
Substrate:								
Bedrock								
Boulder	H	H			2,4,6,7	4		
Rubble	H	H	H	H	2,*3*, 4,6,7	3,4	3	3
Cobble	H	H	H	H	2,3,4,6,7	3,4	3	3
Gravel	H	H	H	H	3,4,6,7	3,4	3	3
Sand	H	H			4,6	4		
Silt								
Muck(detritus)								
Clay(mud)								
Pelagic								
Cover:								
None								
Submergents								
Emergents								
Overhead								
In situ	H				2,3,6,7			
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
In the Northwest Territories, slimy sculpin have been found in shallow (<10 m) rocky areas of lakes that are exposed to wind and wave action (3).
In thermally stratified lakes, water temperature appears to be the most critical factor determining sculpin distribution and under such conditions they appear to aggregate within the metalimnion (4,5).
Male selects a spawning site under rocks, submerged logs, tree roots or other foreign debris over a sand/gravel substrate (2,3,5,6,7, Ryan 1980).
Slimy sculpin feed mainly on benthic organisms and thus commonly inhabit bottom areas of lakes (4,7,9).

Table 25. Lacustrine habitat requirements data for rainbow smelt (freshwater resident).

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	H		1,2,9,10	1	1	
1-2 meters	H	H	H		1,2	1	1	
2-5 meters	H	H	H		8	1,5	1	
5-10 meters		H	H			1,5	1	
10+ meters		H	H	H		1,5	1,11	11
Substrate:								
Bedrock								
Boulder	H	*H*			2	*2*		
Rubble	H	*H*			2,*9*,10	*2*		
Cobble	H	*H*			2,*8*,*9*,10	*2*		
Gravel	H				2,4,8,*9*,10,12			
Sand	H				2,8,*9*,10			
Silt	*H*	*H*			*2*	*2*		
Muck(detritus)	H				2			
Clay(mud)	H				2			
Pelagic	H	H	H	H		5,6	6	1,3,6,7,11,12
Cover:								
None								
Submergents	H				2,8			
Emergents	H				2			
Overhead								
In situ	H				2,8			
mussel shells					8			

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Although lake-spawning has been observed before ice-out, spawning in tributary streams usually does not begin until after ice-out (2).
Spawning in lakes usually occurs near mouths of inlet streams over a variety of substrates (2).
In the Soviet Union, spawning usually occurs in the protected littoral zone where there is little or no wind or wave action (8).
Deepwater lake-spawning has been reported in Quebec (Legault and Delisle 1968) and New York (Plosila 1980).

Table 26. Lacustrine habitat requirements data for fourspine stickleback.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H			H	*1*,*2*,*5*			3
1-2 meters				H				3
2-5 meters								
5-10 meters								
10+ meters								
Substrate:								
Bedrock								
Boulder								
Rubble	*H*				*2*			
Cobble	*H*				*2*			
Gravel	*L*				*1,2*			
Sand	*L*				*1*			
Silt					*4,6,7,8*			
Muck(detritus)	*L*				*1*,*2*,4			
Clay(mud)	*H*			H	*1,2*,4,*6*,7,8			3
Pelagic								
Cover:								
None								
Submergents	H	H		H	*1*,*2*,*4*,5,6,7,8	6,7		7
Emergents		H						3
Overhead								
In situ								
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:

Although fourspine stickleback typically inhabit brackish or estuarine waters (1,4,5,6,7; Scott and Crossman 1964; Leim and Scott 1966; Campbell 1992) it has been noted to occur in freshwater lakes (3; Nelson 1968a; Van Vliet 1970; Baker 1971; Dadswell 1972; Coad and Power 1973d; Rombough et al. 1978; Campbell 1992).

Male constructs a nest made of aquatic plants and twigs bound together by a glutinous kidney material secreted by the male (1,2,4,6, Leim and Scott 1966; Courtenay 1985).

There does not appear to be any clear substrate preference for nest building except that breeding grounds are commonly associated with aquatic vegetation (2).

Sexual maturity is generally attained in one year, therefore a distinct category for a juvenile life history stage is not required.

In Pt. Verde, Newfoundland, no individuals were found to live past the age of 2 years (3).

Table 27. Lacustrine habitat requirements data for ninespine stickleback.

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H		H	5,*6,7,8*	7,8		3,9
1-2 meters	L	H		H	7,8	7,8		3,9
2-5 meters	*L*	H		H	*1,7,8*	7,8		*3,9*
5-10 meters	L	*M*		M	1,8	*1,3,8*		*3,7,8*
10+ meters	L	*M*		M	1,8	*1,3,8*		3,8
Substrate:								
Bedrock								
Boulder								
Rubble	H			H	5			9
Cobble	H			H	5			9
Gravel	L			L	5			6
Sand	L	*L*		L	5	*5*		6
Silt	*H*	*H*			*4,6,7,8,10,11,12,13*	*8*		
Muck(detritus)	*H*	*H*			2,4,6,7,8,10,*11,12,13*	*8*		
Clay(mud)	H	*H*		H	2,4,6,7,8,10, 11,12,13	*8*		9
Pelagic								
Cover:								
None	L	L		L	5	10		10
Submergents	H	H		H	2,4,6,7,8,10,11,12,13	6,8,*12,13*		6,*12,13*
Emergents	H	H		H	2,4,6,7,8,10,11	6,8,*12,13*		6,9,*12,13*
Overhead								
In situ								
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Although spawning has generally been reported in relatively shallow areas containing dense aquatic vegetation (6,7,9,10,11,13), males have been observed constructing nests under or between rocks (4) as well as in open water at depths >9 m (1,8).
Males may construct a 'nursery' for newly hatched larvae (6,7,12).
Sexual maturity is generally attained in one year, therefore a distinct category for a juvenile life history stage is not required.
In lakes exhibiting thermal stratification, ninespine stickleback generally occupy warmer, deeper waters in early spring and late fall, but are evenly distributed at all depths during spring turnover when the waters mix and the water temperatures are the same at all depths (3).

Table 28. Lacustrine habitat requirements data for threespine stickleback (freshwater resident).

Habitat Features:	**Ratings**[1]				**Sources**[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	*H*	*H*	H	7,9,10,12,*17*,18	*6,12,16,17*	*6,16,17*	2,4,8,13,*16*,*17*
1-2 meters	H	*H*	*H*	H	7,9,10,12,*17*,18	*6,12,16,17*	*6,16,17*	2,4,8,13,*16*,*17*
2-5 meters	L			H	9,18			2,8,13
5-10 meters	L			H	9,18			2,13
10+ meters	L			L	5,9			2,15
Substrate:								
Bedrock								
Boulder								
Rubble	L			L	18			8,15,16
Cobble	L			L	18			8,13,15,16
Gravel	L			L	18			8,13,15
Sand	H			L	12,17,18			8
Silt	H				18			
Muck(detritus)	*H*			*H*	*5*			*8*
Clay(mud)	H	*L*	*L*	H	5,11	*10*	*10*	4,*8*,16
Pelagic				H				1,2,10,12,14
Cover:								
None	M				5,9,10,18			
Submergents	M	H	H	H	3,7,10,11,12,15	6,12	6	10,11,13,14,15
Emergents	M	H	H	H	3,7,10,11,12,15,16	6,12	6	4,10,11,13,14
Overhead				H				10
In situ				H				10
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
There was a general lack of information in the literature reviewed on habitat requirements of both YOY and juveniles.
Spawning may occur in open water (5,9,10, Wootton 1976) or in association with aquatic plants (10,11,12,15).
Males tend to avoid nesting in water shallower than 0.2 m (7,9).
Larson (1976) noted that threespine stickleback were generally associated with aquatic vegetation and/or submerged logs in the littoral zone, while they were associated with surface cover such as trees when near the surface in the limnetic zone.
Sexual maturity is generally attained in their second or third year and they normally have a maximum lifespan of 2 and one-half years (14).

Table 29. Lacustrine habitat requirements data for longnose sucker.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	H	*H*		3,9	1,5,7,8,9	*2*	
1-2 meters			*H*				*2*	
2-5 meters			*H*				*2*	
5-10 meters								
10+ meters				H				5,4
Substrate:								
Bedrock								
Boulder		*H*				*2*		
Rubble		*H*				*2*		
Cobble	*H*				3,7,*8*			
Gravel	*H*				3,5,*7,8*			
Sand	*L*				3,7			
Silt								
Muck(detritus)								
Clay(mud)								
Pelagic								
Cover:								
None								
Submergents		H	*H*			1	*2*	
Emergents		H	*H*			1	*2*	
Overhead								
In situ				H				6
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Although longnose suckers typically spawn in streams, they have been reported to spawn
along wave-swept shores of lakes at depths of 15-30 cm (3,9).
In a Maine reservoir, longnose suckers were shown to have an attraction to submerged pulpwood
logs (6).

Table 30. Lacustrine habitat requirements data for white sucker.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depths:								
0-1 meters	H	*H*	*H*	*H*	2,4,6	*3*	*3*	*3*
1-2 meters	H	*H*	*H*	*H*	2,4,6	*3*	*3*	*3*
2-5 meters		*H*	*H*	H		*3,7*	*3,7*	*3*,7
5-10 meters		*L*	*L*	L		*7*	*7*	7
10+ meters								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	H				2,4,6			
Sand								
Silt								
Muck(detritus)		*M*	M			*1*	1	
Clay(mud)								
Pelagic		L	M	M		6	6	6
Cover:								
None								
Submergents								
Emergents								
Overhead								
In situ				H				5
Other								

[1]Ratings are Nil, L-Low, M-medium or H-high.

[2]Sources are numbered by species/morph in reference list below.

[3]Categories are S-spawning, Y-young-of-the-year, J-juveniles and A-adults.

Comments and observations:
Although white suckers typically spawn in streams, they have been found to spawn along lake margins in shallow water (2,4,6; Geen et al. 1966; Ryan 1980).
In streams, white suckers tend to prefer shady areas and are often associated with large woody debris (Hubert and Rahel 1989).
White suckers spawn at depths of 20-25 cm in streams (Curry and Spacie 1984).
In a Maine reservoir, white suckers were shown to have an attraction to submerged pulpwood logs (3).
White suckers feed almost exclusively on benthic invertebrates once they attain a size of 16-18 mm (1,3,4,6, Parsons 1975).

Table 31. Species for which there are no available lake habitat requirements data.

Species/morph	Comments and observations	Sources
Atlantic tomcod	A totally landlocked population has been reported in Deer Lake, NF, however, there is no information available on lake use. Atlantic tomcod have been reported to spawn in estuaries and rivers in shallow water over sand or gravel substrates.	4 1,2,3,4,5,6
American shad	No evidence of American shad occurring in lakes. American shad captured in coastal waters off Newfoundland and Labrador probably represent stray occurrences rather than self-sustaining populations. Shad always seem to spawn in rivers or brackish estuarine waters, seldom if ever in alkes and return to sea shortly after spawning. By the fall, young have all left freshwater.	2 3,5,6 1,4,5
anadromous Arctic charr	Anadromous Arctic charr have been observed spawning in lakes adjacent to inlet streams (Dempson and Green 1985).	1
pink salmon	There was no information in the literature reviewed on lake use by pink salmon.	
anadromous rainbow smelt	There was no information in the literature reviewed on lake use by anadromous smelt.	
blackspotted stickleback	Blackspotted stickleback are found predominantly in coastal waters, although they may penetrate brackish waters in the spring to spawn. Spawning typically occurs in relatively open areas over a sand or mud bottom containing abundant rooted aquatic plants, stones or sunken logs. Sexual maturity is generally attained in one year.	2,3 1
anadromous threespine stickleback	Spawning has been observed in marine, brackish or freshwater. In marine and estuarine habitats, spawning may occur in a variety of substrates including rock crevices, eelgrass beds, algal mats and sometimes over sand and silt near aquatic vegetation. Sexual maturity is generally attained in one year.	1,2,4,5 1,3
Atlantic sturgeon	There have been no reports of Atlantic sturgeon occurring in lakes. Atlantic sturgeon occur mainly in coastal waters, entering freshwater rivers and estuaries to spawn (Dees 1961; Scott and Scott 1988).	1,2

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2. **Dempson** and O'Connell. 1993.

3. **Halvorsen** and Jorgensen. 1996.

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APPENDIX 1 – GLOSSARY OF TERMS

Adhesive - Sticking or clinging.

Adult - Life stage of fish where they have matured and are able to reproduce.

Aquatic plants - Plants whose photosynthetically active parts are permanently, or at least for several months each year, submerged in, or floating on, fresh water.

Alevin - A stage of embryonic development of salmonid fish species which refers to fish recently hatched from the egg and before the absorption of the yolk sac and emergence from spawning gravel.

Allopatric - Species inhabiting geographically separated areas from other stocks of the same species.

Ammocete - A name applied to the larval form of lampreys.

Anadromous - Fish which breed in fresh water but spend most of their adult life at sea; also commonly referred to as sea-run.

Aquatic - Living in (freshwater, estuarine or marine).

Benthic - Living on or near the bottom of aquatic habitats.

Benthos - Organisms, both plant and animal, that inhabit the bottom substrates (sediments, debris, logs, macrophytes) of aquatic habitats for at least part of their life cycle.

Catadromous - Fish which migrate to sea to spawn but spend most of their life in freshwater.

Cover - Features within the aquatic environment that may be used by fish for protection (or refuge) from predators, competitors and adverse environmental conditions.

Demersal - Living on or near the bottom of a lake; often said of fishes and fish eggs.

Depth - Distance from the lake bottom to the water surface.

Detritus - Organic material from dead organisms, plant and animal.

Diadromous - Pertaining to fishes that migrate between fresh and salt water.

Dissolved Oxygen - Atmospheric oxygen that has been absorbed by water and upon which fish and other aquatic organisms depend for respiration; usually expressed in parts per million (ppm) of water.

Embryo - An organism in its earliest stage of development, before emergence from the egg.

Emergent vegetation - Aquatic plants which grow on water-saturated or submerged soils and extend their stems and leaves above the surface of the water (e.g. cattails, grasses, sedges and rushes).

Epibenthic - Living on or near the bottom of aquatic habitats; often said of fishes.

Epilimnion - The upper, well-mixed, well illuminated, nearly isothermal region of a stratified lake characterized by fairly turbulent water; usually rich in oxygen.

Escapement – Fish originally occurred under hatchery conditions and is now established in the wild.

Estuary - A semi-enclosed body of water which has a free connection with the open ocean and within which seawater is measurably diluted with fresh water derived from land drainage.

Eutrophy - Condition of water being rich in plant nutrients.

Exotic Species - Any fish species that does not occur naturally within the geographic range to which it is being introduced.

Fingerling - Young fish, usually late in first year.

Fish Habitat - Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend either directly or indirectly in order to carry out their life processes.

Fry - The life stage of fish, after the yolk sac has been absorbed.

Groundwater - Water present below the surface of the ground; important in lake-spawning site selection for some species of salmonids (e.g. brook trout).

Hybrid - The offspring of parents of different species. Hybrids are generally infertile or have reduced viability, and reproduction is minimal.

Hypolimnion - The poorly illuminated lower region of a stratified lake characterized by denser, colder water protected from wind action; lies below the metalimnion and overlies the profundal zone.

In Situ Cover - Refers to cover on the bottom of a lake or in the water column which provides refugia and feeding surfaces; includes large rocks and boulders on a sand-gravel substrate.

Incubation Period - The time interval between egg laying and hatching.

Indigenous Species - Any naturally occurring fish species of native or local origination (i.e., not imported or introduced).

Insular - Refers to island portion of Newfoundland.

Isotherm - A line joining points of equal temperature.

Juvenile - Young fish, fundamentally like adults in appearance, but smaller and reproductively inactive.

Lacustrine Habitat - Refers to habitat contained in pond or lake areas.

Landlocked – Refers to fish species that are prevented from making return migrations to the sea because of natural obstructions. It also categorizes fish that live entire life cycle in freshwater regardless of whether they have access to the sea.

Larvae - Organisms which at birth or hatching are fundamentally unlike their parents and must pass through metamorphosis before assuming adult characteristics.

Lentic - Refers to standing water, as in ponds and lakes.

Littoral - Refers to the marginal region of a body of water and is usually defined by the band from zero depth to the outer edge of rooted plants; shallow, nearshore region. These areas are subject to fluctuating water temperature and erosion of shore material through wave action and the grinding of ice and are usually well lighted.

Macrophytes - Another term for rooted aquatic plants.

Mainland - Refers to Labrador portion of the province of Newfoundland.

Metalimnion - The central stratum between the epilimnion and hypolimnion in a stratified lake where water temperature drops at least 1^0C with every 1 m decrease in depth; the region occupied by the thermocline.

Metamorphosis - Change in form and structure which fish undergo from the embryo to adult stage.

Migration – The deliberate movement of fish from one habitat to another.

Natal River - Refers to a fish's river of origin (or birth).

Native Species - Fish that originate in the area in which they live (refer to indigenous species).

Nursery (Rearing) Habitat - Generally refers to the portion of fish habitat which provides food and cover for young fish.

Oligotrophy - Condition of water being poor in plant nutrients; characteristic of well oxygenated lakes.

Ontogenetic - Refers to size-related shifts or life history changes that occur during the growth and development of an individual.

Organic - Derived from a living organism.

Organic Debris - Refers to all material in a water course that is of organic origin including algae, aquatic plants, logs, trees, and other woody material.

Overhanging (Riparian) Cover- Refers to cover provided by vegetation such as grasses, shrubs, alders and other low story trees adjacent to the waterbody up to 1.0 meter above the water surface.

Overhead Cover - Refers to riparian cover overhanging littoral habitat, undercut banks, woody debris at the surface providing shade, crevices, etc.

Parr - Juvenile stage in the life cycle of the salmonids from redd dispersal to migration to salt water. Parr are distinguishable by dark vertical bars (parr marks) along the body.

Pelagic (limnetic) - Refers to open-water regions, either middle or surface water levels, that are not directly influenced by the shore or bottom.

Piscivorous - Fish-eating.

Plankton - Small aquatic plants and animals, sometimes microscopic, drifting with the surrounding water.

Population - A group of individuals of a species occupying the same waters during at least part of their life cycle.

Profundal - Refers to the deep, cold region of lakes where currents are at a minimum and where light is much reduced; comprises the deep water and the lake bottom.

Redd - The gravel nest of salmonid fishes where eggs are deposited.

Resident Fish - Fish which remain in freshwater throughout their entire life cycle (non-anadromous).

Shoals - Refers to areas near the mouths of streams where the stream meets the slower water of a pond or lake.

Silt - Very fine sediment particles that can be carried or moved by stream velocities and deposited in slower moving waters. This material can be particularly harmful to invertebrates and extremely detrimental to the quality of fish habitat, especially spawning gravel.

Smolt - A two or more year old juvenile salmonid having undergone physiological changes to cope with a marine environment; usually refers to salmonids exhibiting silvery coloration and downstream movement to sea.

Spawning Habitat - Refers to habitat used by reproductively active fish for spawning and incubation of fertilized eggs.

Straying - Describes the movement of fish into freshwater systems other than their river of origin (i.e. natal river).

Sublittoral – Below littoral; usually refers to the bottom region of a lake, lying between the littoral and the profundal zones where it is too deep for rooted plants to grow.

Submergent Vegetation - Aquatic plants that grow entirely below the water's surface (e.g. elodea, pondweeds, bladderwort, pipewort) and include numerous mosses and macroalgae.

Substrate - The materials of which the lake bottom is comprised including; bedrock, boulder, rubble, cobble, gravel, sand, silt, detritus and mud.

Sympatric - Species inhabiting the same or overlapping geographic areas and are not denied the opportunity to breed by any geographic barrier.

Thermocline - Usually defined as the region in a lake where the water temperature changes at a rate of more than 1^0C per meter depth.

Tributary - Refers to any stream that flows into another, larger stream above its confluence with salt water (river mouth).