Life History Characteristics of Freshwater Fishes Occurring in the Northwest Territories and Nunavut, With Major Emphasis on Lake Habitat Requirements

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ABSTRACT

Richardson, E.S., J.D. Reist and C.K. Minns. 2001. Life history characteristics of freshwater fishes occurring in the Northwest Territories and Nunavut, with major emphasis on lake habitat requirements. Can. MS Rep. Fish. Aquat. Sci. 2569.

An intensive literature review of the life history and habitat requirements of all freshwater fish species in the Northwest Territories (NT) and Nunavut (NU) was performed, with a specific emphasis on lacustrine habitat requirements. Major emphasis was placed on species which use lacustrine environments for a portion of their life history. Preferences for physical habitat features such as water depth, substrate and cover were rated as nil, low, medium, and high. Habitat preference tables were prepared for 36 of 45 species. Where possible habitat preferences of different morphs or life history types were prepared. Habitat requirements across four life history stages (eggs, young-of-the-year, juvenile, and adult) were recorded for each species. Known species life history types and distributions were also recorded. Initial comparisons were to be made between and across ecozone and drainage basins to determine if habitat requirements changed with terrestrial ecosystems. In general, very few studies have examined lacustrine habitat requirements of freshwater fish in the NT and NU. This study has highlighted the substantial data gap which exists in our current understanding of northern freshwater fish species and indicates further studies must be performed.

RÉSUMÉ

Richardson, E.S., J.D. Reist and C.K. Minns. 2001. Life history characteristics of freshwater fishes occurring in the Northwest Territories and Nunavut, with major emphasis on lake habitat requirements. Can. MS Rep. Fish. Aquat. Sci. 2569.

Une revue approfondie de la littérature sur le cycle vital et les besoins en habitat de toutes les espèces de poissons d’eau douce des Territoires du Nord-Ouest (T.N.-O.) et du Nunavut a été effectuée, avec un accent particulier sur les besoins en habitat lacustre. Une grande importance a été accordée aux espèces qui utilisent des milieux lacustres à un stade de leur cycle biologique. Les préférences pour des caractéristiques d’habitat physique telles que la profondeur de l’eau, le substrat et la couverture ont été cotées comme nulles, faibles, moyennes et fortes. Des tableaux des préférences d’habitats ont été créés pour 36 des 45 espèces. Dans les cas où c’était possible, on a établi les préférences de poissons aux différents stades du cycle vital et de l’évolution morphologique. Les besoins en habitat à quatre stades du cycle vital (œufs, jeunes de l’année, juvéniles et adultes) ont été enregistrés pour chacune des espèces. Les types de cycles vitaux et de distributions des espèces connues ont aussi été notés. Des comparaisons initiales devaient être réalisées entre les écozones et les bassins hydrographiques, ainsi que dans leur ensemble, en vue de déterminer si les besoins en habitat changent selon les écosystèmes terrestres. En général, très peu d’études ont examiné les besoins en habitat lacustre des poissons dulçaquicoles des T.N.-O. et du Nunavut. La présente étude souligne les lacunes importantes dans les données qui existent dans notre compréhension actuelle des espèces de poissons dulçaquicoles nordiques et précise qu’il est nécessaire de mener d’autres études.

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INTRODUCTION

Central to the conservation of freshwater fish species is the need to identify and protect important fisheries habitat. Fish habitat requirements are both spatial and temporal, and change with various stages of the life cycle. Many freshwater fish species exhibit more than one life history type, and as such have different habitat requirements both spatially and temporally, indicating a need to manage these types separately. The focus of this report will be on lacustrine habitat requirements of freshwater fish species in the Northwest Territories (NT) and Nunavut (NU). It is important to note that selection of particular habitat types by fish is not entirely related to physical features and may be affected by distribution of prey, water temperature and competition with other fish species. These all contribute to fish distributions and habitat selection within a given environment. In order to assess the potential impacts of development, fisheries managers need to identify species' habitat requirements across all life history stages and life history types.

Most freshwater fish species select shallow water habitats to spawn in spring or fall when water temperatures are relatively cool. These fish also tend to have a specific preference for spawning substrates which are often important for egg survival. Much literature has focused on spawning habitat, however spawning habitat requirements of many species remain poorly understood. Cover also plays an important role in fish habitat requirements. Cover is used to avoid predators, as shelter from environmental conditions, or by predatory fish to ambush prey. Habitat use characteristically changes with age, with young-of-the-year fish occupying different habitats than do adults. Juvenile fish tend to occupy intermediate habitats between those selected by young-of-the-year fish and adult fish. These differences in habitat use throughout a species' life cycle make it important not just to manage for specific life history stages but all life history stages to ensure survival. Temporal changes in habitat selection may occur both seasonally and daily. For instance, selection of water depth may be seasonal as well as diurnal and is affected by several factors, the most important of which is water temperature.

This document is a summary of physical lake habitat requirements of various life history stages of freshwater fish in the NT and NU. Due to the limited amount of information available for northern populations of freshwater fish much of the information was extrapolated from known habitat requirements of freshwater fish species throughout their geographic range in North America. The authors acknowledge a significant amount of grey literature may exist in consultant reports and unpublished data, however it is often very difficult to acquire this information, and thus some studies may have been overlooked. It is also important to note that our assessment of the degree of association between a species and a particular habitat was subjective.

METHODS

This report includes all species of fishes known to occur in fresh waters of the NT and NU. Much of the following methodology parallels that in Bradbury *et al.* (1999). An extensive literature search was performed to collect all available information of lacustrine habitat use of freshwater fish species throughout various stages of their life histories. Databases searched include:

- various reference texts including Scott and Crossman 1973; McPhail and Lindsey 1970;

Morrow 1980; Becker 1983; and Scott and Scott 1988
- Department of Fisheries and Oceans (DFO) Underwater World Factsheets
- DFO (Central and Arctic Region) publications and scientific reports
- DFO WAVES database
- ASFA: Aquatic Sciences and Fisheries Abstracts
- Biological Abstracts and Netdoc databases at the University of Manitoba
- various Habitat Suitability Index (HSI) models published by the U.S. Fish and Wildlife Service, Biological Services.

Throughout the life cycle of a fish various habitat types are used for spawning, rearing, growth and maturation. However it is important to note that with variation in life history these habitat requirements change, and as such species' habitat requirements should be broken down by life history type as well as by life cycle stages. Where possible known life history types were identified for each species.

The following life history types were defined:

(1) Lacustrine: those species which spawn, rear and remain in lake environments for the majority of their life cycle.
(a) Adfluvial: those populations of fish which rear and remain in lacustrine environments for the majority of their life cycle, but which spawn in rivers or streams associated with lakes.

(2) Riverine: those fish species which spawn, rear and remain in river or stream environments for the majority of their life cycle.
(a) Fluvial: those species which spawn and rear in the same section of a stream or river making only minor migratory movements throughout their life time.

(1) Anadromous: those fish species which spawn in freshwater environments and migrate to marine environments for a portion of their life cycle.

The major life history characteristics of all freshwater and anadromous fishes occurring in Northwest Territories and Nunavut is summarized, with major emphasis on lacustrine habitat use by freshwater fish species for at least a portion of their life cycle. Four distinct life stages have been identified, i) spawning (eggs), ii) young-of-the-year (YOY), iii) juveniles, and iv) adults. Habitat requirements were reported on the basis of three physical habitat features i) water depth, ii) substrate type, and iii) structure/cover.

<u>Water Depth</u>

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 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 was defined as any feature within the aquatic environment that may be used by fish for protection from predators, competitors and adverse environmental conditions. Cover may also provide spawning habitat for some species (e.g., Cyprinids).

The following categories were used to define cover:
- submergent vegetation – aquatic plants that grow wholly under the water's surface (e.g., elodea, pondweeds, bladderwort, pipewort) and includes mosses and algae.

- emergent vegetation – all 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 sand/gravel substrates, submerged woody debris, etc.;
- other – any type of cover not defined in the above categories.

The degree of association between a given species and 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)

In cases where no information was available to indicate that a species utilizes a particular habitat, those features were left blank (Tables 3-39). In cases where no information was available on lake habitat utilization, a rating was made based on known habitat requirements of similar life stages and information on diet and feeding. All references containing specific information on species' use of water depth, substrate type and cover were assigned a numerical value for ease of representation and can be found in the reference list for tables starting on p. 128. References cited in the summary section of the report are listed on p. 51.

Initially an ecosystem perspective was taken and species' distributions were examined by terrestrial ecozones as well as by drainage basins. Where possible species' habitat requirements were to be compared across ecozones and drainage basins to establish if changes in terrestrial ecosystems and drainage basins affected their habitat requirements.

RESULTS

A total of 45 fish species are reported to occur in freshwater environments of the NT and NU (see Table 1). Of these, 40 species are known to use lacustrine environments. A total of 40, 34 and 13 species were known to exhibit lacustrine, riverine and anadromous life history types respectively (see Table 2). Hybrid freshwater fish species have been reported to occur in NT and NU, and may inhabit similar habitats as those of the parental species, or totally different habitats all together. The common and scientific names of fish species cited in this report generally follows that of Robins *et al.* (1991). A map of the NT and NU, highlighting areas mentioned in the report is shown in Figure 1. Two species have not been reported to enter lakes during any stage of their life cycle (darktail lamprey and flathead chub) and several other species (bull trout, Dolly Varden, pink salmon, chum salmon) may make only minimal use of lake environments.

The following is a summary of the major life history stages of all freshwater fish species occurring in the NT and NU and their habitat requirements with major emphasis on lacustrine environments.

Cods (Gadidae)

Burbot (*Lota lota*)

Burbot occur throughout the continental portions of the NT and NU exclusive of the northernmost tips, and are reported absent from the Arctic Islands (McPhail and Lindsey 1970; Scott and Crossman 1973; Tripp *et al.* 1981). The burbot typically occurs in deep-water lakes throughout its range, however it may also occur in rivers, small streams and low lying ponds (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973). Burbot exhibit both lacustrine and riverine life history types within the NT and NU (Rawson 1951; Scott and Crossman 1973; Stein *et al.* 1973; Johnson 1975). Freshwater populations can be separated into resident species which complete their life cycle within a single lake (lacustrine) and migratory species which feed and rear mainly in lakes but spawn in rivers (adfluvial) (Burmakin and Tyurin 1959; Muller 1971; Muss and Dahlstrom 1971; Sorokin 1971; Ford *et al.* 1995; McPhail 1997).

Burbot are known to spawn in lakes, rivers and streams (Carl *et al.* 1967; McPhail and Lindsey 1970; Muss and Dahlstrom 1971; Scott and Crossman 1973; Stein *et al.* 1973). Throughout the geographic range, burbot spawn under the ice at night between November and May, with most Canadian populations spawning between January and April (Carl *et al.* 1967; McPhail and Lindsey 1970; Muller 1971; Muss and Dahlstrom 1971; Sorokin 1971; Scott and Crossman 1973; Ford *et al.* 1995). Local timing of spawning is associated with water temperatures which are usually between 0.6 and 1.7 °C (Scott and Crossman 1973). Burbot are broadcast spawners, and spawn over sand, gravel or rubble substrates at a depth of 0.5–3.0 m (Lehtonen 1963; Muss and Dahlstrom 1971; Sorokin 1971; Scott and Crossman 1973; Morrow 1980; Goodyear *et al.* 1982; Mansfield *et al.* 1983; Ford *et al.* 1995). Although burbot typically spawn in shallow water, several authors have reported burbot spawning at much greater depths (Muss and Dahlstrom 1971; Morrow 1980; Goodyear *et al.* 1982). Burbot are highly fecund and may lay over a million semi-buoyant eggs which become demersal within a few days, settling into the interstices of the substrate (Fabricius 1954; McPhail and Lindsey 1970; Sorokin 1971; Scott and Crossman 1973; Ford *et al.* 1995). Egg incubation is dependent on water temperature, and varies from three weeks to three months (Muss and Dahlstrom 1971; Scott and Crossman 1973; Goodyear *et al.* 1982; Mansfield *et al.* 1983; Ford *et al.* 1995).

Upon hatching sac fry are found primarily in the pelagic zone and congregate over sand and rubble substrates (Berry 1981; McPhail 1997). Young-of-the-year burbot become benthic littoral feeders when they reach the fingerling stage between 20 and 40 mm in length (Muller 1971; Muss and Dahlstrom 1971; Ryder and Pisendorfer 1992). McPhail (1997) notes that this change in habitat is accompanied by a transition from a crepuscular to nocturnal activity pattern. Once nocturnal, young burbot seek suitable shelter in shallow water during the daytime under physical structure such as boulders, cobble, logs, or within submergent vegetation, and remain inactive unless disturbed (Muss and Dahlstrom 1971; Berry 1981; Ryder and Pisendorfer 1992; Ford *et al.* 1995). Juveniles are typically found over rock and gravel bottoms along rocky shorelines (Lawler 1963; McPhail 1970; Ford *et al.* 1995). Both juvenile and adult burbot seasonally move offshore to deeper waters in the hypolimnion in early summer (Scott and Crossman

1973; Ford *et al.* 1995). Age of maturity varies latitudinally, with males usually reaching sexual maturity a year or two before females (Ford *et al.* 1995; McPhail 1997). Burbot generally reach sexual maturity between three and four years of age, and have been shown to mature somewhat later at five years of age in the NT (Scott and Crossman 1973; Tallman 1996).

Although most adult burbot seek cooler deeper waters in the summer, some fish may make diel movements into shallower water at night to feed (Scott and Crossman 1973; Wang and Appenzeller 1998). As with juvenile burbot, adults are found over boulder, rubble, cobble and sand substrates (Lawler 1963; Scott and Crossman 1973; Ford *et al.* 1995; Edsall *et al.* 1993; Fischer and Eckmann 1997). Burbot are sensitive to sub-surface illumination and seek shelter under stones, roots and amongst aquatic plants during the day (McPhail and Lindsey 1970; Muss and Dahlstrom 1971; Edsall *et al.* 1993; Ryder and Pisendorfer 1996). While the burbot is considered to be a sedentary fish, extensive migrations over 400 km have been observed in the NT (Keleher 1963). Northern populations of burbot appear to live longer and reach greater size than other populations, with the largest known fish being caught in Great Slave Lake, weighing 18.5 pounds with a fork length of 38.3 inches (Scott and Crosman 1973). Adult burbot are primarily piscivorous feeding on ciscoes, cottids, whitefish, sticklebacks and trout-perch (Rawson 1951; Lawler 1963).

Lampreys (Petromyzontidae)

Arctic lamprey (*Lampetra japonica*)

The Arctic lamprey is the most widely distributed species of Holarctic lamprey and is common in both freshwater and marine environments in the NT, but has not been reported in NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Vladykov and Kott 1979). Within the NT the Arctic lamprey occurs from the mouth of the Mackenzie River upstream to Great Slave and Artillery lakes, and to Fort Smith on the Slave River (McPhail and Lindsey 1970; Nursall and Buchwald 1972; Scott and Crossman 1973; Lee *et al.* 1980). The life history of the Arctic lamprey is largely unknown and varies between anadromous and freshwater fluvial and adfluvial life history types, with adult parasitic and non-parasitic forms (Heard 1966; McPhail and Lindsey 1970; Nursall and Buchwald 1972). McPhail and Lindsey (1970) note that the apparent variability in life history types exhibited may be the result of treating several species as a single species group.

Arctic lamprey spawn in streams and rivers from May to July (Walters 1955; Heard 1966; Nursall and Buchwald 1972). The Great Slave Lake population is known to spawn in the Mackenzie, Hay and Slave rivers (Nursall and Buchwald 1972). Spawning occurs in shallow water between 8-20 cm in depth, over sand and gravel substrates. Both sexes participate in the construction of the nest site, by thrashing their bodies violently against the substrate and by clearing of stones with their oral suckers (Heard 1966; McPhail and Lindsey 1970; Hardisty and Potter 1971b; Nursall and Buchwald 1972; Scott and Crossman 1973; Lee *et al.* 1980). Adults lay an average of 21,415 eggs and die shortly after spawning (Heard 1966; Nursall and Buchwald 1972).

Eggs incubate for one to two weeks and, upon hatching, ammocoetes drift downstream and settle in eddies and backwaters, where they burrow into silty mud and filter feed on aquatic organisms (Hardisty and Potter 1971a; Nursall and Buchwald 1972; Scott and Crossman 1973; Lee *et al.* 1980). The ammocoetes remain in these beds for several years and may move between spawning beds as they migrate downstream. When ammocoetes reach about 150–210 mm in length they undergo transformation into immature adults, at which point they either migrate downstream to a lake, the ocean or remain within a river system (Nursall and Buchwald 1972; Scott and Crossman 1973).

Immature adult lampreys are primarily found in the limnetic areas of lakes in late summer and fall (Heard 1966). During the summer the immature lamprey feed extensively and may grow 180 to 300 mm in one season. The following winter adults cease to feed, their intestines degenerate and their gonads begin to mature (Nursall and Buchwald 1972). Adults migrate upstream the following year to spawn (Hardisty and Potter 1971b; Nursall and Buchwald 1972; Scott and Crossman 1973). The Arctic lamprey of Great Slave Lake exhibits a five year life cycle, spending four years as an ammocoete within spawning tributaries and one year as an adult in the lake itself (Nursall and Buchwald 1972). Adults are parasitic of many fish species in the region including ciscoes, burbot, longnose suckers, lake trout and whitefish (Nursall and Buchwald 1972; Scott and Crossman 1973; Valdykov and Kott 1979).

Darktail lamprey (*Lethenteron alaskense*)

The darktail lamprey is found in northwestern North America and is known to occur in the NT, but is absent from NU (Lee *et al.* 1980). The darktail lamprey has only been reported at one locality in Canada, in the Martine River, a tributary of the Mackenzie River in NT (Vladykov and Kott 1978). Darktail lamprey are known to occur in rivers, creeks, and lakes in the Naknek River system of Alaska (Heard 1966; Houston 1991). Although little is known of its biology, the darktail lamprey is a non-anadromous species and may exhibit both fluvial and adfluvial life history types (Heard 1966; Vladykov and Kott 1979; Houston 1991). Heard (1966) originally described the darktail lamprey as a dwarf non-parasitic form of *L. japonicum*, consequently continued confusion in the differentiation of these species may prevent the discrimination of *L. alaskense* and *L. japonica* populations in the NT.

Darktail lamprey spawn from May to July with both sexes active in excavation of the nest site (Heard 1966). Eggs hatch within a few weeks and ammocoetes feed almost exclusively on phytoplankton (Vladykov and Kott 1978). Transformation takes place in the fall at about four years of age, when ammocoetes are between 150 and 210 mm in length (Houston 1991). Following transformation immature adults migrate downstream and overwinter in lakes (Houston 1991). Immature adults are found primarily in the limnetic areas of lakes, but have been caught in streams (Heard 1966). Adults are non-parasitic, spawn only once and die shortly after spawning (Vladykov and Kott 1979; Vladykov *et al.* 1980; Houston 1991). Information on the darktail lamprey is very limited and further studies should be conducted to determine the distribution, life history types, and habitat requirements of this species within the NT.

Carps and Minnows (Cyprinidae)

Emerald shiner (*Notropis atherinoides*)

The emerald shiner has been reported in the tributaries of the Mackenzie River south from the junction of the Mackenzie and Liard rivers within the NT, however it has not been reported to occur in NU (McPhail and Lindsey 1970; Scott and Crossman 1973). The emerald shiner is a pelagic species inhabiting large open lakes and rivers in many parts of Canada (Dymond 1926; McPhail and Lindsey 1970; Scott and Crossman 1973; Tripp *et al.* 1981). It is known to exhibit primarily a lacustrine life history type, although riverine and adfluvial life history types likely exist (Scott and Crossman 1973; Becker 1983; Lee *et al.* 1980). Scott and Crossman (1973) note that very few studies have been published on its biology in Canada.

The emerald shiner spawns in late spring or early summer in mid-water as well as shallow shore waters of lakes, at depths from 2-6 m (Campbell and McCrimmon 1970; McPhail and Lindsey 1970; Scott and Crossman 1973; Goodyear *et al.* 1982; Becker 1983). Eggs are scattered at the surface or in mid-water, commonly over sand and gravel substrates, occasionally in association with vegetation (Flittner 1964; Goodyear *et al.* 1982). The fertilized non-adhesive eggs fall to the bottom and hatch very rapidly within 24-32 hours of fertilization (McPhail and Lindsey 1970; Scott and Crosman 1973; Goodyear *et al.* 1982; Becker 1983).

Prolarvae remain on the bottom for about four days until they become free swimming, at this point they form large schools and may be found over sand, rock, clay and silt substrates occasionally in association with vegetation (McPhail and Lindsey 1970; Tripp *et al.* 1981; Goodyear *et al.* 1982; Leslie and Timmins 1998a). Young emerald shiners are planktonic, and form large schools remaining in the upper 2-4 m of water in nearshore areas of lakes, although some young may rear in creeks (Becker 1983; Scott and Crossman 1973; Goodyear *et al.* 1982; Leslie and Timmins 1998b). In Canada young shiners mature between 1 and 2 years of age, and rarely live beyond 3 years (Cambell and McCrimmon 1970; Scott and Crossman 1973; Nelson and Paetz 1992).

Adult emerald shiners are pelagic and remain in deepwater during the daytime, coming to the surface at night to feed (Becker 1983; Scott and Crossman 1973; Goodyear *et al.* 1982). Seasonally adults move offshore to deeper water in the summer, returning in the fall to inshore areas where they are often found aggregated around docks, piers and river mouths (Dymond 1926; Fish 1932; Scott and Crossman 1973). Later on in the season adults return to deepwater areas to overwinter (Scott and Crossman 1973). Emerald shiner feed heavily on corixids, algae, midge larvae and *Daphnia* sp. (Fuchs 1967; Scott and Crossman 1973; Tripp *et al.* 1981; Hartman *et al.* 1992).

Fathead minnow (*Pimephales promelas*)

The fathead minnow occurs in the very south central portion of the NT in the Hole Lakes and Little Buffalo River, however it has not been reported to occur in NU (McPhail and Lindsey 1970; Scott and Crossman 1973). The preferred habitat of this species seems to vary throughout its geographic range, and it may inhabit still water ponds, muddy streams, mud-bottomed lakes, muddy ditches and warm brooks (McPhail and Lindsey 1970; Scott and Crossman 1973). The fathead minnow exhibits both lacustrine and riverine life history types (Wynne-Edwards 1932; Scott and Crossman 1973).

Spawning activities take place from April to mid-August in southern portions of its range, usually commencing at 15.6 °C with a prolonged spawning period occurring (McPhail and Lindsey 1970; Scott and Crossman 1973; Nelson and Paetz 1992). Males build nest sites usually on the underside of rocks, logs, branches, boards and sometimes lily pads in 2-3 feet of water (Wynne-Edwards 1932; Markus 1934; McPhail and Lindsey 1970). Males seek out females and herd them into position below the nest site, the female deposits several adhesive eggs on the under surface of the nest site with her ovipositor, which are then fertilized by the male. The female is driven off and the male defends the nest aggressively, but may seek out of a number of other females to deposit eggs in the nest (Markus 1934; McPhail and Lindsey 1970; Scott and Crossman 1973; Nelson and Paetz 1992). Incubation usually takes between 4.5 to 6 days depending on the water temperature (Markus 1934; Scott and Crossman 1973; Goodyear *et al.* 1982).

Young may be found over sand and mud substrates in protected shallow water areas such as marshes, harbours and creek mouths (Goodyear *et al.* 1982). Adults are typically active at night whereas juveniles are more active during the day (Price *et al.* 1991). Sexual maturity is reached in one year, and adults rarely live beyond two years (Markus 1934; Scott and Crossman 1973). The diet of the fathead minnow consists mostly of algae, insect larvae, amphipods, microcrustaceans and detritus (Lee *et al.* 1980; Price *et al.* 1991). Although spawning is well documented very little is known of the biology and life history of the fathead minnow (Scott and Crossman 1973).

Finescale dace (*Phoxinus neogaeus*)

Within the NT the finescale dace may be found within the Mackenzie River system downstream to the Arctic Circle, however it does not occur in NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The finescale dace occurs in bog ponds, streams, larger lakes and is often found in stained boggy waters (McPhail and Lindsey 1970; Scott and Crossman 1973). The finescale dace is known to exhibit both lacustrine and riverine life history types (Stasiak 1978; Das and Nelson 1990).

The finescale dace spawns from spring to mid-summer (McPhail and Lindsey 1970; Scott and Crossman1973). Das and Nelson (1990) reported a spawning period from mid-June to late July in Alberta. Finescale dace have been observed spawning under the cover of trees, brush and logs in 0.5-0.9 m of water (Stasiak 1978). Eggs incubate for four days before hatching, and young begin to swim three days later (Becker 1983). Adult dace are most often found in light to dark brown waters at depths of 0.1-0.5 m primarily over sand, gravel, silt and mud substrates (Dymond 1926; Becker 1983). The finsescale dace is known to hybridize with the northern redbelly dace and likely shares similar spawning habitat requirements (McPhail and Lindsey 1970; Scott and Crossman 1973; Das and Nelson 1990). Finescale dace feed primarily on insects, which form a major portion of the summer di*et al.*ong with plankton and crustaceans (Scott and Crossman 1973; Becker 1983). Relatively little information exists on the biology and life history of this species and further studies should be performed.

Flathead chub (*Platygobio gracilis*)

Within the NT the flathead chub occurs from Great Slave Lake down the

Mackenzie River to the delta, but is absent from NU (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973). The flathead chub may occur in large flowing turbid rivers, preferring cool sluggish creeks throughout its range and is seldom found in the still waters of ponds and lakes (Carl *et al.* 1967). It exhibits primarily a riverine life history type throughout its range, and only one report of lacustrine habitat use was found for this species (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Prouse and Derksen 1974).

Prouse and Derksen (1974) provide the only report of lake habitat use by the flathead chub. They reported catching a record size flathead chub in 11 m of water over a mud bottom in Lake Winnipeg, Manitoba. Although, other specimens have been caught from various lakes, this is the only record of lacustrine habitat use found for this species.

Lake chub (*Coeusius plumbeus*)

The lake chub is present in both the NT and NU (Scott and Crossman 1973). In NU it ranges from the Chesterfield Inlet tributaries, Thelon, Dubawnt, and Kazin rivers and Nueltin Lake westward to the NT where it is common throughout the Mackenzie River system (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973). Lake chub are frequent in rivers and streams and inhabit a wide variety of habitats from outlets of hot springs to cool northern rivers, but seem to prefer lakes when they are available (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973). The lake chub is known to exhibit lacustrine, adfluvial, and riverine life history types (Brown *et al.* 1970; Scott and Crossman 1973; Stein *et al.* 1973).

Spawning occurs from April to early August along lake shores or in steams (Carl *et al.* 1967; Scott and Crossman 1973). Brown *et al.* (1970) described both river and lake spawning populations of lake chub in Lac La Ronge Saskatchewan. Within the NT lake chub were observed spawning in May in the Root and North Nahanni rivers, with nursery grounds being found in many parts of the Mackenzie River (Stein *et al.* 1973). Lake chub spawn over and amongst rubble, cobble and gravel substrates at depths of 0.5-2.0 m (Brown *et al.* 1970; McPhail and Lindsey 1970; Scott and Crossman 1973; Lawrence *et al.* 1977; Lee *et al.* 1980; Morrow 1980; Goodyear *et al.*1982). Females may lay as many as 500 yellow eggs, which hatch in about two weeks (Carl *et al.* 1967; Scott and Crossman 1973). Fish mature in their third or fourth year and seldom survive beyond five years (Carl *et al.* 1967).

Lake chub occupy the bottom water zone close to shore, but may seek deeper water in the summer when lakes begin to warm (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Morrow 1980). Adults prefer sand, rubble, cobble and boulder substrates and are frequent at depths of 12–16 feet (Brown 1969; Machniak 1979; Becker 1983). Brown (1969) notes that exposure plays a more critical role in the distribution of lake chub than vegetation and substrate. Although the lake chub is typically considered to be a shallow water species (Becker 1983), it has been reported in deepwater regions throughout its range (Brown 1969). Terrestrial and aquatic insects as well as algae and zooplankton form the major part of the diet (McPhail and Lindsey 1970; Tripp *et al.* 1981).

Longnose dace (*Rhinichthys cataractae*)

The longnose dace occurs throughout the Mackenzie River system north almost to the Arctic Circle in the NT, but is absent from NU (McPhail and Lindsey 1970; Scott and Crossman 1973). The longnose dace is characteristically found in either clear or muddy swiftly flowing gravel or bouldery streams, and may inhabit very turbulent waters (McPhail and Lindsey 1970; Scott and Crossman1973; Lee *et al.* 1980; Becker 1983). Although characteristically a stream species, the longnose dace may also occur in inshore waters of lakes over boulder or gravel bottoms (Gee and Machniak 1972; Scott and Crossman 1973; Lee *et al.* 1980). The longnose dace may exhibit both lacustrine and riverine life history types (Gee and Machniak 1972; Scott and Crossman 1973; Hubert and Rahel 1989).

Spawning may occur from May to August throughout its range, commonly over a gravel or stone bottom (McPhail and Lindsey 1970; Gee and Machniak 1972; Scott and Crossman 1973; Brazo *et al.* 1978; Nelson and Paetz 1992). Females lay between 200-1200 adhesive eggs, which hatch in 3-10 days depending on local water temperature (McPhail and Lindsey 1970; Goodyear *et al.* 1982; Becker 1983). Prolarvae hide among rocks for about one week, then rise to the surface, and may be found under cover of overhanging vegetation (Gee and Machniak 1972; Goodyear *et al.* 1982). Young are pelagic for about four months inhabiting shallow areas over sand, gravel and rock substrates (McPhail and Lindsey 1970; Scott and Crossman 1973; Brazo *et al.* 1978; Goodyear *et al.* 1982). Sexual maturity occurs in their third year, with a maximum age of four years for males and five years for females (McPhail and Lindsey 1970; Nelson and Paetz 1992).

Mullen and Burton (1995) noted that juvenile and adult longnose dace select similar habitats, although adults were more selective than juveniles. Adults are bottom dwelling and inhabit quiet waters near shore and may be found over sand-gravel-boulder substrates on beaches in May, June and July (McPhail and Lindsey 1970; Scott and Crossman 1973). As adults the longnose dace exhibit a nocturnal foraging pattern and may live in crannies between as well as under stones during daylight hours, possibly to avoid predation (McPhail and Lindsey 1970; Brazo *et al.* 1978; Culp 1989). Lake dwelling populations may occupy deep channels between islands and windswept shore where currents resemble those of rivers (Gee and Machniak 1972; Becker 1983). The longnose dace is a benthic species and feeds heavily on chironomids, algae, midge larvae and diptera larvae (McPhail and Lindsey 1970; Gee and Machniak 1972; Scott and Crossman 1973).

Northern redbelly dace (*Phoxinus eos*)

The northern redbelly dace is present in the Peace-Mackenzie drainage basin and reaches the northern portion of its distribution at the mouth of the Arctic Red River in the NT, but is absent from NU (Carl *et al.* 1967; McPhail and Lindsey 1970; Stein *et al.* 1973; Lee *et al.* 1980). It occurs in boggy lakes, beaver ponds, small lakes and quiet pool-like expansions of streams (Carl *et al.* 1967; McPhail and Lindsey; Scott and Crossman 1973). The northern redbelly dace exhibits both lacustrine and riverine life history types (Cooper 1935; McPhail and Lindsey 1970; Scott and Crossman 1973).

Spawning occurs in spring or early summer depending on the geographic location and the local environment (Scott and Crossman 1973; Becker 1983; Powles *et al.* 1992). Das and Nelson (1990) reported ripe males from the beginning of June to the beginning of August in Upper Pierre Grey Lake, Alberta. Northern redbelly dace spawn amongst aquatic filamentous masses of algae and are believed to be fractional spawners, with an extended breeding season (Cooper 1935; Carl *et al.* 1967; McPhail and Lindsey 1970; Powles *et al.* 1992). Eggs are scattered amongst aquatic vegetation over gravel substrates and are abandoned, hatching in 8-10 days depending on water temperature (Cooper 1935; Carl *et al.* 1967; Goodyear *et al.* 1982; Nelson and Paetz 1992). Maturity is usually reached in the second summer of life and some individuals may live as long as eight years (Legendre 1969).

Adults are frequently found over substrates of finely divided brown detritus, sand, gravel, silt and mud, often in association with vegetated areas (Scott and Crossman 1973; Becker 1983; Naud and Magnan 1988). Northern redbelly dace are most often encountered at depths between 0.1-0.5 m and less frequently at 0.6-1.5 m (Becker 1983). Adults may make diel movements and occur most commonly in the littoral zone (0-1 m depth) during the day and the pelagic zone (> 2 m depth) at night (Naud and Magnan 1988; Gauthier and Bosclair 1997). Food consists primarily of algae but may include zooplankton and aquatic insects (Scott and Crossman 1973; Becker 1983; Naud and Magnan 1988; Cochran *et al.* 1998). Both the northern redbelly and finescale dace occupy similar habitats and spawn at similar times, making hybrids common between these two species (New 1962; Scott and Crossman 1973; Das and Nelson 1990).

Peamouth (*Mylocheilus caurinus*)

The peamouth has been reported in the Upper Peace River drainage of British Columbia, however it is not known if its distribution now extends into NT; it is not known to occur in NU (Scott and Crossman 1973). Peamouth are typically found in slow stretches of rivers and lakes (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The peamouth may exhibit lacustrine, adfluvial and riverine life history types (Nishimoto 1973; Hill 1962).

Peamouth spawn from May to June (Hill 1962; Carl *et al.* 1967; McPhail and Lindsey 1970; Nishimoto 1973). Peamouth lay grey-green adhesive eggs, which settle over stones, gravel, rubble and sand substrates in the shallows of lakes or in outlet streams close to lakes (Schultz 1935; Miura 1962; McPhail and Lindsey 1970; Nishimoto 1973). Eggs hatch in 7-8 days and newly hatched young remain in schools along the shoreline over rubble and gravel substrates in areas of submerged vegetation, until late summer when they apparently move into deeper water (Schultz 1935; Carl *et al.* 1967). Conversely, Miura (1962) noted that young were pelagic, occurring in the mid-water zone, rarely occuring near the bottom. Male peamouth mature at age three and females mature at age four. Adults and young tend to remain congregated in schools (Carl *et al.* 1967).

Adults frequent areas where aquatic vegetation is abundant, although no preference for substrate was found (Clemens 1939; Hill 1962; Miura 1962; Carl *et al.* 1967; Scott and Crossman 1973). Adult peamouth may make diel movements in their distribution, feeding on the bottom during the day at depths of 20 m or more, rising to the surface at night to feed on emerging insects (Northcote *et al.* 1964). In Stave Lake, British Columbia, Aspinwall *et al.* (1992) reported that peamouth were most common in the limnetic zone in the top 0-2.4 m of water, and occur to depths of 7.6 m. Alternatively, Nishimoto (1973) notes that although peamouth are generally found on the bottom throughout the year, they may be found in open water at the 20-50 foot zone over depths of 60 feet. Adults consume primarily zooplankton as well as aquatic and terrestrial insects (Clemens 1939; Aspinwall *et al.* 1992). The peamouth chub has similar habitat requirements to that of the squawfish and redside shiner and hybrids may occur between these species (Carl *et al.* 1967; Aspinwall and McPhail 1995).

Pearl dace (*Margariscus margarita*)

The pearl dace reaches the northern limit of its distribution in the NT and is found from the Lower Sass River southward, and has not been reported to occur in NU (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973). The pearl dace occurs in cool bogs, creeks, lakes, ponds and slow streams (Carl *et al.* 1967; Scott and Crossman 1973; Lee *et al.* 1980). The pearl dace may exhibit both lacustrine and riverine life history types (Becker 1983).

Across its geographic range, spawning takes place from May to June (Carl *et al.* 1967; Scott and Crossman 1973). Spawning in northern lakes occurs about the same time as spring melt and ice-off (Tallman *et al.* 1984). No nest is built by this species, however a spawning territory is usually guarded by the male (Carl *et al.* 1967; Scott and Crossman 1973). Stream spawning takes place in shallow water 18-24 inches deep over sand and gravel in weak to moderate current (Langlois 1929), while lake spawning occurs over soft organic substrates (Bendell and McNicol 1987). Tallman *et al.* (1984) note that dace may also spawn in vegetation on the periphery of lakes. No information on habitat use of young dace in lakes was found, however in stream environments young dace are typically found over silt, clay and detritus substrates at depths of 0-5 m often in association with vegetation (Tallman and Gee 1982). Pearl dace are a relatively short lived species, with sexual maturity occurring at one year of age, and a life span of no more than three years for males and four years for females (Nelson and Paetz 1992; Tallman *et al.* 1984; Bendel and McNicol 1987). In deep lakes (> 5 m), adult pearl dace move to cooler hypolimnetic waters when epilimnetic temperatures rise in the summer (Tallman *et al.* 1984). The pearl dace is omnivorous consuming insects, filamentous algae and detritus (McPhail and Lindsey 1970; Tallman and Gee 1982; Tallman *et al.* 1984).

Spottail shiner (*Notropis hudsonius*)

The spottail shiner occurs in the Mackenzie River system downstream to Fort Good Hope NT, but has not been reported to occur in NU (McPhail and Lindsey 1970; Scott and Crossman 1973). Spottail shiners are found in larger lakes and rivers throughout their geographic range, and are often the most abundant minnow in northern lakes (Scott and Crossman; Becker 1983). The spottail shiner is known to exhibit both lacustrine and riverine life history types (Wells and House 1974; Mansfield 1984).

Spawning occurs from spring to early summer throughout its geographic range depending on latitude, however in Canada spawning typically occurs in June and July (Peer 1966; McPhail and Lindsey 1970; Scott and Crossman 1973). Spottail shiners spawn over sandy shoals, gravel and rubble, commonly in shallow water 0-5 m in depth

(Peer 1966; McPhail and Lindsey 1970; Scott and Crossman 1973; Goodyear *et al.* 1982; Becker 1983). Both Wells and House (1974) and Goodyear *et al.* (1982) noted that female spottail shiners often deposit eggs in *Cladophora sp.* Some populations of spottail shiner may make use of tributary streams to spawn, however this is a relatively rare occurrence (Scott and Crossman 1973; Mansfield 1984). Spottail shiners typically mature between age one and two, although maturation may be related to body length and not age (Peer 1966; Wells and House 1974). During spring and summer spottail shiners favour shallow, warmer water over sand and gravel substrates and are typically found at depths of less than 13 m (Peer 1966; Wells and House 1974; Lee *et al.* 1989; Becker 1983). The diet of the spottail shiner varies and may include insect larvae, plankton and masses of algae (McCann 1959; McPhail and Lindsey 1970).

Mooneyes (Hiodontidae)

Goldeye (*Hiodon alosoides*)

The goldeye has a limited distribution within the NT and has not been reported in NU (Carl *et al.* 1967; Kennedy and Sprules 1967; McPhail and Lindsey 1970). Within the NT goldeye are present from the mouth of the Mackenzie River upstream to Great Slave Lake, as well as within the Liard, Slave and Athabasca rivers (Kennedy and Sprules 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Tripp *et al.* 1981). Goldeye tolerate very turbid water and may be found in large rivers, small lakes, ponds, marshes, and in the muddy shallows of larger lakes (Sprules 1954; Kennedy and Sprules 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Nelson and Paetz 1992). Goldeye may exhibit both riverine and adfluvial life history types, however no information pertaining to a lacustrine life history type was found (Kennedy and Sprules 1967; Hatfield *et al.* 1972; Stein *et al.* 1973).

Goldeye spawn annually from May to early July after ice break up, primarily in pools of rivers or in backwater lakes and ponds associated with rivers (Carl *et al.* 1967; Battle and Sprules 1960; Kennedy and Sprules 1967; Scott and Crossman 1973; Donald and Kooyman 1977a). Goldeye lay between 5,000 to 25,000 semibuoyant eggs over shallow, firm bottom substrates consisting of gravel and sand (Sprules 1946; Sprules 1954; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The eggs incubate for close to two weeks, and after hatching the young larvae float at the water surface in a vertical position (Battle and Sprules 1960; McPhail and Lindsey 1970; Scott and Crossman 1973; Donald and Kooyman 1974). Wind plays an important role in the distribution of young goldeye, which often appear in greater numbers along windward shorelines (Kristensen 1981). Kristensen and Sekerak (1976) suggest that vegetation type or a factor affecting vegetation type, influences the distribution of young goldeye along lakeshores. However, a more recent study by Kristensen (1981) found no correlation between the two.

Young goldeye are most frequent in waters within a hundred meters of the shoreline at depths of 1-1.5 m (Kristensen and Sekerak 1976; Donald and Kooyman 1977a). Juvenile goldeye are pelagic and feed primarily on terrestrial and aquatic insects at the water surface (Sprules 1946; Hatfield *et al.* 1972). Juveniles migrate in the summer and fall out of spawning areas into deeper areas of rivers and lakes to overwinter with adults, returning with the adults during the spring spawning migration (Kristensen and Sekerak 1976; Donald and Kooyman 1977). Age at maturity varies according to latitude, with males maturing anywhere from 3-9 years of age and females maturing somewhat later between 4-10 years of age (Battle and Sprules 1960; Scott and Crossman 1973).

Following spawning adult goldeye may continue to migrate upstream to feed (Scott and Crossman 1973). During summer and early fall adults make a return migration to overwintering areas in deeper areas of lakes and rivers (Sprules 1954; Scott and Crossman 1973; Kristensen and Sekerak 1976). Adult goldeye are found at depths of five to ten feet in sheltered bays and shore regions of lakes in association with soft mud substrates (Sprules 1954). Goldeye are mainly nocturnal and are well adapted to the low light conditions associated with turbid habitat, thus making observations of this species very difficult (Scott and Crossman 1973). Adult goldeye feed primarily on aquatic and terrestrial insects taken at the water surface (Kennedy and Sprules 1967; Donald and Kooyman 1977b; Tripp *et al.* 1981).

Perches (Percidae)

Iowa darter (*Etheostoma exile*)

The distribution of the Iowa darter within the NT is unconfirmed but likely occurs within the very south central portion. Scott and Crossman (1973) reported an isolated population from Pine Lake, Alberta 40 miles south of the NT boarder, however it is unlikely that its distribution has expanded into NU (Scott ad Crossman 1973). The Iowa darter is typically found in lakes, bog ponds, rivers as well as fast flowing streams (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Becker 1983). It is known to exhibit both lacustrine and riverine life history types (Winn 1958a; McPhail and Lindsey 1970; Scott and Crossman 1973).

Spawning occurs from the first two weeks of April into the last week of May (Winn 1958b; Scott and Crossman 1973; Nelson and Paetz 1992). Males migrate from deeper water into shallow water, arriving on the spawning grounds before females in order to establish and defend a territory (Winn 1958a). Females migrate in from deeper water into a male’s territory when they are ready to mate (Winn 1958a). Iowa darters typically spawn amongst submerged fibrous roots and vegetation often under undercut banks usually in 10-40 cm of water along the shores of lakes (Winn 1958a; 1958b; Simon and Faber 1987). However, Goodyear *et al.* (1982) reported spawning occurred in anywhere from four inches to four feet of water. Iowa darters may also spawn on gravel and sand when roots, undercut banks and vegetation are not available (Winn 1958a). Females lay several adhesive eggs, which adhere to roots and other vegetation in which they are deposited (Winn 1958a; 1958b). Eggs incubate for 9-18 days before hatching depending on water temperature (Winn 1958a; Scott and Crossman 1973). However, Goodyear *et al.* (1982) report a much longer incubation period of 18-26 days for Great Lakes populations.

Cucin and Faber (1985) reported larvae occurred over sand and gravel substrates in the shallows of bays close to lake shores in 0.5 m of water. Young are most often found amongst vegetation over sand, silt and mud substrates in sheltered shallow areas including marshes (Goodyear *et al.* 1982). Adults are typically found over sand and boulder substrates amongst vegetation at depths of 0.5-1.5 m, often in association with fallen trees (Emery 1975). Adult darters are most active during the day and at night are found hidden in rock crevices and underneath submerged tree roots (Emery 1975). Winn (1958a) reported that the Iowa darter usually lives at least to three years of age.

Walleye (*Stizostedion vitreum*)

Within the NT walleye are distributed throughout the Mackenzie River drainage from Great Slave and Great Bear lakes north to the delta of the Mackenzie River, and may also occupy the very southwest portion of NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The walleye tolerates a wide variety of environments and may inhabit large rivers, streams and lakes, but prefers large shallow turbid lakes (Scott and Crossman 1973; Becker 1983). Walleye are known to exhibit lacustrine, adfluvial and riverine life history types (Eschmeyer 1950; Scott and Crossman 1973; Goodyear *et al.* 1985).

Walleye spawn from spring to early summer throughout their geographic range, with northern populations spawning in June or later (Rawson 1957; Scott and Crossman 1973; Becker 1983). Lake populations spawn either in tributary streams or within the lake itself as soon as the ice goes out (Carl *et al.* 1967; Becker 1983; Ford *et al.* 1985). Walleye favor inshore areas for spawning, often in association with moderate wave action (Eschmeyer 1950; Becker 1983). Walleye typically spawn over gravel, boulder and rubble substrates primarily at depths of 0.3-2 m (Eschmeyer 1950; Johnson 1961; McPhail and Lindsey 1970; Priegel 1970; Becker 1983; Ford *et al.* 1985; Hartley and Kelso 1991). Walleye egg survival varies with substrate conditions, and is greatest over clean gravel and rubble substrates, with the lowest rate of survival occurring over areas with soft mud and detritus bottoms (Johnson 1961). In turbid lakes with silt and mud bottoms tributary streams may provide essential spawning habitat for walleye, which is not present in these lakes. Lake populations may also make use of marshes to spawn, laying eggs amongst dense vegetative mats consisting of grasses and sedges (Priegel 1970). Walleye are broadcast spawners and do not exercise any parental care (Eschemeyer 1950; Becker 1983). Eggs incubate for anywhere from 12-18 days before hatching, depending on water temperatures at spawning grounds (Scott and Crossman 1973). Although southern populations of walleye typically spawn every year, some northern populations may not, due to unfavourable temperature conditions (Hokanson 1977; Colby *et al.* 1979; Ford *et al.* 1985) and perhaps also due to lower forage productivity.

The movement of young walleye after hatching is not well known (Priegel 1970). Raney and Luchner (1942) found young walleye were most abundant in shallow water a few inches to two feet in depth in early summer, often amongst weeds. Newly hatched walleye are typically found over gravel, sand, mud and clay substrates in shallow water usually less than two meters in depth (Dymond 1926; Eschmeyer 1950; Priegel 1970; Kristensen 1979; Goodyear *et al.* 1982). Kristensen (1979) and Summers (1978) found that the distribution of young walleye was positively correlated with shoreline vegetation dominated by paper birch (*Betula papyrifera*) and willows (*Salix* spp.). As young walleye mature they become pelagic, gradually moving to deeper water over the summer, occupying depths between 10-30 feet of water (Raney and Lachner 1942; Eschmeyer

1950; Scott and Crossman 1973; Ford *et al.* 1985). Male yellow walleye mature from 2-4 years of age, and females from 3-6 years of age (Wolfert 1969; Scott and Crossman 1973; Nelson and Paetz 1992). In Great Bear Lake walleye are slow growing and long living, and fish 16 years of age are not uncommon (McPhail and Lindsey 1970).

Both adult and juvenile walleye are photonegative and seek cover from the sun under banks, sunken trees, logs, boulder shoals, weed beds, as well as in deep water and turbid water (Eschmeyer 1950; Scott and Crossman 1973; Scherer 1976; Ryder 1977; Becker 1983). As a result, walleye undergo diel changes in activity, migrating into shallows at night to feed and retreating to deep water during the day (Eschmeyer 1950; Kelso 1976). Adults are usually found in moderately shallow water at depths between 5-10 m (Rawson 1951; Kelso 1976; Ford *et al.* 1985). Walleye of all ages seek deeper water in the summer, possibly to avoid warming lake temperatures or as a response to shifts in the distribution of prey such as cisco and whitefish (Rawson 1957; Scott and Crossman 1973; Colby *et al.* 1979; Bodaly 1980; Tripp *et al.* 1981; Ford *et al.* 1985). In Great Slave Lake walleye are most frequently caught in depths of less than five meters and none below ten meters (McPhail and Lindsey 1970). Adults are typically found over gravel, rubble and sand substrates (Hatfield *et al.* 1972; Becker 1983; Ford *et al.* 1985). Walleye are piscivorous and feed on many fish species including burbot, Arctic grayling, trout-perch, northern pike, longnose sucker, white sucker, yellow perch and freshwater drum as well as aquatic insects (Scott and Crossman 1973; Stein *et al.* 1973; Machniak and Bond 1979; Becker 1983).

Yellow perch (*Perca flavescens*)

The yellow perch reaches the northern portion of its distribution in the NT. It is present in the NT north to Great Slave Lake but not much further, and is absent from NU (McPhail and Lindsey 1970; Scott and Crossman 1973). Yellow perch prefer lakes, ponds, and sluggish streams and are rarely found in strong currents (Carl *et al.* 1967). Yellow perch are a primarily a lacustrine species but are known to exhibit adfluvial and riverine life history types (Scott and Crossman 1973; Goodyear *et al.* 1982; Becker 1983).

Spawning occurs from mid-April to August throughout its range (Scott and Crossman 1973; Goodyear *et al.* 1982; Becker 1983). Adults migrate into the shallows of lakes into areas of < 5 m of water to spawn, most often in < 2 m of water (Harrington 1947; Scott and Crossman 1973; Becker 1983; Krieger *et al.* 1983). Spawning usually takes place at night or early morning near vegetation, brush, fallen trees and rocks but may also occur over gravel and sand substrates (Scott and Crossman 1973; Goodyear *et al.* 1982; Liaw 1998). A semi-buoyant transparent string of gelatinous eggs are laid, which adhere to submerged vegetation or sometimes the bottom (McPhail and Lindsey 1970; Scott and Crossman 1973; Becker 1983). Under normal spring conditions eggs incubate for 8-10 days, however incubation may takes as long as 27 days depending on local water temperatures (McPhail and Lindsey 1970; Scott and Crossman 1973; Goodyear *et al.* 1982). Prolarvae hatch and remain near spawning grounds for 3-4 days, larvae then become pelagic (Goodyear *et al.* 1982; Becker 1983).

After 4-5 weeks young become benthic and are typically found in near shore shallow waters at depths of 0-5 m and rarely at depths greater than ten meters, often in association with submergent and emergent vegetation (Fish 1932; Scott and Crossman

1973; Lee *et al.* 1980; Cooper *et al.* 1981; Goodyear *et al.* 1982; Becker 1983; Krieger *et al.* 1983; Cucin and Faber 1985; Leslie and Moore 1985; Post and McQueen 1988; Liaw 1998). Cooper *et al.* (1981) note that shallow inshore areas serve as important nursery areas for this species. Young yellow perch are most often found over sandy, rocky and silt substrates, but may also occur over gravel and mud substrates in some areas (Goodyear *et al.* 1982; Krieger *et al.* 1983; Cucin and Faber 1985). Juvenile yellow perch are most frequently found in areas with sand, silt, gravel and mud substrates at depths between 0-5 m (Becker 1983; Krieger *et al.* 1983; Post and McQueen 1988). Sexual maturity is usually reached by males at three years and females at four years of age, with a maximum age of nine or ten years (Scott and Crossman 1973; Nelson and Paetz 1992).

Adults are typically a shallow water species and are most commonly located at depths between 1–10 m (Scott and Crossman 1973; Becker 1983; Danehy *et al.* 1991). They are frequently located over sand, gravel, cobble, rubble and mud substrates often in association with macrophytes (Kitchell *et al.* 1977; Becker 1983; Savitz *et al.* 1983; Danehy *et al.* 1991). Danehy *et al.* (1991) showed that improved growth in yellow perch was associated with structured habitat and that natural shoals may be important to local fish populations. Adults make seasonal migrations in the spring into shallow waters to spawn and move to deeper water in the summer in response to temperature and food (Scott and Crossman 1973). Yellow perch tend to be concentrated offshore during the winter (Scott and Crossman 1973; Tonn and Paszkowski 1987). During open water seasons fish tend to be concentrated inshore and close to the bottom (Tonn and Paszkowski 1987). Perch feed primarily on immature insects, crustaceans, snails, larger invertebrates and other fishes (Scott and Crossman 1973; Bond and Machniak 1979; Nelson and Paetz 1992; Carlander 1997).

Pikes (Esocidae)

Northern pike (*Esox lucius*)

The northern pike is distributed throughout the NT and NU, however has not been reported from the northern Keewatin and the Arctic islands (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973). In Canada the northern pike inhabits weedy areas of slow meandering rivers and weedy bays of lakes throughout its range (McPhail and Lindsey 1970; Scott and Crossman 1973; Becker 1983). The northern pike is known to exhibit lacustrine, adfluvial and riverine life history types (McPhail and Lindsey 1970; Cheney 1971; Stein *et al.* 1973; Bregazzi and Kennedy 1980; Holland and Huston 1984).

Northern pike begin to spawn after ice break-up in April and May (Fish 1932; Scott and Crossman 1973; Jessop and Lilley 1975). Northern populations spawn somewhat later, starting at the end of May through to June (Stein *et al.* 1973; Lawrence *et al.* 1977). Pike may spawn in both the shallows of lakes as well as in the backwaters of rivers (Diana *et al.* 1977; Bond and Machniak 1979; Holland and Huston 1984; Kozmin 1981). Spawning in lakes usually occurs in very shallow water < 1 m deep, in wind sheltered areas (Frost and Kipling 1967; McCarraher and Thomas 1972; Lawrence *et al.* 1977; Goodyear *et al.* 1982; Inskip 1982; Ford *et al.* 1985; Casselman and Lewis 1996; Craig 1996). Northern pike spawn in association with a variety of vegetation types, although short emergent vegetation such as grasses, sedges and bulrushes with fine leaves seem to make the best substrates for egg deposition (McCarraher and Thomas 1972; Mayhood *et al.* 1981; Becker 1983; Casselman and Lewsi 1996). Bottom substrate at spawning grounds consists primarily of soft fine substrates of silt and mud, although spawning may occur in areas gravel, rock, boulder and cobble substrates (Frost and Kipling 1967; Machniak 1975; Goodyear *et al.* 1982; Inskip 1982; Holland and Houston 1984; Casselman and Lewis 1996). Rawson (1932) noted that pike were found spawning around sedge hummocks in protected weedy areas, over very soft muskeg. Adhesive eggs are laid and adhere to the vegetation above the substrate (Frost and Kipling 1967; Scott and Crossman 1973; Becker 1983). Eggs incubate from 10-21 days depending on local water temperatures before hatching (Frost and Kipling 1967; Goodyear *et al.* 1982).

Young remain attached to the vegetation for 6-10 days before they become free swimming (Frost and Kipling 1967; Goodyear *et al.* 1982; Becker 1983; Ford *et al.* 1985), remaining in spawning areas for several weeks after hatching (Scott and Crossman 1973; Machniak 1975b; Inskip 1982; Holland and Houston 1984). Consequently, young pike are found in areas with abundant vegetation and soft bottom substrates (Goodyear *et al.* 1982). For the most part, young pike are found in areas < 1 m deep, but frequently move to deeper water in the summer (Frost and Kipling 1967; Goodyear *et al.* 1982). Young move out from wetlands as soon as they are large enough to swim effectively, often into deeper areas of spawning grounds (Morrow and Miller 1998). Juvenile pike frequent quiet bays and are found in association with submergent vegetation, which provides cover from predators as well as shelter for potential food resources (Bregazzi and Kennedy 1980; Inskip 1982; Ford *et al.* 1985). Age at maturity varies with latitude, and northern populations have been shown to reach sexual maturity at age 6 for females and age 5 for males (Scott and Crossman 1973).

Adult pike remain in areas < 5 m deep for most of the year, but move into deeper water to overwinter (Diana *et al.* 1977; Inskip 1982; Becker 1983; Chapman and Mackay 1984a; Cook and Bergersen 1988). Rawson (1951) reported that very few pike were taken in waters deeper than ten meters in Great Slave Lake. Adult pike are ambush predators and use cover such as logs, weeds and stumps to ambush prey (Inskip 1982). Adult northern pike are more common in areas of moderate vegetation density in open waters, rather than heavily vegetated areas which inhibit foraging (Inskip 1982; Ford *et al.* 1985; Vollestad 1986; Grimm and Backx 1990; Wright 1990; Randall *et al.* 1996). Adults are most often found over soft substrates, although they may be found in association with boulders, cobble and gravel in some areas (Hatfield *et al.* 1972; Diana *et al.* 1977; Chapman and Mackay 1984b; Ford *et al.* 1985; Casselman and Lewis 1996). Eklov (1997) notes that both juvenile and adult pike avoid areas with sandy substrates, although Becker (1983) notes the presence of pike in relation to sandbars in Wisconsin. Growth of pike is slower in northern populations, with fish typically living longer in northern areas than in southern areas (Scott and Crossman 1973; Stein *et al.* 1973).

Sculpins (Cottidae)

Deepwater sculpin (*Myoxocephalus thompsoni*)

The deepwater sculpin is found within Great Slave, La Matre, Keller, and Great Bear lakes in the NT (Scott and Crossman 1973; Parker 1988). An intermediate form, between *M. thompsoni* and *M. quadricornis*, has been identified from Lake Garrow, Little Cornwallis Island in NU (Dickman 1995). The deepwater sculpin inhabits deep-water lakes throughout its range, and is known to exhibit primarily a lacustrine life history type (Delisle and Van Vilet 1968; Scott and Crossman 1973; Mansfield *et al.* 1983; Parker 1988).

Relatively little is known of the spawning period and habitats of the deepwater sculpin (Scott and Crossman 1973; Parker 1988). Deepwater sculpin are believed to spawn from late fall through the winter (Black and Lankester 1981; Selgeby 1988), although some evidence suggests that year round spawning may occur (Scott and Crossman 1973; Mansfield *et al.* 1983). Spawning likely occurs at depths similar to those inhabited by adults in offshore areas, with eggs being deposited underneath objects on gravel or rock substrates (Goodyear *et al.* 1982; Mansfield *et al.* 1983; Geffen and Nash 1992). Unlike adults, which typically inhabit demersal habitats, young deepwater sculpin may be found at the surface or in midwater zones of lakes (Mansfield *et al.* 1983). From the examination of larval fish distributions, it is believed that larvae hatch in deepwater, move to the surface, and are transported to inshore areas during the spring (Mansfield *et al.* 1983; Geffen and Nash 1992). Larvae remain pelagic throughout the summer and at approximately 33 mm in length they transition to the bottom of lakes where they remain at depths > 50 m (Mansfield *et al.* 1983; Nash and Geffen 1991; Geffen and Nash 1992). Young deepwater sculpin may be found in association with rock and boulder substrates (Goodyear *et al.* 1982). Age at maturity is estimated at two years for males and three years for females, with mature fish reaching a maximum age of seven years (Black and Lankester 1981; Selgeby 1988).

Adult deepwater sculpin are demersal and are most abundant at depths greater than 70 m (Dryer 1966; Scott and Crossman 1973; Selgeby 1988; Geffen and Nash 1992). In Great Slave Lake specimens have been collected from depths of up to 115 m (Rawson 1951), and in Great Bear Lake at depths of over 220 m (Johnson 1975). Although no clear preference for substrate type has been identified for this species (Parker 1988), McPhail and Lindsey (1970) reported that deepwater sculpin were often captured in areas with mud bottoms. Deepwater sculpin consume a variety of prey items including amphipods, mysids, chironomids, as well as other benthic and planktonic invertebrates (McPhail and Lindsey 1970; Black and Lankester 1981; Wojcik *et al.* 1986; Selgeby 1988).

Slimy sculpin (*Cottus cognatus*)

The slimy sculpin occurs throughout the NT and NU, but is absent from the Arctic islands and the main stem of the Mackenzie River (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973). The slimy sculpin is typically found in rivers, streams, creeks and is less typical of lakes (Carl *et al.* 1967; McPhail and Lindsey 1970). The slimy sculpin is known to exhibit both lacustrine and riverine life history types (McPhail and Lindsey 1970; Scott and Crossman 1973; Craig and Wells 1976; Hughes and Penden

1984).

Spawning occurs in May, usually over sand, gravel and rock substrates in shallow waters of lakes (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Morrow 1980; Mohr 1984; Selgeby 1988). Males select nest sites on the under side of stones and logs in shallow water < 1.5 m deep (Scott and Crossman 1973; Morrow 1980; Goodyear *et al.* 1982; Mohr 1985; Mousseau and Collins 1987). Males court females into their nest site and once inside the female lays a clutch of adhesive eggs on the ceiling of the nest (Carl *et al.* 1967; Goodyear *et al.* 1982; Mousseau and Collins 1987). Several females may lay eggs in one nest and males guard the eggs until they hatch some four weeks later (Goodyear *et al.* 1982; Mousseau and Collins 1987). Young are commonly found over gravel and sand substrates, in shallow water 0.5-1.5 m deep (Mohr 1984). Young slimy sculpin gradually shift from shallow water habitat to deepwater habitat as they mature (Mohr 1985; Brandt 1986). Age at maturity varies, however most males and females reach maturity at age two, and almost certainly by age three (Mohr 1984; Selgeby 1988).

Adult slimy sculpin are found at depths from 0.5-210 m and frequent gravel and rocky substrates in lakes (Scott and Crossman 1973; McDonald *et al.* 1982; Mohr 1984; 1985; Selgeby 1988). McDonald and Hershey (1992) found that slimy sculpin inhabiting soft sediment substrates showed increased growth, indicating that these environments may be more productive. In small shallow lakes the distribution of slimy sculpin has been shown to change seasonally and diurnally with changes in water temperature and oxygen concentrations, with sculpins preferring to occupy the metalimnion (Mohr 1984; 1985). Within the NT, slimy sculpin were found in areas with current and wind action in waters < 10 m deep (McPhail and Lindsey 1970). Slimy sculpin consume a variety of prey items including aquatic insects, crustaceans, small fishes and aquatic vegetation (McPhail and Lindsey 1970; Mohr 1984; Brandt 1986).

Spoonhead sculpin (*Cottus ricei*)

The spoonhead sculpin in present throughout much of the Mackenzie River basin, the Thelon River system (Beverly and Dubawnt lakes) and the Keewatin District of the NT and NU (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973). The spoonhead sculpin occurs in shallows of large muddy rivers and may occur at considerable depths in large lakes (Carl *et al.* 1967; McPhail and Lindsey 1970). The spoonhead sculpin is known to exhibit a lacustrine life history type (Delisle and Van Vilet 1968) and although is known to occur in rivers, no information regarding a riverine life history type was found.

Relatively little is known of the biology of this species (Scott and Crossman 1973; Houston 1990). Spawning has been suggested to occur in the spring from early to mid-May (Carl *et al.* 1967; Selgeby 1988) as well as in the summer or fall (Delisle and Van Vilet 1968). Eggs are deposited under stones or logs, usually over rubble, boulder, gravel, sand or mud substrates at depths up to 270 feet (Goodyear *et al.* 1982). Eggs incubate for four weeks before hatching, and young-of-the-year may be found amongst rocks at depths between 40-67 feet, primarily in the hypolimnion (Goodyear *et al.* 1982). Adults may be found at a variety of depths ranging from 5-210 m, but generally are more abundant in water 50 to 90 m deep (Selgeby 1988). Dadswell (1972) reported that spoonhead sculpin were found at depths of 15-50 m in deep stratified lakes and were very abundant at depths of 5-10 m in turbid shallow lakes. Scott and Crossman (1973) suggested that depth preference of this species was intermediate between that of the deepwater sculpin (*Myoxocephalus quadricornis*) and the slimy sculpin (*Cottus sognatus*). Selgeby (1988) noted a maximum age of six years for spoonhead sculpin in Lake Superior.

Smelts (Osmeridae)

Pond smelt (*Hypomesus olidus*)

Within the NT the pond smelt occurs in the lower portions of the Mackenzie and Peel rivers, lakes of Tuktoyaktuk Peninsula, and is found as far south as Great Bear Lake (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; De Graaf 1986; Platts and Millard 1995). The pond smelt is not known to occur in NU (Scott and Crossman 1973; De Graaf 1986). Pond smelt are commonly found in lakes, rivers and streams (McPhail and Lindsey 1970; Scott and Crossman 1973; De Graaf 1986) and are known to exhibit both riverine and lacustrine life history types (Scott and Crossman 1973; De Graaf 1974; 1986; Katayama and Okata 1995).

Spawning occurs immediately after lakes become ice-free, in June and July in northern regions (De Graaf 1974). Pond smelt spawn in the littoral areas of lakes over organic debris in shallow water (McPhail and Lindsey 1970; Scott and Crossman 1973). Females lay adhesive eggs on the bottom, incubating for 14-28 days before hatching (De Graaf 1974; Gritsenko 1984). Young pond smelt occur most often over sandy bottoms, but may also occur in association with cobble/boulder substrates, organic detritus and macrophytes (De Graaf 1974). Pond smelt mature between the ages of three and five (De Graaf 1986). Adult pond smelt are pelagic (McPhail and Lindsey 1970) and may exhibit diurnal inshore-offshore movements (De Graff 1974). Evidence from De Graaf (1974) suggests that small tundra lakes and ponds may be important habitat for this species. Pond smelt are known to consume benthos, adult insects, rotifers, chironomids, copepods and cladocerans (Stein *et al.* 1973; De Graaf 1974; Gritsenko 1984). Very little is known of the biology and life history requirements of pond smelt, and further studies should be performed.

Rainbow smelt (*Osmerus mordax*)

The rainbow smelt is found in the northwest portion of the NT in the Mackenzie River Delta, ranging to the confluence of the Arctic Red River (Wynne-Edwards 1952; Scott and Crossman 1973). Rainbow smelt may be found in lakes, streams, rivers and inshore coastal waters (Lee *et al.* 1980; Scott and Crossman 1973; Scott and Scott 1988). The rainbow smelt exhibits anadromous as well as freshwater resident lacustrine and adfluvial life history types (Scott and Crosmman 1973; Bruce 1975; Buckley 1989; Scott and Scott 1988).

<u>Anadromous</u>

Anadromous rainbow smelt are found in coastal waters from Alaska to the Mackenzie River Delta, as well as in Atlantic Canada (Scott and Crossman 1973; Scott and Scott 1988). Anadromous rainbow smelt typically spawn in the lower reaches of streams and rivers above the head of the tide, from April to May in southern populations (McKenzie 1964; Scott and Crossman 1964; Morrow 1980; Scott and Scott 1988; Buckley 1989). Smelt may also spawn offshore on gravel shoals, if exceedingly stormy weather prevails during the spawning run (Rupp 1965; Scott and Crossman 1973; Morrow 1980). Spawning in rivers and streams usually occurs at night, at depths of 0.1-1.3 m over sand, gravel and rock substrates, sometimes in association with vegetation (McKenzie 1964; Murawski *et al.* 1980; Scott and Scott 1988). Eggs are released and settle to the bottom, attaching to the substrate via a short stalk formed from the outer coat of the egg (McKenzie 1964; Rupp 1965; Scott and Crossman 1973). Incubation varies from 11 to 29 days, depending on local water temperatures (McKenzie 1964). Upon hatching larvae drift down stream into estuaries (McKenzie 1964; Scott and Crossman 1973; Morrow 1980; Scott and Scott 1988). During the day larvae may be found 1-1.5 m off the bottom in water 11-12 m deep, along gravel and sand beaches, at times in association with eelgrass beds (McKenzie 1964; Scott and Crossman 1973; Buckley 1989).

Adult smelt may remain in estuaries during the summer, occupying shallow water areas < 6 m in depth (Buckley 1989). Adult and juvenile smelt may migrate out into coastal waters, always within two kilometers of the coast, but return in the fall and winter to estuaries to avoid cold marine waters (McKenzie 1964; Scott and Scott 1964; Haldorson and Craig 1984; Scott and Scott 1988; Buckley 1989). Atlantic populations reach maturity at 2-3 years of age, whereas, Pacific-Arctic populations mature much later at 6-7 years of age (Bruce 1975; Haldorson and Craig 1984; Scott and Scott 1988). Pacific-Arctic populations also exhibit greater longevity as well as lower growth and mortality rates than Atlantic populations (Haldorson and Craig 1984).

<u>Freshwater resident</u>

Freshwater resident rainbow smelt have not been reported in the NT, but exist in other parts of Canada mostly in Atlantic coastal regions (Scott and Crossman 1973; Scott and Scott 1988; Buckley 1989). Lacustrine populations may spawn in both offshore and inshore areas of lakes as well as rivers if they are available (Rupp 1965; Scott and Crossman 1973; Bruce 1975; Lee *et al.* 1980; Morrow 1980; Nelbring 1989.) Eggs are broadcast over a wide variety of substrates including boulder, rubble, cobble, gravel, sand, mud, silt and clay in 0.1-5 m of water (Rupp 1965; Ivanova and Polovka 1972; Scott and Crossman 1973; Bruce 1975; Lee *et al.* 1980; Morrow 1980; Goodyear *et al.* 1982). Goodyear *et al.* (1982) note that spawning may take place in wave swept areas of lakes in association with beaches, shoals, ledges, bars and stream mouths. Conversely, Ivanova and Polokova (1972) note that spawning usually takes place in protected areas with little wind or wave action. Eggs become adhesive shortly after they are released, attaching to the bottom (Scott and Crossman 1973). Eggs incubate for 2-4 weeks and usually hatch from mid-May to July (Goodyear *et al.* 1982).

Larvae show a diel migration pattern from shallow water (2-4 m) during the day, to deeper water at night (> 15 m), concentrating 2-3 m above the bottom (Emery 1973; Evans and Loftus 1987). Young rainbow smelt may be found in inshore areas shortly after hatching along gravel and sand beaches (Scott and Crossman 1973; Goodyear *et al.* 1982; Dunstall 1984). Juveniles are most often found in mid-water depths, whereas adults are most commonly found closer to the bottom at depths > 10 m during the day (Emery 1973; Argyle 1982; Evans and Loftus 1987). Adult rainbow smelt are most often found in deep benthic areas, although they may make diel movements from the bottom to surface waters at night in association with the thermocline (Argyle 1982; Heist and Swenson 1983; Sandlund *et al.* 1985; Burczynski *et al.* 1987; Evans and Loftus 1987). Juvenile and adult fish are rarely caught concurrently in mid-water, and this spatial separation is believed to help minimize intraspecific interactions and competition between various life history stages (Dryer 1966; Argyle 1982; Evans and Loftus 1987). Smelt feed on a variety of food items including small crustaceans, amphipods, ostracods, aquatic insect larvae and variety of fish species (Scott and Crossman 1973; Evans and Loftus 1987).

Sticklebacks (Gasterosteidae)

Brook stickleback (*Culaea inconstans*)

Within the NT the brook stickleback is found from the Hay River region of Great Slave Lake down the Mackenzie River to the Arctic Red River, however it is not known to occur in NU (Falk 1972; Scott and Crossman 1973; Lee *et al.* 1980; Wooton 1984). The brook stickleback inhabits a wide variety of environments and may be found in heavily weeded areas of spring fed brooks, boggy lakes, beaver ponds and trout streams (McPhail and Lindsey 1970; Wootton 1976; Lee *et al.* 1980; Nelson and Paetz 1992). The brook stickleback is known to exhibit both lacustrine and riverine life history types (McPhail and Lindsey 1970; Foster 1971; MacLean and Gee 1971; Scott and Crossman 1973; Wootton 1976; Lee *et al.* 1980).

The brook stickleback spawns from late April to early July depending on local water temperatures (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1976). Males move into shallow water areas before females, establishing a territory and building a nest (Scott and Crossman 1973; Wootton 1976). Nests are usually built in shallow water < 40 cm deep, typically close to the bottom and infrequently on the bottom itself (Wootton 1976; Goodyear *et al.* 1982). Nests are predominately constructed directly on reeds or grass, mostly from vegetation, sticks, and debris using a filamentous thread secreted from the kidneys of the males (Scott and Crossman 1973; Wootton 1976). Females are courted into the nest in which they lay a clutch of eggs, the then female leaves the nest and the male enters and fertilize the eggs (Reisman and Code 1967; Wooton 1976). The female is subsequently chased off, although other females may be allowed to lay eggs in the nest, the male remains to guard the nest (Wooton 1976). When food is abundant females may spawn every three days (Moodie 1986). Eggs incubate for 7-10 days before hatching depending on water temperature (McKenzie 1974; Wootton 1976). During the incubation period males may build a second nest and transfer eggs to the new nest site (McKenzie 1974). Once the eggs hatch the male guards the young, bringing them back to the nest as they leave until he can no longer keep them from swimming away (Reisman and Code 1967; Scott and Crossman 1973; Wootton 1976).

Young brook stickleback are found in association with vegetation in shallow water habitats (Goodyear *et al.* 1982). Brook stickleback grow rapidly and attain sexual maturity in one year (Scott and Crossman 1973; Becker 1983). Adults make seasonal migrations from shallow-water in the spring to deepwater in which they overwinter (Wootton 1976). Although it is typically considered a shallow-water species, brook stickleback have been found at depths > 50 m (Scott and Crossman 1973). As with all other life history stages adult brook stickleback are commonly found in association with vegetation (Winn 1960; Reisman and Code 1967; McPhail and Lindsey 1970; Wootton 1976; Nelson and Paetz 1992). Brook stickleback often make use of cover and have been observed burrowing into silty substrates in streams and hiding amongst rocks, dead leaves and vegetative detritus (Reisman and Code 1967; Degraeve 1970). Brook stickleback are mainly carnivorous and prey upon aquatic insect larvae, crustaceans, eggs and larvae of other fish, snails, oligochetes and algae (Scott and Crossman 1973; Wootton 1976; Lee *et al.* 1980).

Ninespine stickleback (*Pungitius pungitius*)

The ninespine stickleback is distributed throughout the NT and NU, and is found from the Mackenzie Delta throughout the Mackenzie River system; most rivers and lakes of north-central Canada; and in portions of the Arctic Archipelago (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The ninespine stickleback is known to inhabit shallow bays of lakes, slow streams and tundra ponds (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The ninespine stickleback is known to exhibit lacustrine, riverine and andromous life history types (McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1976; Lawrence *et al.* 1984).

Spawning occurs in the spring and summer in relatively shallow water, from May to late July (McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1976). Although spawning has been observed at depths up to 40 m in some areas (Griswold and Smith 1972; Goodyear *et al.* 1982). Males typically build their nests amongst weeds in densely vegetated areas, usually 10-15 cm off the bottom or occasionally in contact with the bottom (Scott and Crossman 1964; 1973; McPhail and Lindsey 1970; Wootton 1976; Morrow 1980; Scott and Scott 1988). Nests are constructed from aquatic vegetation and debris bound together by a threadlike kidney secretion (McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1976; Morrow 1980). Males may also nest in burrows constructed in muddy organic bottoms (Griswold and Smith 1972) or under and between rocks along wave swept lake shores (Mckenzie and Keenleyside 1970). Females are enticed into the nest, depositing 20-30 eggs, the male then enters the nest and fertilizes the eggs, and chases the female away (Scott and Crossman 1973). Eggs incubate for 4-7 days before hatching, upon which time the young are moved into a nursery area, which the male constructs from nest building material just above the nest (McPhail and Lindsey 1970; Wootton 1976; Morrow 1980).

Young remain in the nursery until they become free swimming at which time they disperse into shallow water areas amongst vegetation, moving to deepwater areas in the fall to overwinter (McPhail and Lindsey 1970; Morrow 1980; Goodyear *et al.* 1982; Becker 1983). Most ninespine sticklebacks mature in their first year, and have a life expectancy of about three and a half years (Scott and Crossman 1973; Wootton 1976). Although adult sticklebacks are found in association with dense vegetation and are tolerant of low oxygen tensions, they may also frequent open water areas over sand and gravel beaches with sparse vegetation (Nelson 1968b; McPhail and Lindsey 1970; Lewis *et al.* 1972; Scott and Crossman 1973). Although the ninespine stickleback frequents shallow water areas, adults have been taken at depths > 70 m in Lake Superior (Scott and Crossman 1973). Ninespine stickleback feed primarily on aquatic insects, chironomid larvae, small crustaceans, mollusks, cladocerans and other zooplankton (McPhail and Lindsey 1970; Scott and Crossman 1973; Cameron *et al.* 1973).

Threespine stickleback (*Gasterosteus aculeatus*)

The threespine stickleback is absent from the NT, but may be found in the western Hudson Bay region of NU north to the Maguse River, as well as on Devon and Baffin islands (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Morrow 1980). The threespine stickleback inhabits both freshwater and saltwater habitats in lakes, ponds, lowland streams and sheltered coastal bays (McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1984). The threespine stickleback is known to exhibit lacustrine, riverine and anadromous life history types (Scott and Crossman 1973; Wootton 1984; Nelson and Paetz 1992). Elsewhere isolated lacustrine populations of threespine stickleback are known to exhibit more than one distinct morphological type within a single lake (Larson 1976; Wootton 1984; Mori 1990; Cresko and Baker 1996).

<u>Anadromous</u>

Anadromous populations of threespine stickleback may spawn in brackish water or freshwater (Coad and Power 1973; Morrow 1980; Wootton 1984). Anadromous populations migrate into freshwater in late spring (June) and spawn shortly after (McPhail and Lindsey 1970). Similar to freshwater resident populations, anadromous populations build nests, defend territories and exhibit analogous courtship behaviours (Black and Wootton 1970; Morrow 1980). Spawning in marine habitats may take place in sheltered areas such as tidal pools (Black and Wootton 1970; Coad and Power 1973). Anadromous stickleback may spawn in a variety of habitats including rock crevices, clumps of algae, vertical rock surfaces and eel grass beds as well as in exposed areas over silt and sand substrates (Black and Wootton 1970; McPhail and Lindsey 1970; Morrow 1980). Young hatch in streams and estuaries and move into salt water, staying close to shore in shallow water in association with floating seaweed and debris (Morrow 1980; Scott and Scott 1988). Both young and adults migrate in the fall into coastal waters to overwinter, with most individuals remaining close to shore, although some individuals may move considerable distances offshore (Morrow 1980; Wootton 1984). Very little is known of the anadromous life history of the threespine stickleback in the north, thus further studies should be conducted.

<u>Freshwater resident</u>

Resident freshwater populations of threespine stickleback spawn in the spring or summer, from May to July (McPhail and Lindsey 1970; Coad and Power 1973; Scott and Crossman 1973; Pepper 1976; Wotton 1976). Although freshwater resident populations of threespine sticklebacks frequently spawn in association with vegetation (Black and Wootton 1970; McPhail and Lindsey 1970; Coad and Power 1973; Scott and Crossman 1973; Larson 1976; Morrow 1980) they may also spawn in open water habitats (Fish 1932; Black and Wootton 1970; Lewis *et al.* 1972; Griswold and Smith 1972; Larson

1976; Wootton 1976; 1984). Nests are constructed of algae, small twigs and debris from aquatic plants usually over mud and sand substrates or on the flat surface of rocks (Fish 1932; Black and Wootton 1970; McPhail and Lindsey 1970; Griswold and Smith 1972; Goodyear *et al.* 1982; Scott and Scott 1988). Males usually avoid nesting in water < 20 cm deep (Lewis *et al.* 1972; Kynard 1978) and may nest at depths of up to 40 m (Griswold and Smith 1972). Males entice females into the nest site with a series of courtship behaviours, females move into the nest deposit their eggs and leave; the male enters the nest and fertilizes the eggs, and then chases the female away (McPhail and Lindsey 1970; Scott and Crossman 1973; Morrow 1980). Males guard and fan the nest (McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1976; Scott and Scott 1988) while the eggs incubate from 4-27 days (McPhail and Lindsey 1970; Goodyear *et al.* 1982). Upon hatching young emerge from the nest, the male retrieves young returning them to the nest as they escape, until the young become free swimming and disperse (McPhail and Lindsey 1970; Wootton 1976; Scott and Scott 1988).

Young remain in shallow water areas in association with vegetation and migrate into deeper water in the fall (Goodyear *et al.* 1982). Both juveniles and adults move to deepwater areas to overwinter (Wootton 1976; Morrow 1980; Scott and Scott 1988). Outside the breeding season, sticklebacks are found in schools (Wootton 1976) in shallow littoral regions of lakes, in association with submerged vegetation (McPhail and Lindsey 1970; Kerfoot 1975; Lee *et al.* 1980) or over rocky substrates (Pepper 1976; Sandlund *et al.* 1992b; Scott and Crossman 1964). Sticklebacks occur at depths from < 1 m to 20 m in lakes (Campbell and Knoechel 1990; Sandlund *et al.* 1992b) and may occur in both pelagic and littoral regions of lakes (Lewis 1972; Kerfoot 1975; Wootton 1976; Jakobsen 1988; Sandlund *et al.* 1992b). Adults live from two and a half to three and a half years, and sexual maturity is usually reached during the first year (Scott and Crossman 1973). Threespine stickleback feed on a variety of zooplankton species as well as benthic microorganisms (Wootton 1976; Ryan 1984; Campbell and Knoechel 1988; Larson and McIntire 1993).

Suckers (Catostomidae)

Longnose sucker (*Catostomus catostomus*)

The longnose sucker is common throughout the NT and NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). Longnose suckers occur in freshwater lakes, rivers and streams throughout their geographic range (McPhail and Lindsey 1970; Scott and Crossman 1973). The longnose sucker is known to exhibit lacustrine, adfluvial and riverine life history types (Harris 1962; Geen *et al.* 1966; Walton 1980; Edwards 1983; Stein *et al.* 1983).

Longnose suckers spawn in the spring shortly after melting of ice cover on lakes, from April to June (Rawson and Elsey 1950; Harris 1962; McPhail and Lindsey 1970; Stein *et al.* 1973; Jesop and Lilley 1975; Dion *et al.* 1994). Longnose suckers spawn primarily in rivers but may spawn in the shallows of lakes (Brown and Graham 1954; Harris 1962; Geen *et al.* 1966; Galloway and Kevern 1976; Morrow 1980; Walton 1980). In lakes spawning usually takes place at depths of 15-30 cm, along rocky wave-swept shorelines, over gravel and sand substrates (Geen *et al.* 1966; Scott and Crossman 1973;

Walton 1980; Goodyear *et al.* 1982). Eggs are adhesive and are broadcast over gravel and sand substrates, incubating from 11-15 days before hatching (Geen *et al.* 1966; McPhail and Lindsey 1970; Scott and Crossman 1973; Goodyear *et al.* 1982). Young remain in gravel for 1-2 weeks before emerging (Geen *et al.* 1966; McPhail and Lindsey 1970; Scott and Crossman 1973; Becker 1983). Young frequent shallow areas of lakes often in association with vegetation and sandy substrates (Brown and Graham 1953; Goodyear *et al.* 1982; Edwards 1983). Correspondingly, juveniles have also been shown to inhabit shallow weedy areas (Edwards 1983). Carl *et al.* (1967) reported that males first spawn at about five years, and females at six or seven years of age, while Harris (1962) notes that spawning longnose suckers in Great Slave Lake were between nine and 15 years of age.

The longnose sucker usually inhabits deeper water than that of the white sucker (Carl *et al.* 1967) and may occur at considerable depths (183 m) (Scott and Crossman 1973; Lee *et al.* 1980). Harris (1962) reported catching suckers at depths from 1-24 m in Great Slave Lake, although they are considered uncommon below 17 m within the lake (McPhail and Lindsey 1970). Longnose sucker in a Maine reservoir showed an attraction to submerged pulpwood logs, which may provide cover as well as habitat for aquatic invertebrates upon which sucker feed (Moring *et al.* 1986). Longnose sucker grow considerably larger and live much longer in Great Slave Lake than in southern water bodies (Brown and Graham 1954; Harris 1962; Scott and Crossman 1973). Keleher (1961) reported that the North American record longnose sucker was taken from Great Slave Lake at a fork length of 642 mm, a weight of 3.3 kg and was 19 years old. Longnose sucker from Great Slave Lake feed mostly on amphipods, chironomids, midge larvae, caddis fly larvae and sphaeriid clams (Rawson 1951; Scott and Crossman 1973; Becker 1983).

White sucker (*Catostomus commersoni*)

The white sucker is common throughout most of the Mackenzie River system north to the Arctic Circle, and south to Great Slave Lake, but has been reported absent from Great Bear Lake (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The white sucker is found within treeline from Hudson Bay to Great Slave Lake, occupying the southwestern portions of NU (Scott and Crossman 1973). White sucker occur in freshwater lakes, rivers and streams throughout their geographic range, primarily in warm shallow environments (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973). The white sucker is known to exhibit lacustrine, adfluvial and riverine life history types (Geen *et al.* 1966; Scott and Crossman 1973; Walton 1980; Tripp *et al.* 1981; Corbett and Powles 1983).

White suckers may spawn in both rivers and lakes, in outlets or along lake shores, however there seems to be a preference for inlet streams (Carl *et al.* 1967; Nelson 1968a; McPhail and Lindsey 1970; Curry and Spacie 1984; Corbett and Powles 1986). White suckers spawn in the spring shortly after melting of ice cover on lakes, from May to June (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Jessop and Lilley 1975; Dion *et al.* 1994). Eggs are adhesive and are broadcast over gravel, incubating from 5-15 days before hatching (Geen *et al.* 1966; Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Goodyear *et al.* 1982; Becker 1983).

Young remain in gravel for 1-2 weeks before emerging (Geen *et al.* 1966; McPhail and Lindsey 1970; Scott and Crossman 1973; Corbett and Powles 1983). Young are found in shallow protected waters along lake shores, over rock and sand substrates often in association with vegetation (Goodyear *et al.* 1982; Corbett and Powles 1983). Later in the summer, young move offshore to deeper water, possibly to avoid high inshore water temperatures (Corbett and Powles 1983). Sexual maturity is reached from 5-7 years (Carl *et al.* 1967). Adult white suckers usually inhabit shallower waters than the longnose sucker (Carl *et al.* 1967) at depths of 7-13 m (Galloway and Kevern 1976). White sucker in a Maine reservoir, showed an attraction to submerged pulpwood logs, which may provide cover as well as habitat for aquatic invertebrates upon which sucker feed (Moring *et al.* 1986). Adult white sucker feed mostly on insects, chironomids, crustaceans and mollusks (Galloway and Kevern 1976; Becker 1983).

Trouts (Salmonidae)

Arctic char (*Salvelinus alpinus*)

Arctic char occur in coastal regions of NT and NU as well as on many of the islands of the Arctic Archipelago as far north as northern Ellesmere Island (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). Arctic char may be found in rivers, lakes, estuaries and marine environments throughout their life cycle (Sprules 1952; McPhail and Lindsey 1970; Scott and Crossman 1973; Johnson 1989). Arctic char are known to exhibit both anadromous and freshwater resident lacustrine life history types (Scott and Crossman 1973; Lee *et al.* 1980; Johnson 1980; 1989).

<u>Anadromous</u>

Anadromous Arctic char begin migrating upstream from July to September (Sprules 1952; McPhail and Lindsey 1970) and likely spend some time in brackish water estuaries before entering freshwater rivers and streams (Sprules 1952). Throughout their geographic range anadromous Arctic char are known to spawn in rivers and lakes (Balon 1980; Dempson and Green 1985; Cunjak *et al.* 1986), however northern populations seem to spawn exclusively in lakes which provide sufficient water depth, preventing ice from freezing to the bottom in winter. Lake spawning has been reported to occur in autumn from September through October (Sprules 1952; Johnson 1980; 1989). Spawning takes place primarily over cobble and gravel substrates (Sprules 1952; McPhail and Lindsey 1970; Scott and Crossman 1973; Moore 1975; Johnson 1980; Gyselman 1984; Scott and Scott 1988). Spawning usually takes place in water 0.5-1.5 m deep (Dempson and Green 1985) but may occur in slightly deeper water from 2-6 m deep (Gyselman 1984; Nordeng and Skurdal 1985; Johnson 1989). Like most other salmonids females construct a redd in which eggs are deposited and later covered with gravel (Scott and Crossman 1973; Johnson 1989; Communications Directorate 1991a). Post-spawning fish remain in lakes to overwinter and migrate downstream the following spring to the sea to feed (Johnson 1989).

Eggs hatch in the spring from late March to April, and remain in the gravel for several weeks before emerging sometime around ice breakup (Sprules 1952; Scott and Crossman 1973; Johnson 1980; Scott and Scott 1988; Johnson 1989). Young Arctic char, unlike coregonines, do not make a downstream migration and likely remain on the spawning grounds, moving to the lacustrine littoral zone later in the summer (Johnson 1980). Within the littoral zone young-of-the-year may be found amongst rocks (McPhail and Lindsey 1970). Juvenile char may be found in creek and lacustrine habitats and move to deeper lacustrine areas in the fall to overwinter (Johnson 1980). Arctic char remain in freshwater systems usually for 4-5 years, but may leave as early as two years or as late as nine years to make their first migration to sea (McPhail and Lindsey 1970; Johnson 1980; Johnson 1989; Stewart *et al.* 1993). First-time migrants migrate to the sea some time in early July after the adults (Johnson 1980). Juveniles are believed to remain in estuarine environments for 27-44 days before migrating back upstream to overwinter in lakes shortly after adults (Johnson 1980). Juveniles become sexually mature at about 12-13 years of age (Grainger 1953; Johnson 1989).

Adults do not spawn every year; spawning occurs on an intermittent basis every 2-5 years, with three likely being the average (Johnson 1980; 1989). Anadromous Arctic char have much higher salinity tolerance than most anadromous coregonids and enter wholly marine environments during their life cycle (Sprules 1952; Gyselman 1984). Anadromous adult char overwinter in lakes and migrate downstream in the spring during ice break-up (Scott and Crossman 1973; Morrow 1980; Communication Directorate 1991a). Adult char that spawned the previous year migrate downstream to estuarine and marine environments and make a return migration in August to overwinter in lakes (Grainger 1953; Scott and Crossman 1973; Moore 1975; Johnson 1980; 1989). However, migrating char do not always return to the same river and may immigrate to other river systems (Johnson 1980; Gyselman 1984; Dempson and Kristofferson 1987). During annual migrations to the sea, adult char may remain in warmer brackish waters of arctic estuaries for a significant portion of the summer, before migrating out to sea (Anras *et al.* 1999a). Sea-run char feed on several marine fish species during summer migrations including capelin, sand lance, Arctic cod and young Greenland cod (Sprules 1952; Grainger 1953; Johnson 1989).

<u>Freshwater resident</u>

Lacustrine populations spawn in the autumn from September to October (Hunter 1970; Scott and Crossman 1973; MacCallum and Regier 1984) at approximately the same time as anadromous char (Gyselman 1984). Spawning takes place primarily over gravel and cobble substrates at depths ranging from 2-10 m (Sprules 1952; McPhail and Lindsey 1970; Lawrence and Davies 1978; Morrow 1980; Jonsson and Hindar 1982; Gyselman 1984; Nordeng and Skurdal 1985; Rubin 1987; Sandlund *et al.* 1987; Communications Directorate 1991a; Rubin and Buttiker 1992). Arctic char have also been reported to spawn in shallow water (0.5–2 m) over silt, mud and clay substrates at times in association with vegetation (Hunter 1970; Lawrence and Davies 1978; Jonsson and Hindar 1982; Gyselman 1984; Nordeng and Skurdal 1985; Johnson 1989; Sigurjónsdóttir and Gunnarsson 1989; Skulason *et al.* 1989; Sandlund *et al.* 1992a). Similar to anadromous fish, freshwater residents construct a redd in loose gravel where they deposit their eggs (Scott and Crossman 1973; Communications Directorate 1991a). As with other northern anadromous populations spawning occurs every 2-3 years (Scott and Crossman 1973; MacCallum and Regier 1984). Eggs incubate over the winter and hatch from

March to April, but may not emerge from the gravel until mid-July (Scott and Crossman 1973; Johnson 1989).

Young char are most often found in nearshore shallow water areas (Johnson 1976; Sparholt 1985; Riget *et al.* 1986; Sandlund 1992a and b; Johnson 1989), but are also known to occur in pelagic habitats (Sandlund *et al.* 1988). Young char often use cobble, rubble and boulder substrates as cover (Lawrence and Davies 1978; L'Abee-Lund *et al.* 1992), likely to avoid predation by larger fish. Juveniles are most often found in deeper benthic habitats of lakes at depths > 5 m, avoiding littoral and shallow benthic habitats which are often occupied by large conspecifics and potential predators (Johnson 1980; Sandlund *et al.* 1987; Hegge *et al.* 1989; Klemetsen *et al.* 1989; Bjoru and Sandlund 1995; Naesje 1995). Similar to young-of-the-year, juveniles make use of cover amongst boulder, rubble and cobble substrates as well as in vegetation (Sandlund *et al.* 1987; L'Abee-Lund *et al.* 1993; Halvorsen *et al.* 1997). As juveniles mature they shift from benthic to pelagic habitats (Jonhson 1980; Sandlund *et al.* 1987; L'Abee-Lund *et al.* 1993; Bjoru and Sandlund 1995; Naesje 1995). Landlocked populations are reported to mature from two to nine years of age in the Canadian Arctic (Sprules 1952; MacCallum and Regier 1984).

Adult Arctic char usually occupy the pelagic zone of lakes during the summer feeding on zooplankton, and make seasonal shifts to benthic/littoral areas in the fall when food is less abundant (Hindar and Jonsson 1982; Riget *et al.* 1986; Hegge *et al.* 1989; L'Abee-Lund *et al.* 1992, 1993; Bjoru and Sandlund 1995; Jamet 1995; Naesje 1995; O'Connell and Dempson 1996). Within lakes Arctic char may be found at a variety of depths, but are most common in < 5 m of water (Hindar and Jonsson 1982; Sandlund *et al.* 1987; Sandlund *et al.* 1992a and b; Jamet 1995; Naesje 1995; O'Connell and Dempson 1996; Hesthagen *et al.* 1997) over boulder, rubble and cobble substrates (Sandlund *et al.* 1988; Sandlund *et al.* 1992a and b; O'Connell and Dempson 1996). Freshwater resident Arctic char grow much slower than anadromous forms (McPhail and Lindsey 1970) likely as a result of the limited productivity of arctic lakes. Freshwater char feed on a wide variety of organisms including algae, insects, fish and plankton (Hunter 1970; McPhail and Lindsey 1970).

<u>Dwarf freshwater resident</u>

The coexistence both normal and dwarf forms of Arctic char in the same lake has been well documented (Klemetsen and Grotnes 1975; 1980; Hindar and Johnson 1982; Jonson and Hindar 1982; Sparholt 1985; Parker and Johnson 1991; Reist *et al.* 1995). Adult dwarf char generally inhabit shallow littoral habitats 0-5 m in depth, moving to the pelagic zone during late summer and fall (Klemetsen and Grotnes 1980; Hindar and Jonsson 1982; Sparholt 1985; Klemetsen *et al.* 1989a; Bjoru and Sandlund 1995). In contrast, normal Arctic char occupy shallower littoral and benthic habitats, as well as pelagic areas, similar to those inhabited by single-form freshwater resident populations (Hindar and Johnson 1982; Sparholt 1985; Parker and Johnson 1991). Differences in spawning is also known to occur between forms. Dwarf char spawn at greater depths (30 m) than normal char and in European lakes are believed to spawn in February, several months after the normal form (Klemetsen and Grotnes 1980; Johnson and Hindar 1982; Klemetsen *et al.* 1997). In addition to differences in habitat requirements, dwarf char appear to mature much earlier (4-9 years) than resident normal char (13-15) (Parker and Johnson 1991).

Multiple freshwater resident morphs

It is of interest to note that in other areas sympatric populations of three and four freshwater resident morphs of Arctic char are known to occur in the same lake. Populations containing three freshwater morphs have been described by Hindar and Johnson (1982), Hammar (1984), Riget *et al.* (1986) and Savvaitova (1991). Sandlund *et al.* (1987, 1992a) have described the occurrence of four sympatric landlocked Arctic char morphs occurring in Iceland. Although only populations containing two freshwater morphs have been described so far in Canada, future research in the north may reveal the existence of multiple resident morphs in northern waters.

Arctic cisco (*Coregonus autumnalis*)

The Arctic cisco is present in coastal regions of the NT and NU, throughout the Mackenzie River and may be found as far south as the Liard River in B.C. (Scott and Crossman 1973; McLeod and O'Neil 1983). Arctic cisco are common in coastal areas and have been reported from Cape Bathurst, Bathurst Inlet, Cambridge Bay on Victoria Island and in the Mackenzie Delta (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The Arctic cisco inhabits the lower reaches of large muddy rivers, streams, coastal beaches, lagoons and brackish water areas (McPhail and Lindsey 1970; Scott and Crossman 1973; Craig and Mann 1974). Arctic cisco apparently only exhibit a wide-ranging anadromous life history type, although anecdotal evidence suggests that non-anadromous populations may exist in the NT (McPhail and Lindsey 1970; Scott and Crossman 1973; Craig and Mann 1974; Reist and Bond 1988; Dillinger *et al.* 1992).

Anadromous

Arctic cisco begin spawning migrations in late summer and early autumn, from July to mid-September in the Mackenzie River system (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Stein *et al.* 1973; Percy 1975; Dillinger *et al.* 1992), although they may enter the Mackenzie River as early as May (Stein *et al.* 1973). Actual spawning occurs between late September and early October (Percy 1975). Within the NT, Arctic cisco ascend the Mackenzie, Arctic Red, Peel, Great Bear and Liard rivers to spawn (Wynne-Edwards 1952; Craig and Mann 1974; McCart 1982; Dillinger *et al.* 1992). Although Arctic cisco are known only to exhibit an anadromous life history type, it is believed that populations of Arctic cisco in the Liard River may show a mixed life history with a portion of the populations being non-anadromous (Dillinger *et al.* 1992). Spawning is believed to take place over gravel in fast water in areas of low turbidity (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973; Dillinger *et al.* 1992). After spawning Arctic cisco migrate downstream to overwinter in the Mackenzie Delta and nearshore areas (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973; Stein *et al.* 1973; Dillinger 1992). Arctic cisco are believed to be at least alternate-year spawners (Scott and Crossman 1973; Percy 1975; Strange 1985; Reist and Bond 1988).

Eggs hatch in the spring and young are swept downstream into estuaries and nearshore areas (Scott and Crossman 1973; Reist and Bond 1988; Fechhelm and Griffiths 1990). Arctic cisco make extensive migrations from the Mackenzie River Delta west to the Colville River delta, Alaska and east along the Tuktoyaktuk Peninsula perhaps to the Anderson River. They may remain in these areas for several years, overwintering in the Colville River delta and foraging along the Beaufort Sea coast in the summer (Craig 1984; Reist and Bond 1988). The recruitment of young Arctic cisco from the Mackenzie River into the central Alaskan Beaufort Sea is believed to be highly affected by wind driven currents (Fechhelm and Fissel 1988; Fechhelm and Griffiths 1990). Juvenile Arctic cisco are tolerant of high salinities and forage in coastal waters of the Beaufort Sea in the spring and summer; returning to overwintering sites in the Colville and Mackenzie river deltas, Tuytoyaktuk Harbour, and bays and lagoons of Richards Island (Percy 1975; Bond 1982; Reist and Bond 1988; Jarvela and Thorsteinson 1999). Unlike lake and broad whitefish, Arctic cisco do not use lakes as feeding and overwintering grounds (Strange 1985) and it appears that juvenile and mature non-spawners do not migrate upstream (Craig and Mann 1974). First spawning for most coregonids in the Mackenzie River does not occur before age 6-8 (Reist and Bond 1988) and Arctic cisco have been reported to mature between 7-8 years of age (Stein *et al.* 1973; Percy 1975). Arctic cisco prey mostly on crustaceans, amphipods, copepods and mysids (Craig and Mann 1974; Strange 1985; Bond and Erikson 1993).

Arctic grayling (*Thymallus arcticus*)

The Arctic grayling is found throughout most of the NT and NU, but has not been recorded from the Arctic Islands (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Ford *et al.* 1985). The Arctic grayling is commonly found in clear water of large cold rivers, streams and lakes throughout the north (McPhail and Lindsey 1970; Scott and Crossman 1973; Ford *et al.* 1985). The Arctic grayling is known to exhibit lacustrine, adfluvial as well as riverine life history types (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Jessop and Lilley 1975; Krueger 1981).

Grayling spawn from April to mid-June, around the same time as ice breakup in streams and on lakes (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Machniak and Bond 1979; Ford *et al.* 1985). Both lacustrine and riverine populations spawn primarily in streams over gravel and rock substrates at depths of 0.7 m (Bishop 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; McCart *et al.* 1976; Lawrence and Davies 1978; Falk *et al.* 1982) although Machniak and Bond (1979) noted that water depth appeared not to be an important factor in spawning location. No information of grayling spawning in lakes was found for the NT or NU, however in Alaska grayling have been observed spawning over coarse sand, gravel, silt and organic substrates in water 0.15 to 0.9 m deep in lakes (Bendock 1979; Cuccarease *et al.* 1980; Tack 1980; Krueger 1981; Reed 1964). Spawning in lakes usually occurs in association with outlet and inlet streams (Krueger 1981). Eggs incubate for 13-18 days before hatching (Bishop 1967; Scott and Crossman 1973), and young grayling may remain within the gravel substrate for 3-4 days before they emerge (Kratt and Smith 1977). After spawning, adults leave the area returning to lakes or rivers (Scott and Crossman 1973; Lawrence and Davies 1978; Tack 1980). Young grayling are found in lotic and littoral areas at depths ranging from 0.20–0.46 m (Krueger 1981). Beauchamp (1982) noted that young grayling were infrequently found schooling under an overhanging boulder in Upper Granite Lake, British Columbia. Ford *et al.* (1985) notes similar use of boulders as cover in stream populations.

In Great Slave and Great Bear lakes grayling are reported to mature from 3-6 years of age and may live as long as 12 years (Miller 1946; McPhail and Lindsey 1970; Tripp and McCart 1974; Machniak and Bond 1979). Adult Arctic grayling may be found over sand, silt and gravel substrates in lakes (Bishop 1967; Hatfield *et al.* 1972) as well as along rocky shorelines (Rawson 1951; McPhail and Lindsey 1970). Grayling are typically a shallow water species inhabiting depths < 3.0 m in most lakes (Bishop 1967; McPhail and Lindsey 1970; Stein *et al.* 1973; Lawrence and Davies 1978; Krueger 1981). In Great Slave Lake grayling were not taken over depths of 3.05 m (Scott and Crossman 1973). Miller (1946) noted that grayling in Great Bear Lake were most often found in association with streams in bays of the lake. Although no specific information was found concerning overwintering habitat of grayling, it is assumed that they overwinter in deep pools of rivers and in deeper portions of lakes (Stein *et al.* 1973; Du Bruyn and McCart 1974; Lawrence and Davies 1978; Krueger 1981; Ford *et al.* 1985). Within the Mackenzie River grayling are often found under trees overhanging the water feeding on insects (Bishop 1967), and may use similar overhead cover in lakes. Adult grayling feed on a variety of aquatic and terrestrial insects including mayflies, caddisflies, midges, bees, wasps, grasshopers, ants and a variety of beetles (Miller 1946; Bishop 1967; Scott and Crossman 1973; McCart *et al.* 1976; Bond and Machniak 1979; Machniak and Bond 1979).

Broad whitefish (*Coregonus nasus*)

The broad whitefish is found in northern coastal regions of the NT and NU from the Perry River west to the Anderson and Mackenzie rivers (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Bond and Erikson 1992). Within the Mackenzie River system broad whitefish are found as far upstream as Fort Simpson (Stein *et al.* 1973). Broad whitefish are primarily an anadromous species and are most often found in large river systems and delta lakes, as well as in brackish estuarine waters (Scott and Crossman 1973). Broad whitefish are known to exhibit lacustrine and anadromous life history types and may also exhibit a riverine life history type in the NT (Berg 1962; Scott and Crossman 1973; Reist and Bond 1988; Reist and Chang-Kue 1997).

<u>Anadromous</u>

In the Mackenzie River pre-spawning migrations begin as fish move into the inner Delta in late August (Stein *et al.* 1973; Chang-Kue and Jessop 1992; Strange 1985). Spawning occurs between mid-October and November (Stein *et al.* 1973; Reist and Bond 1988). Spawning may occur in the Mackenzie, Peel, and Arctic Red rivers as well as in the Travaillant Lake system (Stein *et al.* 1973; Reist and Bond 1988; Thera 1998). Post-spawning adults move downstream in November to overwinter in the outer delta, nearshore areas, and the Tuktoyaktuk Peninsula (Stein *et al.* 1973, Strange 1985; Reist and Bond 1988; Chang-Kue and Jessop 1997). It is believed that broad whitefish likely spawn every other year or less often (Bond 1982; Reist and Bond 1988). Eggs hatch in the spring and most young broad whitefish are swept downstream into the outer delta or estuary (Reist and Bond 1988; Reist and Chang-Kue 1997; Thera 1998). Young broad whitefish move to nursery areas near Tuktoyaktuk Peninsula, the outer delta, the inner delta and nearshore areas, returning to coastal streams and migrating into the Tuktoyaktuk lake systems when they reach 50 mm in length (Bond and Erickson 1982; 1985; Reist and Bond 1988). Young broad whitefish remain in these tundra lakes for several years before returning to coastal waters (Bond and Erickson 1982; Strange 1985; Reist and Bond 1988; Chang-Kue and Jessop 1992; Thera 1998).

In late June to mid-July when freshwater creeks become ice free young-of-the-year and 2-4 year old small juvenile fish migrate upstream to feed in tundra lakes of the Tuktoyaktuk Peninsula and the outer delta (Bond 1982; Bond and Erickson 1985; Chang-Kue and Jessop 1992; Reist and Chang-Kue 1997). Large juvenile broad whitefish also migrate upstream and spend a variable amount of time feeding in lakes (Bond and Erickson 1985; Chang-Kue and Jessop 1992; Reist and Chang-Kue 1997). Young may overwinter in lakes of sufficient depth on the Tuktoyaktuk Peninsula (Lawrence *et al.* 1984) or in the Mackenzie River and coastal bays of the estuary (Chang-Kue and Jessop 1992). Juveniles appear to overwinter in the outer delta and along the Tuktoyaktuk Peninsula (Reist and Chang-Kue 1997). During the summer juvenile broad whitefish remain in nearshore areas migrating along the southern Beaufort Sea coast in and out of creeks and lake systems of Richards Island and the Tuktoyaktuk Peninsula (Bond 1982; Bond and Erickson 1982; 1985; Lawrence *et al.* 1984; Reist and Bond 1988). Freshwater lakes along the Tuktoyaktuk Peninsula are used extensively by this species and represent important nursery and overwintering areas (Stein *et al.* 1973; Lawrence *et al.* 1984; Bond 1982; Bond and Erickson 1982; 1985; Chang-Kue and Jessop 1992).

Juvenile broad whitefish usually mature between seven and eight years of age (Bond 1982; Chang-Kue and Jessop 1992) however they have been reported to mature as early as 3-4 years of age (Percy 1975). Broad whitefish are common in lakes throughout the Mackenzie Delta region (Percy 1975; Lawrence *et al.* 1984; Bond and Erickson 1982; Taylor *et al.* 1982) and may also be found in freshwater lakes of Richards Island and Langley Island (De Graaf and Machniak 1977). Adults spend the summer feeding in delta and peninsula lakes or nearshore estuarine environments (Reist and Chang-Kue 1997). Broad whitefish overwinter in lakes along the Tuktoyaktuk Peninsula in the Mackenzie River Delta, and along the Beaufort Sea coast (Jessop and Lilley 1975; Bond 1982; Strange 1985). The most important food for broad whitefish in lakes is zooplankton and macroinvertebrates (Strange 1985). Broad whitefish feed mostly on bottom organisms including aquatic insect larvae, small mollusks and crustaceans (Scott and Crossman 1973). The delta lakes of the Mackenzie River Delta may play a major role in the maintenance of Mackenzie broad whitefish populations (Bond and Erickson 1982) and more detailed studies on specific lake attributes and species habitat requirements should be conducted.

<u>Freshwater Resident</u>

Although the existence of a freshwater lacustrine population of broad whitefish has not been confirmed in the NT, evidence from traditional knowledge, surveys of the Travaillant Lake system and genetic work suggests that lacustrine populations do exist

(Reist and Chang-Kue 1997). Furthermore, it is believed that the lacustrine life history form of broad whitefish exists in association with large lake systems present on the east side of the Mackenzie River, in upstream areas of the Peel and Arctic Red rivers, and possibly in areas such as the Outer Delta (Reist and Chang-Kue 1997). It is expected that the lacustrine life history form would exhibit similar timing for major events such as spawning and feeding as that of the anadromous form (Reist and Chang-Kue 1997). Further studies are necessary to confirm the presence and distribution of lacustrine broad whitefish and to determine basic biological parameters for this life history type (Reist and Chang-Kue 1997).

Bull trout (*Salvelinus confluentus*)

Considerable taxonomic confusion has existed between bull trout (*S. confluentus*) and Dolly Varden (*S. malma*) leading to discrepancies in understanding the geographical distribution of both species. Recent work has confirmed the presence of bull trout from several locations in the Mackenzie River valley extending its known range northward by approximately four degrees of latitude (N. Mochnacz unpublished data; Reist *et al.* 2001b). Previous to this, the most northern known locality of bull trout was from Prairie Creek NT (Haas and McPhail 1991). Bull trout are not known to occur in NU. Bull trout are most often found in rivers and streams although they may be found in lakes in association with spawning streams and rivers (Haas and McPhail 1991; Nelson and Paetz 1992; Ford *et al.* 1995; Boag and Hvenegaard 1997). Bull trout are known to exhibit riverine, stream resident as well as adfluvial life history types (Ford *et al.* 1995; Stelfox and Egan 1995; James and Sexauer 1997; Wilhelm *et al.* 1999).

Typically, lake resident populations of bull trout exhibit an adfluvial life history type, spawning in tributary rivers and streams. Herman (1997) provides the only account found here of lake spawning bull trout, although no observations of habitat were made. In central portions of its distribution, bull trout spawn in the fall, from September until late October (McPhail and Murray 1979; Goetz 1989; Stelfox and Egan 1995) entering spawning rivers in August (Stelfox and Egan 1995). It is assumed that spawning occurs at earlier dates in northern regions. Within spawning streams, bull trout spawn in areas with cobble and gravel substrates (Goetz 1989; Nelson and Paetz 1992; Ford *et al.* 1995; Baxter and McPhail 1996; Fernet and Bjornson 1997; Reiser *et al.* 1997; Watson and Hillman 1997) preferring to spawn at depths between 0.20–0.60 m (Frayley and Shepard 1989; Kitano *et al.* 1994; Ford *et al.* 1995; Stelfox and Egan 1995; Baxter and McPhail 1996; Fernet and Bjornson 1997; James and Sexauer 1997). Females construct redds in areas of relatively low water velocity, often in association with areas of groundwater upwelling (Fraley and Shepard 1989; Goetz 1989; Ford *et al.* 1995; Baxter and McPhail 1996). Eggs incubate from 34-125 days before hatching depending on local water temperatures and newly hatched alevins remain within the substrate for several weeks before emerging (Ford *et al.* 1995). Bull trout are known to spawn in non-consecutive years (Haas and McPhail 1991; McCart 1997), however annual spawning may also occur (Stelfox and Egan 1995).

After emerging, young bull trout may remain in nursery streams from one to four years before moving into lake environments (Bjorn 1961; Ford *et al.* 1995; Stelfox and Egan 1995). Specifically, young are most often found in shallow waters 0.15-0.50 m deep

(Frayley and Shepard 1989; Ford *et al.* 1995; Saffel and Scarnecchia 1995; Baxter and McPhail 1996; McPhail and Baxter 1996) in association with large, loose cobble substrates which provide interstitial cover for young fish (Goetz 1989; Ford *et al.* 1995; Saffel and Scarnechia 1995; Baxter and McPhail 1996; Baxter 1997). Within rivers juveniles are found in similar habitats as young bull trout. Both young and juvenile bull trout make use of woody debris and substrate for cover (Pratt 1985; Frayley and Shepard 1989; Goetz 1989; Pratt 1992; Ford *et al.* 1995; Baxter and McPhail 1996; Connor *et al.* 1997; Hauer *et al.* 1999). In addition juveniles are known to make use of overhead cover (Stelfox and Egan 1995; McPhail and Baxter 1996; Fernet and Bjornson 1997; Watson and Hillman 1997). Bull trout usually reach sexual maturity at five years of age (McPhail and Murray 1979; Mason 1985; Nelson and Paetz 1992).

Lacustrine adults are primarily found in profundal and littoral areas of lakes (Ford *et al.* 1995; McPhail and Baxter 1996; Connor *et al.* 1997). Connor *et al.* (1997) noted that bull trout were most often caught within three meters of the bottom, and were most often observed at depths ranging from 22.5 to 40 m using hydroacoustics. In rivers adults seek cover in undercut banks and amongst woody debris (Goetz 1989; Underwood *et al.* 1995; Baxter and McPhail 1996; Watson and Hillman 1997; Hauer *et al.* 1999) and it is assumed that bull trout may use similar habitats along the shorelines of lakes, if littoral water temperatures are low enough. Although adult bull trout are known to select a variety of substrates from large boulders to sand in rivers (Goetz 1997; Watson and Hillman 1997; Wissmar and Craig 1997) no information is available on lacustrine substrate requirements. Bull trout feed on a wide variety of fish, benthic organisms and invertebrates species including chironomids, *Daphnia*, *Gammarus* and *Mysis relicta* in lakes (Bjornn 1961; Fraley and Shepard 1989; Donald and Alger 1993; Wilhelm *et al.* 1999; Mushens and Post 2000). Although spawning in adfluvial populations of bull trout has been well documented, very little information exists on the lacustrine habitat requirements of this species and further studies should be conducted.

Chum salmon (*Oncorhynchus keta*)

Chum salmon are found in coastal regions near the Peel and Mackenzie rivers and possibly as far east as the Anderson River. Within the Mackenzie River drainage chum salmon may be found in the Slave River below Fort Smith, to the mouth of the Hay River and into Great Bear Lake, but are absent from NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Salo 1991). Chum salmon enter freshwater habitats only to spawn and spend a relatively small portion of their life history in freshwater. Use of freshwater habitats is primarily restricted to rivers and lakes for spawning migrations and strictly to riverine environments for spawning. The chum salmon is strictly anadromous and is not know to exhibit any other life history types (McPhail and Lindsey 1970; Scott and Crossman 1973; Salo 1991).

<u>Anadromous</u>

Very little information on the biology of the chum salmon has been collected in the NT. Chum salmon generally spend very little time in freshwater ascending rivers in late July (McPhail and Lindsey 1970). Chum salmon in the NT are known to ascend the Mackenzie River to the rapids below Fort Smith, the Hay River and may enter Great Bear

Lake (McPhail and Lindsey 1970; Scott and Crossman1973; Craig and Haldorson 1986). A spawning population may also spawn in the Anderson River in the NT (Craig and Haldorson 1986). Chum salmon appear at the mouth of the Mackenzie River in August and reach Great Slave Lake in September or October (McPhail and Lindsey 1970). Spawning has been reported to occur in riffle areas over gravel, in which females construct a redd (McPhail and Lindsey 1970; Scott and Crossman 1973; Salo 1991). Spawning may also take place over bedrock strewn with boulders, in which case the eggs are deposited directly over the substrate and settle into interstices (Scott and Crossman 1973). The female and male fish extrude their eggs and sperm simultaneously over the redd, the female then covers the redd with gravel (Salo 1991). All adults die after spawning (McPhail and Lindsey 1970; Salo 1991).

Eggs incubate for three to four months depending on water temperature, and young remain in the gravel for several weeks after hatching before emerging and migrating downstream (Scott and Crossman 1973). In the Mackenzie River system migrations are extensive and young must feed along the way (McPhail and Lindsey 1970) and may make use of lakes as nursery and feeding areas. Young salmon that make these extensive migrations will hide in gravel during the day migrating mostly at night (Scott and Crossman 1973; Salo 1991). Once the young salmon reach the estuarine environments of the delta, they may remain there feeding for several weeks before smolting and migrating out to sea (McPhail and Lindsey 1970; Scott and Crossman 1973; Salo 1991). Chum salmon return 3-4 years later as adults to spawn in their natal streams (Scott and Crossman 1973). Relatively very little information has been collected on the Mackenzie River population of chum salmon and further studies should be conducted relating to the general biology and habitat requirements of this species.

Dolly Varden (*Salvelinus malma*)

Dolly Varden are known to occur in the NT within the Big Fish, Rat and Vittrekwa rivers as well as in rivers of the north slope Yukon Territory (Reist *et al.* 2001a). Dolly Varden typically inhabit rivers and streams, and nearshore waters of the Beaufort Sea (Glova and McCart 1974; McCart 1980; Craig 1989; Sandstrom 1995). Dolly Varden are known to exhibit both anadromous and riverine resident life history types (McCart 1980; Sandstrom 1995). Although considerable confusion has existed in the past, lacustrine populations of char from the north slope west of the Mackenzie River region in Canada are considered to be relict Arctic char, whereas riverine char (anadromous, residual, and isolated stream resident forms) from this area are Dolly Varden (Reist *et al.* 1997). Furthermore, it is believed that records of Dolly Varden from the mid-upper Mackenzie River system are likely bull trout.

<u>Anadromous</u>

Dolly Varden in the NT and the Yukon are believed to spend less than 10% of their lives in marine environments as large juveniles and adults feeding during the summer months (Craig 1989) and as such are considered to be amphidromous rather than truly anadromous (Reist *et al.* 2001a). Dolly Varden spawn in the fall from August through to early October (McPhail and Lindsey 1970; Glova and McCart 1974; Sandstrom 1995; Reist *et al.* 2001a) primarily in upstream reaches of rivers fed by perennial springs (McCart 1980; Sandstrom 1995). Females excavate redds in gravel habitats in areas with slow currents, but may spawn in areas with cobble substrates (McPhail and Lindsey 1970; McCart 1980; Kitano and Shimazaki 1995). These fish are usually closely shadowed by residual males who dart in and release milt as the andromous female releases her eggs (Reist *et al.* 2001a). Eggs are deposited in the nest and are covered with gravel (McPhail and Lindsey 1970). Eggs overwinter and hatch in early spring, and young remain in shallow areas of streams for 2-3 years (McPhail and Lindsey 1970). Reist *et al.* (2001a) define four life history stages for Dolly Varden (1) young-of-the-year (age 0+), (2) small juveniles (age 1-3), (3) large juveniles (age 4-7), and (4) adults (age 8 or more). The first two groups remain in freshwater environments throughout the year, with the latter two groups migrating to feed in saline environments in the summer (Reist *et al.* 2001a).

Young emerge from gravel spawning grounds in May or June and are believed to remain in the vicinity of their natal springs for their first summer (McCart 1980; Reist *et al.* 2001a). Small juveniles migrate throughout the river system in the summer returning to their natal spawning areas to overwinter (McCart 1980; Reist *et al.* 2001a). At 2-3 years of age juveniles transition to an anadromous life history type, or may become residual residents if they are males (Reist *et al.* 2001a). Smoltification to large anadromous juveniles commonly occurs at three to four years of age but may occur as early as two years of age and as late as five years of age (McCart 1980; Sandstrum 1995; Reist *et al.* 2001a). Male Dolly Varden become sexually mature as early as two years of age but usually do not mature until five years, with all males being mature by eight or nine (McCart 1980). Females usually mature between 4-9 years of age (McCart 1980). Residual males mature as early as two years with all being mature by six years of age (McCart 1980).

Adult Dolly Varden migrate downstream to coastal areas following the spring breakup to feed for the summer (Sandstrom 1995). Dolly Varden remain close to shore in the summer usually within 500 m in freshened warmer waters (McCart 1980; Sandstrom 1995; Reist *et al.* 2001a). However, adult fish may move offshore in freshened surface waters (Jarvella and Thorsteinson 1997). Adult Dolly Varden do not spawn consecutively and adults may rest for one or more years between spawnings (Reist *et al.* 2001a). Sandstrom (1995) noted that Dolly Varden appear to spawn annually in the Big Fish River unlike closely related populations in nearby rivers. McCart (1980) noted that both juvenile and mature non-spawners migrate seaward in the summer, and although mature non-spawners do enter the sea it is not known to what degree this occurs. Mature fish migrate upstream to spawning and overwintering grounds in the autumn, and are followed later by juveniles and mature non-spawners (McCart 1980; Sandstrom 1995; Reist *et al.* 2001a). After spawning, adults retreat downstream to overwinter in flowing water habitat (Reist *et al.* 2001). Upwelling and springs provide important overwintering habitat for Dolly Varden, due to the fact that these areas of rivers are often the only place where the water is deep enough to overwinter (Armstrong and Morrow 1980; Sandstrom 1995; Everett *et al.* 1997; Reist *et al.* 2001a). Dolly Varden may spend a significant portion of their life history (8-9 months a year) in these habitats making them important for survival (Reist *et al.* 2001a). Very little is know of the life history of residual males, but they are assumed to disperse throughout the system to feed in the summer, returning to spawn in the fall. As mentioned earlier residual males are sneak spawners and participate in reproduction with anadromous pairs, although it is not known if the residual life history type has a genetic basis or is facultative (Reist *et al.* 2001a). Areas of upwelling provide crucial habitat (spawning/overwintering) for anadromous as well as resident populations of Dolly Varden (McCart 1980), and further detailed investigations should be conducted to identify and protect these areas.

Inconnu (*Stenodus leucichthys*)

The inconnu is found throughout the Mackenzie River basin, up the Mackenzie River as far as Fort Nelson on the Liard River and throughout Great Slave Lake up to the rapids at Fort Smith on the Slave River (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). Inconnu are not known to occur in NU. Inconnu are found primarily in large muddy rivers and associated lakes (McPhail and Lindsey 1970; Percy 1975). Within the NT inconnu are known to exhibit both anadromous and adfluvial life history types (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973) and may exhibit a riverine life history type similar to that described in Alaska (Alt 1988; Howland *et al.* 2000).

<u>Anadromous</u>

In the lower Mackenzie River inconnu are anadromous, but probably do not stray far from the mouth of the river, restricting their distribution to freshened areas within the delta (Carl *et al.* 1967; McPhail and Lindsey 1970; Lawrence *et al.* 1984; Reist and Bond 1988). Inconnu in the Anderson River also occur in freshened areas more so than in marine waters (Bond and Erikson 1991; 1993). Coastal bays and lagoons appear to be critical habitat for inconnu (Bond and Erikson 1982). The inconnu is abundant in the Mackenzie River and fairly so in the Yukon River, Alaska. In lower portions of these rivers it is apparently anadromous entering brackish water for a period before proceeding upstream in late summer to spawn (Carl *et al.* 1967).

Inconnu make a downstream migration in October after spawning (Howland *et al.* 2000). Post-spawning inconnu overwinter in main channels of the delta, nearshore areas of the outer delta and possibly in delta lakes (Mann 1975; Percy 1975; De Graaf and Machniak 1977; Howland *et al.* 2000). No detailed information on spawning habitat was found but it assumed, as with other coregonine species, that inconnu spawn over gravel substrates. Eggs hatch in the spring and young are likely washed downstream similar to other coregonines in this area (Reist *et al.* 2001a). Very little is known of the biology of young-of-the-year and juveniles, and it is assumed that they rear and grow in nursery areas in delta and nearshore coastal regions in which they are most commonly found (Stein *et al.* 1973; Percy 1975; De Graff and Machniak 1977; Lawrence *et al.* 1984). As with adults, distribution of young inconnu appears to be severely restricted by salinity (Bond and Erickson 1992). In Alaska male inconnu reach maturity from 4-9 years of age whereas females mature somewhat later at 6-12 years of age (Alt 1988). Howland (1997) reported that males begin to mature at age seven and females at age 11 in the Mackenzie River system. Inconnu are piscivorous and feed on a variety of freshwater and marine fish species including least cisco, smelt, smaller inconnu, ninespine sticklebacks, herring, cod, sculpins and flounder (Percy 1975; Lawrence *et al.* 1984).

Freshwater resident

Inconnu from Great Slave Lake and the upper Mackenzie River do not migrate to coastal areas and are thus considered to be freshwater residents (Fuller 1955; Stein *et al.* 1973; Reist and Bond 1988). Inconnu are known to exhibit a riverine life history type in Alaska (Alt 1988) although a distinct riverine life history type for inconnu has not been described in the NT (Howland *et al.* 2000).

Inconnu from Great Slave Lake are adfluvial and are known to make upstream spawning migrations over several months in the summer, returning in a mass migration in larger tributary streams in autumn (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973). Inconnu first enter the Slave River in mid-August and spawning occurs in early to mid-October (McLeod *et al.* 1985; Tallman *et al.* 1996b). Spawning has not been observed in this area, however inconnu in Alaska are known to spawn over coarse gravel substrates, in water 1.2–2.3 m deep in clear tributaries of larger river systems (Alt 1969; 1988). Spawning is intermittent and may occur every two to four years (Scott and Crossman 1973). Inconnu only use the Slave River system seasonally, spending the rest of the year in Great Slave Lake, although the Slave River is considered to be an important spawning river for inconnu (Tripp *et al.* 1981; McLeod *et al.* 1985; Tallman 1996a). After spawning inconnu migrate downstream to Great Slave Lake leaving the Slave River by late October (Tallman *et al.* 1996a; 1996b). Further studies should be conducted to reveal important nursery and feeding areas in Great Slave Lake. Radio-tagged fish from the Slave River were seldom relocated after entering Great Slave Lake, this may be due to the fact that fish occupy considerable depths in the lakes and may make extensive migrations within Great Slave Lake during winter months (Tallman *et al.* 1996b).

As with anadromous populations the young and juvenile life history stages of this species are poorly understood in this area. Young may remain in tributary streams for two years before entering Great Slave Lake (McPhail and Lindsey1970). In Great Slave Lake inconnu mature in 7-10 years but few live longer than 11 years (Scott and Crossman 1973). Once in Great Slave Lake inconnu probably reside in offshore deep areas (Howland *et al.* 2000). As with many other species in the NT very little is known of its biology and further research needs to be done.

Lake herring (*Coregonus artedi*)

The lake herring or cisco is present in the NT in the Mackenzie River system from Great Bear Lake south to the border with Alberta and east to the western Hudson Bay coast of NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). Ellis (1962) reported a single specimen from Bernier Bay, Baffin Island as the most northern record of this species. The lake cisco is primarily a lacustrine species although it may be found in large rivers in the western portion of its distribution (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The lake cisco primarily exhibits a lacustrine life history type, although anadromous forms are known to occur in the James Bay region (Scott and Crossman 1973; Morin *et al.* 1981). As with other coregonine species lake cisco exhibit a dwarf form (Shields and Underhill 1993), however no differentiation in habitat use has been defined in the literature, thus for the purposes of this report, it is assumed that dwarf and normal forms select similar habitat types.

Like most coregonine species spawning takes place in the fall of the year (Scott and Crossman 1973), however spring spawning has been recorded in some Quebec and Ontario populations (Todd 1981; Hénault and Fortin 1991). In the Great Lakes region spawning takes place as late as November or December (Fish 1932; Scott and Crossman 1973; Becker 1983), but likely occurs much earlier in northern populations. Spawning usually takes place in shallow water 1-5 m deep (Pritchard 1930; Colby and Brooke 1973; Scott and Crossman 1973; Goodyear *et al.* 1982), however deep-water spawning has been known to occur at 120-140 m (Dryer and Beil 1964). Spawning most often takes place over sand and gravel substrates (Koelz 1929; McPhail and Lindsey 1970; Scott and Crossman 1973; Lawrence and Davies 1978; Cucin and Faber 1985). Spawning has also been reported to occur over boulders, rubble, clay, mud and vegetation (Koelz 1929; Pritchard 1930; Colby and Brooke 1973; Goodyear *et al.* 1982; Cucin and Faber 1985). Eggs incubate over the winter for 10-14 weeks and hatch in the following spring just before ice breakup (Fish 1932; Goodyear *et al.* 1982). As with many other northern fish populations, northern populations of ciscoes may not spawn every year (Kennedy 1949).

Very little is known of the habitat requirements of young lake cisco. Young lake cisco are often found schooling with whitefish in shallow-water areas of protected bays until they are about a month old (Pritchard 1930; Rawson 1951; Goodyear *et al.* 1982; Cucin and Faber 1985). Within these areas young are often found in association with rocky substrates and vegetation (Pritchard 1930; Goodyear *et al.* 1982). By summer most young move to deep water where they assume a pelagic existence (Goodyear *et al.* 1982). In southern populations cisco mature from two to four years of age (Scott and Crossman 1973), whereas ciscoes in Great Bear Lake usually do not mature until age five or six (Kennedy 1949).

The lake cisco is typically a pelagic species and occurs in both shallow and deep-water areas (McPhail and Lindsey 1970; Scott and Crossman 1973) and is most commonly found at depths from 10-60 m throughout the year (Dymond 1926; Koelz 1929; Dryer 1966; Lawrence and Davies 1978). Rawson (1947) reports that in Great Slave Lake cisco are common down to 30 m, and became less frequent at greater depths. Lake cisco generally move from shallow waters in the spring to deeper waters in the summer (Koelz 1929; Scott and Crossman 1973). Along with seasonal migrations, cisco may also make diel migrations toward shore at sunrise and away from shore at sunset (Engel and Magnuson 1976). Although typically considered to be a pelagic species, Jansen and Aku (1998) note the potential importance of the littoral zone habitats for the lake cisco. Northern populations are known to live longer and lake cisco have been reported to reach 13 years of age in Great Bear Lake (Scott and Crossman 1973). Being a pelagic species the lake cisco feeds primarily on plankton and to a lesser extent on large crustaceans, chironomid larvae and young fish (Rawson 1947; Kennedy 1949; McPhail and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973; Stein *et al.* 1973).

Lake trout (*Salvelinus namaycush*)

The lake trout is found throughout the NT and NU mostly in deep-water lakes (McPhail and Lindsey 1970; Lee *et al.* 1980) as well as on many Arctic Islands (Baffin, South Hampton, King William, Victoria, and Banks) (Carl *et al.* 1967; Scott and

Crossman 1973). Lake trout are most commonly found in large deep lakes but may also be found in large clear rivers (McPhail and Lindsey 1970; Scott and Crossman 1973; Lawrence and Davies 1978; Morrow 1980). Lake trout may exhibit both lacustrine and adfluvial life history types (Scott and Crossman 1973; Goodyear *et al.* 1982) and although they are known to occur and spawn in rivers, no distinct riverine populations have been identified in Canada. In addition lake trout also appear to exhibit several ecological forms or morphs within larger lakes.

Lake trout spawn in late summer and early autumn, from September to October in northern regions (Scott and Wheaton 1954; McPhail and Lindsey 1970; Scott and Crossman 1973; Martin and Olver 1980; Ford *et al.* 1995) and may spawn as late as November in southern regions (Scott and Crossman 1973). Most spawning occurs in shallow inshore areas of lakes, although river-spawning populations may also exist in the north, as is the case in the Laurentian Great Lakes (Loftus 1958; Carl *et al.* 1967; McPhail and Lindsey 1970; Machniak 1975c; Ford *et al.* 1995). Lake trout spawn primarily over cobble, rubble and large gravel substrates, interspersed with boulders in areas free of sand, silt, clay and mud (Paterson 1968; DeRoche 1969; Normandeau 1969; McPhail and Lindsey 1970; Scott and Crossman 1973; Lawrence and Davies 1978; Martin and Oliver 1980; Dorr *et al.* 1981; Dumont *et al.* 1982; Goodyear *et al.* 1982; Marcus *et al.* 1984; Cucin and Faber 1985; Thibodeau and Kelso 1990; Marsden and Krueger 1991; Kelso *et al.* 1995; Ford *et al.* 1995). Spawning grounds are often associated with areas affected by wave action and water currents, which are believed to keep these areas free of silt, sand and detritus (Normandeau 1969; McPhail and Lindsey 1970; Martin and Oliver 1980; Gunn 1995; Sly and Evans 1996). Although lake trout are considered to avoid areas with sand, silt and mud several authors have observed spawning over these substrate types (Goodyear *et al.* 1982; Beauchamp *et al.* 1992). Lake trout spawn at a variety of depths from 0.12 m to 55 m deep (Carlander 1969; DeRoche 1969; Morrow 1980; Dumont *et al.* 1982; Goodyear *et al.* 1982; Marcus *et al.* 1984) to depths in excess of 100 m (Thibedeau and Kelso 1990). In Great Slave and Great Bear lakes lake trout appear to spawn every second or third year respectively (McPhail and Lindsey 1970).

Eggs are laid and settle into cracks and crevices amongst the rocks, where they incubate from four to five months (DeRoche 1969; Machnaik 1975; Goodyear *et al.* 1982; Thibedeau and Kelso 1990; Marsden *et al.* 1995). Eggs usually hatch in March or April, however hatching may occur as late as June in Great Bear Lake (Scott and Crossman 1973). Young-of-the-year remain in spawning areas from several weeks to several months (DeRoche 1969; Scott and Crossman 1973; Martin and Oliver 1980; Morrow 1980; Goodyear *et al.* 1983; Peck 1982) moving to deeper water areas as water temperatures exceed 15° C (Peck 1982). Young lake trout are solitary and are often found in close association with the bottom, usually < 0.3 m above the bottom (Davis *et al.* 1997), often in association with sandy substrates (Peck 1982; Bronte *et al.* 1995). Juvenile lake trout show a diel depth distribution and are found in deeper waters during the day (15-20 m) and in shallow water habitat (5-10 m) at night (Davis *et al.* 1997). Juveniles may be found over cobble, boulder and rubble substrates usually within 0.3 m of the bottom, and may often seek shelter amongst boulders and woody debris (Ford *et al.* 1985; Davis *et al.* 1997). In Great Slave Lake individuals may mature as early as five years of age with most maturing by their eleventh year (McPhail and Lindsey 1970).

Scott and Crossman (1973) report that sexual maturity is usually reached in Great Slave Lake at age six or seven, but not until age 13 in Great Bear Lake.

After spawning adults may disperse to deeper water habitats (Scott and Crossman 1973; Machniak 1975c; Goodyear *et al.* 1982). Adults are most commonly found at depths in excess of ten meters (Scott and Crossman 1973; Johnson 1975; Machniak 1975c; Martin and Olver 1980) and are often found in the pelagic zone of lakes (Scott and Crossman 1973; Ford *et al.* 1985; Sellers *et al.* 1998). During the summer, as surface temperatures rise, adult lake trout seek deeper, cooler (~10° C) waters below the thermocline (Scott and Crossman 1973; Martin and Olver 1980; Morrow 1980; Communications Directorate 1991b; Sellers *et al.* 1998). Lake trout exhibit a low salinity tolerance, but have been reported to occur in coastal regions of the NT, although they tend not to migrate to sea (Communications Directorate 1991b). Lake trout feed on a wide variety of prey items including fish, mollusks, crustaceans, freshwater sponges and even small mammals (Scott and Crossman 1973; Magnin *et al.* 1978; Madenjian *et al.* 1998).

Lake whitefish (*Coregonus clupeaformis*)

The lake whitefish (*Coregonus clupeaformis*) complex includes the lake whitefish (*C. clupeaformis*), the Alaskan whitefish (*C. nelsoni*) and the humpback whitefish (*C. pidschian*). For the purposes of this report the *Coregonus clupeaformis* species complex will be referred to as lake whitefish.

Lake whitefish occur throughout the NT to a northern limit on Banks Island and across NU from southern Victoria Island to the Keewatin District (McPhail and Lindsey 1970; Scott and Crossman 1973; Babaluk *et al.*, unpublished data). They are most commonly found in lakes, although they may be found in larger rivers and brackish waters (McPhail and Lindsey 1970; Scott and Crossman 1973). Lake whitefish are known to exhibit lacustrine, adfluvial and anadromous life history types (Scott and Crossman 1973; Tripp *et al.* 1981; Reist and Bond 1988). Lacustrine populations have been noted to occur as two separate forms, normal and dwarf, as noted by Kennedy (1943), Fenderson (1964), Edsall (1960) and Bruce (1984). However, there is no distinction in the literature of differential habitat use between the two forms, thus for the purposes of this report it assumed that they exhibit similar habitat preferences.

<u>Anadromous</u>

In the Mackenzie River system anadromous lake whitefish make upstream spawning migrations in September and October (Stein *et al.* 1973; Sturm 1988). Spawning occurs in upstream areas in the rivers in late September and early October and a subsequent post-spawning migration to freshened nearshore areas and deep delta channels to overwinter is made in October and November (Stein *et al.* 1973; Jessop and Lilley 1975; Percy 1975). Spawning is presumed to take place over gravel substrates, as occurs in lacustrine populations. Eggs incubate over the winter and hatching occurs in the spring, at which point in time young fish are entrained in downstream flows into the outer delta or estuary (Reist and Bond 1988). Once in the delta young whitefish appear to use lakes of the western part of the Tuktoyaktuk Peninsula, but to a lesser extent than broad whitefish (Reist *et al.* 2001b). Young-of-the-year are also known to occur in coastal regions in the Mackenzie Delta (Lawrence *et al.* 1984; Bond and Erikson 1987; 1989). Small juvenile lake whitefish remain in lakes and channels of the Mackenzie River Delta (Reist *et al.* 2001b). Large juveniles may also be found in these habitats, as well as in freshened coastal areas (Lawrence *et al.* 1984; Stewart *et al.* 1993; Reist *et al.* 2001b). Nursery areas for young-of-the-year and most small juveniles (i.e., < 4 years) likely occur in the Mackenzie River, in delta or upstream areas (Reist and Bond 1988; Reist *et al.* 2001b). Nursery areas for large juveniles (4-7 years) likely occur in lake systems of outer Richards Island and the western portion of the Tuktoyaktuk Peninsula (Reist *et al.* 2001b). Juveniles likely overwinter in peninsula lakes and freshened nearshore coastal areas (Reist *et al.* 2001b). Juveniles reach sexual maturity from seven to 11 years of age (Stein *et al.* 1973; De Graaf and Machniak 1977). Anadromous lake whitefish prefer waters with relatively low salinity (Reist and Bond 1988) and in the summer they likely feed in the outer delta, channels and nearshore areas (Reist *et al.* 2001a). Anadromous lake whitefish feed on a variety of organisms inlcuding gastropods, pelecypods, amphipods, chironomids, notostracans, cladocerns, ostracods and various insects (Lawrence *et al.* 1974; Bond and Erikson 1985).

<u>Freshwater resident</u>

Lake whitefish may spawn from late summer to November or December (Slastenenko 1958; Qadri 1968; Scott and Crossman 1973; Goodyear *et al.* 1982) usually from mid-September to mid-October in northern regions (Scott and Wheaton 1954; McPhail and Lindsey 1970; Lawrence and Davies 1978; Tripp *et al.* 1981; Roberge *et al.* 1985). Lake whitefish are known to spawn in both lakes (Hart 1930; Goodyear *et al.* 1982; Ford *et al.* 1995) as well as in rivers (Scott and Wheaton 1954; McCart 1982; Roberge *et al.* 1985; Patlas 1993). Lake whitefish spawn over a variety of substrates from large boulders to gravel and occasionally sand (Hart 1930; Carl *et al.* 1967; Scott and Crossman 1973; Ayles 1976; Dumont and Fortin 1978; Lawrence and Davies 1978; Morrow 1980; Fudge and Bodaly 1984; Nester and Poe 1984; Ford *et al.* 1995; Anras *et al.* 1999b). Although lake whitefish appear to avoid soft bottomed substrates when spawning (Machniak 1975a), several authors have reported spawning in areas with silt substrates and emergent vegetation (Hart 1930; Bidgood 1972; Bryan and Kato 1975). Spawning usually takes place in shallow water areas < 5.0 m deep (Bryan and Kato 1975; Machniak 1975a; Lawrence and Davies 1978; Cucin and Faber 1985; Ford *et al.* 1995; Anras *et al.* 1999b). Eggs are released over the substrate and settle in crevices and interstices, where they incubate for several months hatching sometime from March to May (Hart 1930; Scott and Crossman 1973; Goodyear *et al.* 1982; Cucin and Faber 1985). In northern waters individuals may only spawn every second or third year (Scott and Crossman 1973).

Young lake whitefish are commonly found at the surface in shallow water areas < 1 m within the general vicinity of the spawning area (Hart 1930; Slastenenko 1958; Faber 1970; Goodyear *et al.* 1982; Loftus 1982; Cucin and Faber 1985). Within shallow water zones, young lake whitefish are most commonly found in areas with boulder, cobble and sand substrates in association with emergent vegetation and woody debris (Hart 1930; Reckahn 1970; Hoagman 1973; Morrow 1980; Goodyear *et al.* 1982; Ford *et al.* 1995). As water temperatures warm, young move to deeper waters (3-15 m) later in the summer

(Lindstrom 1970; Reckahn 1970; Scott and Crossman 1973; Machniak 1975a; Goodyear *et al.* 1982). As with young lake trout, juveniles are most often found over boulder, cobble and gravel substrates in association with vegetation and woody debris (Ford *et al.* 1995). In Great Slave and Great Bear lakes about half of both sexes mature in their eighth year (McPhail and Lindsey 1970). Kennedy (1954) reported the earliest age of sexual maturity was five years for Great Slave Lake.

Adult lake whitefish leave spawning grounds shortly after spawning, returning to deepwater habitat to overwinter (Slastenenko 1958; Machniak 1975a; Ford *et al.* 1995). Lake whitefish are frequently found at depths > 10 m for most of the year (Hart 1930; Kennedy 1943; Qadri 1961; Rawson 1947; 1951; Ford *et al.* 1985) and have been found at depths in excess of 100 m (McPhail and Lindsey 1970). Lake whitefish may be found over boulder, gravel, cobble, sand and clay substrates (Hatfield *et al.* 1972; Anras *et al.* 1999b), however they generally do not show a preference for substrate type (Ford *et al.* 1995). In addition they are primarily bottom dwelling, although they may be found in the pelagic zone of lakes (Morrow 1980; Bruce 1984; Ford *et al.* 1995). Lake whitefish have been reported to make marked onshore movements into shallow water habitats at night (McPhail and Lindsey 1970; Anras *et al.* 1999) possibly to feed. Lake whitefish are bottom feeders and feed on snails, clams, chironomid larvae and small fishes (Slastenenko 1958; McPhail and Lindsey 1970; Scott and Crossman 1973).

Least cisco (*Coregonus sardinella*)

The least cisco is common in coastal areas near the Mackenzie River delta and as far south as Fort Simpson in the NT, as well as on Victoria and Banks islands east to the Murchison River in NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). Least cisco may be found in estuaries and coastal lagoons as well as in freshwater rivers, streams and lakes (McPhail and Lindsey 1970; Scott and Crossman 1973; Lawrence and Davies 1978). The least cisco exhibits both an anadromous and freshwater lacustrine life history type (McPhail and Lindsey 1970; Scott and Crossman 1973; Mann 1974; Lee *et al.* 1980; Lawrence *et al.* 1984).

<u>Anadromous</u>

Anadromous least cisco may be found in the Mackenzie River delta and nearshore brackish water habitats in the summer (Reist and Bond 1988). Anadromous least cisco begin to migrate upstream in the summer and fall from August to September (Stein *et al.* 1973; Morrow 1980). Spawning takes place in late September and early October, and is assumed as with other coregonine species, to be followed by a downstream migration to overwintering areas (Scott and Crossman 1973; Stein *et al.* 1973; Mann 1975; Reist and Bond 1988). Anadromous least cisco are believed to spawn in the Mackenzie Delta as well as in the Peel and Arctic Red rivers (Stein *et al.* 1973), although it is not known if anadromous populations spawn in lakes or not. Least cisco overwinter in delta channels and freshened nearshore areas of the Mackenzie delta (Bond 1982; Mann 1975).

Hatching has been suggested to occur under the ice prior to spring breakup in Alaska (Cohen 1954; Reist and Bond 1988). As with other anadromous coregonines young least cisco are likely washed downstream by spring flooding out into the outer delta or estuary (Stein *et al.* 1973; Reist and Bond 1988) sometime in May or June

(Hatfield *et al.* 1972; Taylor *et al.* 1982). Young least cisco are most common in the Mackenzie Delta in freshwater habitats (Percy 1975; Lawrence *et al.* 1984) and are less frequently found in coastal areas (Bond and Erikson 1987). Young least cisco feed and overwinter in freshwater systems (Stein *et al.*1973; Lawrence *et al.* 1974; Bond and Erickson 1985) and juveniles are known to make use of lakes in the Tuktoyaktuk Peninsula for feeding and overwintering areas, but not to the same extent as broad whitefish (Lawrence *et al.* 1984; Bond and Erickson 1985; Reist and Bond 1988). Bond and Erickson (1985) note that young cisco may migrate upstream into tundra lakes where they may remain for several years before returning to the coast. Least cisco in the Mackenzie River start to mature by age five (Hatfield *et al.* 1972). Anadromous adults may be found in estuaries and brackish water lagoons (McPhail and Lindsey 1970). Adult anadromous cisco may also overwinter in lakes of the Mackenzie River delta (Jessop and Lilley 1975) as well as in coastal areas (Percy 1975; Bond 1982).

Freshwater Resident

Freshwater populations of least cisco occur throughout Arctic North America (Cohen 1954; Wohlschlag 1954; Mann 1974; Mann and McCart 1981; Lindsey and Kratt 1982), although they have received little attention in the NT and NU. In the past two distinct forms of least cisco, an anadromous and non-migratory freshwater have been described (Wohlschlag 1954; McPhail and Lindsey 1970; Scott and Crossman 1973). However, further investigations have identified a dwarf non-migratory form, a migratory freshwater form, as well as a jumbo spotted non-migratory form (Mann 1974; Mann and McCart 1981; Lindsey and Kratt 1982). For the purposes of this report all freshwater forms will be grouped into a single freshwater lacustrine species complex.

Spawning occurs in autumn, from September to October about the same time as fall freeze-over (Cohen 1954; McPhail and Lindsey 1970; Scott and Crossman 1973; Mann 1974). Freshwater populations may make seasonal migrations from lakes in which they overwinter to other lakes to spawn (Mann 1974; Lawrence *et al.* 1984), indicating that different lacustrine requirements may exist for overwintering and spawning habitat. Spawning takes place in shallow areas of lakes along lake shores usually over sand and gravel substrates (McPhail and Lindsey 1970; Scott and Crossman 1973; Lawrence and Davies 1978). Eggs incubate through the winter, hatching under the ice from late May to mid-June (Cohen 1954; McPhail and Lindsey 1970; Mann 1974).

Young least cisco seem to prefer areas without vegetation > 1.5 m deep, whereas juveniles are often found in association with vegetation (Mann 1974). Mann (1974) found young least cisco over a variety of substrate types and notes that they were found in greater abundance over gravel and shale fragment bottoms (Mann 1974). Least cisco begin maturing at age five or six, with most of the population being mature by age seven or eight (Mann 1974). In freshwater environments least cisco feed on a variety of food items including gastrapods, ostracods, chironomids, fish, as well as aquatic and terrestrial insects (Scott and Crossman 1973; Lawrence *et al.* 1974; Mann 1974). The general biology of this species is poorly understood and further studies of the life history habitat requirements of the various freshwater forms of this species should be performed.

Pink salmon (*Oncorhynchus gorbuscha*)

The pink salmon has been reported to occur in the Mackenzie River system and in the Sachs River estuary of Banks Island in the NT, however has not been reported to occur in NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Hunter 1974; Lee *et al.* 1980; Babaluk *et al.* 2000). The pink salmon is wholly anadromous and is not known to exhibit a freshwater life history type (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). No information relating to lacustrine habitat requirements of this species was found.

<u>Anadromous</u>

Very little is known of northern and arctic populations of pink salmon (McPhail and Lindsey 1970). The pink salmon spends very little time in freshwater, ascending rivers and streams from mid-June to late September, spawning some time between August and November (McPhail and Lindsey 1970; Craig and Haldorson 1986; Heard 1991). Some populations may spawn in intertidal areas, however spawning usually occurs in small streams of moderate velocity over gravel substrates in about 0.3 m of water (McPhail and Lindsey 1970; Heard 1991). Females dig a redd in the gravel, and release their eggs at the same time the male releases its sperm (McPhail and Lindsey 1970; Heard 1991). After spawning both adults die (McPhail and Lindsey 1970). Eggs incubate in gravel interstices for five to eight months depending on water temperatures (McPhail and Lindsey 1970; Scott and Crossman 1973; Heard 1991). Upon hatching, alevins remain in the gravel for several weeks before emerging some time in early April and May, at which time they migrate downstream (McPhail and Lindsey 1970; Scott and Crossman 1973; Heard 1991). Fry emerging from spawning grounds farther from the sea hide in gravel by day, becoming active at night (Scott and Crossman 1973). After migrating downstream fry form large schools and may remain in estuaries for several months before migrating out to sea (McPhail and Lindsey 1970; Scott and Crossman 1973). Pink salmon have a two year life cycle and rarely live to three years of age (McPhail and Lindsey 1970; Scott and Crossman 1973; Craig and Haldorson 1986; Heard 1991).

Round whitefish (*Prosopium cylindraceum*)

The round whitefish is found in both the NT and NU, from Great Slave Lake throughout the Mackenzie River Valley in the NT, eastward through to the Keewatin district of NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980). The round whitefish is most commonly found in shallows of lakes, ponds, slow flowing rivers and streams, as well as in brackish waters (McPhail and Lindsey 1970; Scott and Crossman 1973). Round whitefish are known to exhibit lacustrine as well as adfluvial life history types, and may exhibit a riverine life history type in some regions (Normandeau 1969; Bryan and Kato 1975; Goodyear *et al.* 1982; Morin *et al.* 1982).

Round whitefish spawn from autumn to early winter (McPhail and Lindsey 1970; Scott and Crossman 1973; Goodyear *et al.* 1982) usually in October in northern regions (Lawrence and Davies 1978). Spawning occurs primarily in lakes and on occasion in streams and rivers (Normandeau 1969; McPhail and Lindsey 1970; Scott and Crossman 1973; Bryan and Kato 1975; Morrow 1980; Becker 1983; Haymes and Kolenosky 1984).

Spawning typically takes place over gravel and rubble substrates (Normandeau 1969; Bryan and Kato 1975; Morrow 1980), although spawning has been observed over sand and silt substrates in areas with emergent vegetation (Bryan and Kato 1975). Round whitefish typically spawn in shallow water < 1 m deep (Normandeau 1969; Bryan and Kato 1975) but may spawn at depths from 5-10 m (Koelz 1929; Goodyear *et al.* 1982; Lawrence and Davies 1978; Haymes and Kolenosky 1984). Eggs are broadcast over the substrate and incubate for 4-5 months, hatching some time from March to May (Goodyear *et al.* 1982).

Young are most often found on the bottom in areas with rock, sand and gravel substrates at depths from 1.5-4.5 m (Normandeau 1969; Goodyear *et al.* 1982). Stein *et al.* (1973) found that the minimum age of maturity was eight years, although Kennedy (1949) reported maturation at ages six and seven. Round whitefish frequent depths between seven and 22 m of water (Becker 1983). Adults are typically found over rocky substrates often in association with boulders (Normandeau 1969; McPhail and Lindsey 1970). Kennedy (1949) reported that round whitefish in Great Bear Lake preferred areas with currents, and were common in outlets of the lake. Round whitefish feed on the bottom and feed almost exclusively on small benthic invertebrates (Carl *et al.* 1967; Scott and Crossman 1973; Armstrong *et al.* 1977). Although the round whitefish is widely distributed in northern waters, it is one of the least studied of the coregonines (Mraz 1964), and further investigations should be performed relating to the general biology and habitat requirement of this species.

Shortjaw cisco (*Coregonus zenithicus*)

The shortjaw cisco reaches the northern portion of its known distribution in Great Slave Lake in the NT and is not known to occur in NU (Scott and Crossman 1973; Lee *et al.* 1980). Shortjaw cisco are found in cool deep water lakes at considerable depths (Scott and Crossman 1973; Lee *et al.* 1980; Houston 1988). Shortjaw cisco are only known to exhibit a lacustrine life history type (Scott and Crossman 1973; Houston 1988). Scott and Crossman (1973) note that a dwarf or small form of *C. zenithicus* may exist in southern regions, although there are no reports of this form occurring in the NT.

Shortjaw cisco spawn in the fall (Scott and Crossman 1973), from October to early December in the Great Lakes (Koelz 1929; Goodyear *et al.* 1982), but likely spawn earlier in northern areas. Although, typically spawning in the fall, shortjaw cisco may also spawn in the spring and early summer depending on the population (Todd and Smith 1980; Houston 1988). Shortjaw cisco are believed to spawn over clay and sand substrates depositing their eggs on the bottom (Koelz 1929; Van Oosten 1937; Goodyear *et al.* 1982; Houston 1988). Spawning has been reported to occur at a variety of depths from 9-18 m (Goodyear *et al.* 1982), 37-73 m (Van Oosten 1937), 36.6-73.2 m (Slastenenko 1958), and 18-55 m (Koelz 1929). Larvae are pelagic in open water (Goodyear *et al.* 1982), although no preference for depth was found for this life history stage. Cisco usually reach sexual maturity by their fifth or sixth year in the Great Lakes (Houston 1988). Adult shortjaw cisco typically inhabit deep water areas of lakes from 55-144 m in depth, well below the thermocline (Keolz 1929; Becker 1982; Houston 1988). Although, they have been taken at depths as shallow as 18 m and as deep as 183 m (Scott and Crossman 1973). In Great Slave Lake cisco were most common in 20–60 m of water

(Rawson 1951). Dryer (1966) noted changes in seasonal depth from 110-114 m in the spring, 55-71 m in the summer, to 73-90 m in the winter. The shortjaw cisco feeds on small crustaceans and insects, with *Pontoporeia* and *Mysis* making up a significant portion of the diet (Slastenenko 1958; Becker 1982; Scott and Crossman 1973). Very little is know of the general biology and habitat requirements of this species, and further more detailed studies need to be undertaken.

Trout-Perches (Percopsidae)

Trout-perch (*Percopsis omiscomaycus*)

Within the NT the trout-perch is distributed from the headwaters of the Mackenzie River to the Arctic Circle with its range extending into the southern portions of western NU (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973). The trout-perch is commonly found along sandy beaches of lakes, slow moving streams, and backwaters of large muddy rivers (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The trout-perch is known to exhibit lacustrine, adfluvial, and riverine life history types across its geographic range (Lawler 1954; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Becker 1983).

Trout-perch spawn from late spring to early summer, usually between early May and the first half of July (Fish 1932; Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Hall and Rudstam 1999). Spawning takes place primarily in the shallows of slow streams or along beaches in lakes, mostly at night (Lawler 1954; Magnuson and Smith 1963; McPhail and Lindsey 1970; Becker 1983). In lakes spawning occurs on beaches and shoals typically in shallow water < 1 m deep, over gravel and sand substrates (Magnuson and Smith 1963; Scott and Crossman 1973; Goodyear *et al.* 1982). The eggs are large and adhesive when laid and stick to vegetation or the bottom (Magnuson and Smith 1963; Carl *et al.* 1967; McPhail and Lindsey 1970), incubating for 6-7 days before hatching (McPhail and Lindsey 1970; Goodyear *et al.* 1982). After hatching young remain in inshore areas near spawning grounds for some time and may be found near the bottom over sand, gravel and mud substrates usually in < 10 m of water (Magnuson and Smith 1963; Goodyear *et al.* 1982; Hall and Rudstam 1999). Later on in the summer young move offshore to deeper water (Goodyear *et al.* 1982). Juveniles are primarily benthic (Hall and Rudstam 1999) and no specific information on other habitat requirements for this life history stage was found.

In lakes trout-perch make diel movements to inshore areas at night, and are seldom seen or taken in shallow waters during daylight hours (Carl *et al.* 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Becker 1983). However, this may be due to the fact that like many other small fish species trout-perch often hide under stones during the day (Nelson and Paetz 1992). Trout-perch are found most commonly over sand and mud substrates (Becker 1983) in inshore areas frequently on the bottom (Dahlberg 1981). The trout-perch has been taken at depths of almost 200 feet in Lake Erie (Carl *et al.* 1967), although it is more common at depths from 7-15 m in lakes during the summer (Dahlberg 1981). Little is known of the food habits of this species, however they are known to feed on chironomids, amphipods, mollusks and small crustaceans (Dymond 1926; McPhail and Lindsey 1970; Stein *et al.* 1973). Trout-perch are considered to be an important forage species (McPhail and Lindsey 1970; Scott and Crossman 1973) and further studies should be performed to gain a better understanding of the life history requirements of this species.

SUMMARY AND RECOMMENDATIONS

It is obvious from the information presented above there is a significant lack of information on specific lake habitat requirements of freshwater fish in the NT and NU. In general knowledge is lacking in the discrimination of species, their distributions, life history types, and specific lacustrine habitat requirements. As a result, comparisons of lacustrine habitat requirements across drainage basins and ecozones could not be made and an ecosystem approach could not be taken. It is very likely that differences in habitat requirements and biology occur within a species between different ecozones in the north. Much of the work which has been completed to date has resulted from oil and gas resource development reports in the Mackenzie River Basin. As industrial development increases in northern areas there will be a significant need to identify and protect critical fish habitat such as spawning, nursery, feeding, and overwintering areas as well as the migration routes between these areas. In the interim it is hoped that the information presented in this report will serve as a reference for identifying essential freshwater fish habitat in the Northwest Territories and Nunavut.

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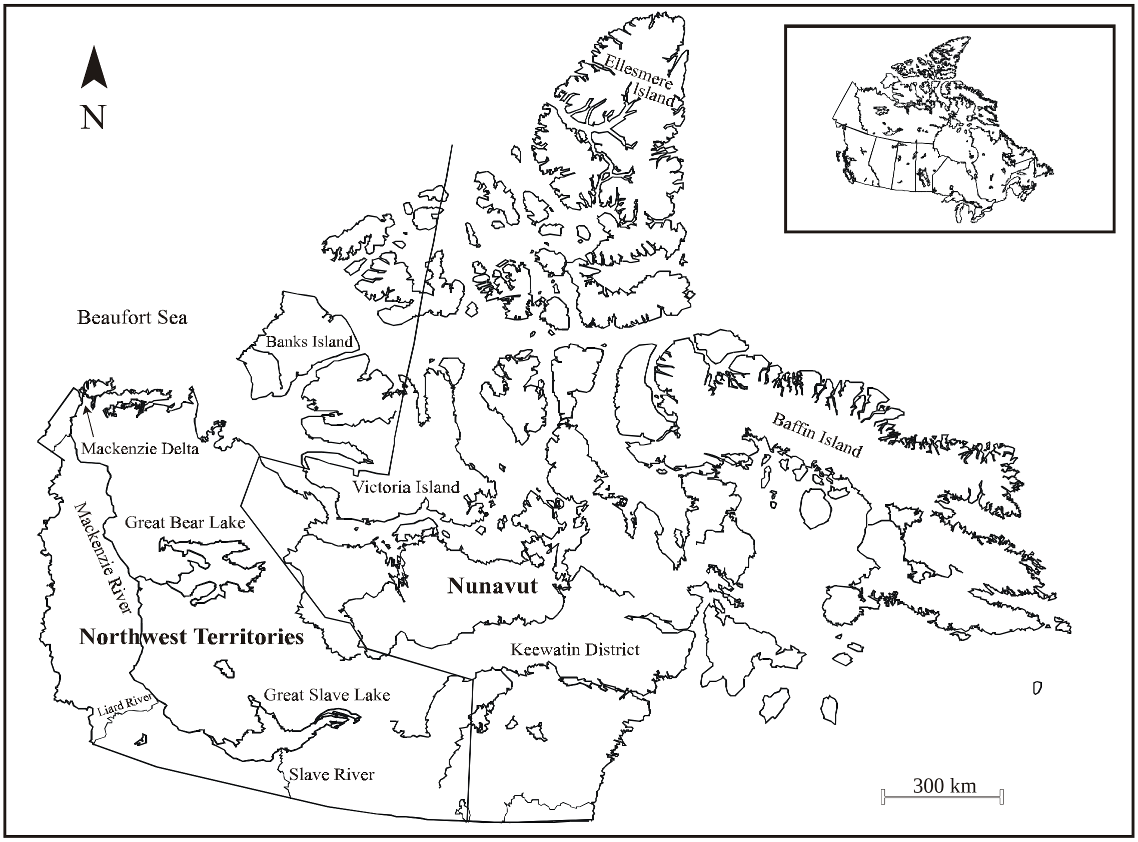

Figure 1. Map of Northwest Territories and Nunavut highlighting reference locations throughout the report.

Table 1. List of fish species occurring in fresh waters in the Northwest Territories and Nunavut.

Commmon Name	Scientific Name	Northwest Territories	Nunavut
CODS	GADIDAE		
burbot	*Lota lota* (Linnaeus, 1758)	X	X
LAMPREYS	PETROMYZONTIDAE		
Arctic lamprey	*Lampetra japonica* (Martens 1868)	X	
darktail lamprey	*Lethenteron alaskense* (Valdykov and Kott, 1978)	X	
CARPS and MINNOWS	CYPRINIDAE		
emerald shiner	*Notropis atherinoides* (Rafinesque, 1818)	X	
fathead minnow	*Pimephales promelas* (Rafinesque, 1820)	X	
finescale dace	*Phoxinus neogaeus* (Cope, 1869)	X	
flathead chub	*Platygobio gracilis* (Richardson 1836)	X	
lake chub	*Couesius plumbeus (Agassiz, 1850)*	X	X
longnose dace	*Rhinichthys cataractae* (Valenciennes,1842)	X	
northern redbelly dace	*Phoxinus eos* (Cope, 1862)	X	
peamouth	*Mylocheilus caurinus* (Richardson, 1836)	X	
pearl dace	*Semotilus margarita* (Cope, 1868)	X	
spottail shiner	*Notropis hudsonius* (Clinton, 1824)	X	
MOONEYES	HIODONTIDAE		
goldeye	*Hiodon alosoides* (Rafinesque, 1819)	X	
PERCHES	PERCIDAE		
Iowa darter	*Etheostoma exile* (Girard, 1860)	X	
walleye	*Stizostedion vitreum* (Mitvhill, 1818)	X	X
yellow perch	*Perca flavescens* (Mitchill, 1814)	X	
PIKES	ESOCIDAE		
northern pike	*Esox lucius* (Linnaeus, 1758)	X	X
SCULPINS	COTTIDAE		
deepwater sculpin	*Myoxocephalus thompsoni* (Linnaeus, 1758)	X	
fourhorn	*Myoxocephalus quadricornis* (Linnaeus, 1758)		X
slimy sculpin	*Cottus cognatus* (Richardson, 1836)	X	X
spoonhead sculpin	*Cottus ricei* (Nelson, 1876)	X	X
SMELTS	OSMERIDAE		
pond smelt	*Hypomesus olidus* (Pallas, 1814)	X	
rainbow smelt	*Osmerus mordax* (Mitchill, 1846)	X	X
STICKLEBACKS	GASTEROSTEIDAE		
brook stickleback	*Culaea inconstans* (Kirtland, 1841)	X	
ninespine stickleback	*Pungitius pungitius* (Linnaeus, 1758)	X	X
threespine stickleback	*Gasterosteus aculeatus* (Linnaeus, 1758)		X
SUCKERS	CATOSTOMIDAE		
longnose sucker	*Catostomus catostomus* (Forster, 1753)	X	X
white sucker	*Catostomus commersoni* (Lacepede, 1803)	X	X
TROUTS	SALMONIDAE		
Arctic char	*Salvelinus alpinus* (Linnaeus, 1758)	X	X
Arctic cisco	*Coregonus autumnalis* (Pallas, 1776)	X	X
Arctic grayling	*Thymallus arcticus* (Pallas, 1776)	X	X
broad whitefish	*Coregonus nasus* (Pallas, 1776)	X	X
bull trout	*Salvelinus confluentus* (Suckley, 1859)	X	
chum salmon	*Oncorhynchus keta* (Walbaum, 1792)	X	
Dolly Varden	*Salvelinus malma* (Walbaum, 1792)	X	
inconnu	*Stenodus leucichthys* (Güldenstadt, 1772)	X	
lake cisco (lake herring)	*Coregonus artedi* (Le Sueur, 1818)	X	X
lake trout	*Salvelinus namaycush* (Walbaum, 1792)	X	X
lake whitefish	*Coregonus clupeaformis* (Mitchill, 1818)	X	X
least cisco	*Coregonus sardinella* (Valenciennes, 1848)	X	X
pink salmon	*Oncorhynchus gorbushca* (Walbaum, 1792)	X	
round whitefish	*Prosopium cylindraceum* (Pallas, 1784)	X	X
shortjaw cisco	*Coregonus zenithicus* (Jordan and Evermann 1909)	X	
TROUT-PERCHES	PERCOPSIDAE		
trout-perch	*Percopsis omiscomaycus* (Walbaum, 1792)	X	X

Table 2. Common life history types of freshwater fish species found in the Northwest Territories and Nunavut.

Common Name	Scientific Name	Anadromous Life History Type	Riverine Life History Type	Lacustrine Life History Type
CODS	GADIDAE			
burbot	*Lota lota*		X	X
LAMPREYS	PETROMYZONTIDAE			
Arctic lamprey	*Lampetra japonica*	X	X	X
darktail lamprey	*Lethenteron alaskense*		X	
CARPS and MINNOWS	CYPRINIDAE			
emerald shiner	*Notropis atherinoides*		X	X
fathead minnow	*Pimephales promelas*		X	X
finescale dace	*Phoxinus neogaeus*		X	X
flathead chub	*Platygobio gracilis*		X	
lake chub	*Couesius plumbeus*		X	X
longnose dace	*Rhinichthys cataractae*		X	X
northern redbelly dace	*Phoxinus eos*		X	X
peamouth	*Mylocheilus caurinus*		X	X
pearl dace	*Semotilus margarita*		X	X
spottail shiner	*Notropis hudsonius*		X	X
MOONEYES	HIODONTIDAE			
goldeye	Hiodon alosoides		X	X
PERCHES	PERCIDAE			
Iowa darter	*Etheostoma exile*		X	X
walleye	*Stizostedion vitreum*		X	X
yellow perch	*Perca flavescens*		X	X
PIKES	ESOCIDAE			
northern pike	*Esox lucius*		X	X
SCULPINS	COTTIDAE			
deepwater sculpin	*Myoxocephalus thompsoni*			X
fourhorn	*Myoxocephalus quadricornis*			X
slimy sculpin	*Cottus cognatus*	X	X	X
spoonhead sculpin	*Cottus ricei*		X	X
SMELTS	OSMERIDAE			
pond smelt	*Hypomesus olidus*		X	X
rainbow smelt	*Osmerus mordax*	X	X	X
STICKLEBACKS	GASTEROSTEIDAE			
brook stickleback	*Culaea inconstans*		X	X
ninespine stickleback	*Pungitius pungitius*		X	X
threespine stickleback	*Gasterosteus aculeatus*	X	X	X
SUCKERS	CATOSTOMIDAE			
longnose sucker	*Catostomus catostomus*		X	X
white sucker	*Catostomus commersoni*		X	X
TROUTS	SALMONIDAE			
Arctic char	*Salvelinus alpinus*	X		X
Arctic cisco	*Coregonus autumnalis*	X		
Arctic grayling	*Thymallus arcticus*		X	X
broad whitefish	*Coregonus nasus*	X	X	X
bull trout	*Salvelinus confluentus*		X	X
chum salmon	*Oncorhynchus keta*	X		
Dolly Varden	*Salvelinus malma*	X	X	
inconnu	*Stenodus leucichthys*	X		X
lake cisco (lake herring)	*Coregonus artedi*			X
lake trout	*Salvelinus namaycush*			X
lake whitefish	*Coregonus clupeaformis*	X	X	X
least cisco	*Coregonus sardinella*	X		X
pink salmon	*Oncorhynchus gorbushca*	X		
round whitefish	*Prosopium cylindraceum*		X	X
shortjaw cisco	*Coregonus zenithicus*			X
TROUT-PERCHES	PERCOPSIDAE			
trout-perch	*Percopsis omiscomaycus*		X	X

Table 3. Lacustrine habitat requirements data for burbot.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Sorokin (1971) notes that burbot eggs only develop when oxygen concentrations are high. Increased flow of water and oxygenation of eggs in riverine environments may be one of key factors influencing tributary spawning migrations in lacustrine populations. Areas of upwelling may also provide important spawning habitat for burbot.

Table 4. Lacustrine habitat requirements data for emerald shiner.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Campbell and McCrimmon (1970) noted that spawning took place on exposed shore lines where wave and ice action kept the bottom free of mud, detritus and aquatic vegetation.
Emerald shiners are often found schooling around man made structures such as boat houses and docks (Campbell and McCrimmon 1970; Scott and Crossman), which may provide cover for this species.

Table 5. Lacustrine habitat requirements data for the fathead minnow.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Wynne-Edwards (1932) reported the use of water-lilies (*Nuphar adveral*) as nest sites for minnows; noting the importance of vegetation for spawning in the absence of other substrates.

Table 6. Lacustrine habitat requirements data for the finescale dace.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Although little is known of the spawning habits of this species, it appears cover plays an important role (3).

Table 7. Lacustrine habitat requirements data for the lake chub.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
There was no information available in the literature reviewed on habitat requirement of YOY lake chub, therefore it was assumed that they spend a portion of their first year of life in spawning areas.
Lake chub move seasonally to deeper waters during the summer as water temperatures increase (1,10,11).

Table 8. Lacustrine habitat requirements data for the longnose dace.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Hubert and Rahel (1989) note that longnose dace are associated with overhead cover and vegetation in streams, making these likely habitat requirements in the littoral zone of lakes.

Table 9. Lacustrine habitat requirements data for the northern redbelly dace.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Dace show a preference for dense cover habitat characterized by *Cassandra calyculata* over sparse cover habitat (*Sparganium* sp.) during the day (Naud and Magnan 1988), with cover likely playing a key role in the reproduction and predator-prey relationships of this forage fish species.
No information was found regarding the depth of spawning for this species but it is assumed that spawning takes place in the shallow waters in which this species is commonly found.

Table 10. Lacustrine habitat requirements data for the peamouth.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Although no specific information relating to substrate requirements of this species was found it appears that submerged aquatic vegetation is an important habitat requirement of this species throughout its life cycle (2,3,4).

Table 11. Lacustrine habitat requirements data for the pearl dace.

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depth:								
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	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								
Trees & Brush								

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
No information on habitat use of young dace in lakes was found so it is assumed that habitat requirements for lake forms will be similar to that of stream forms as described by Tallman and Gee (1982), with young dace being found over silt, clay, and detritus substrates at depths of 0-5 m often in association with vegetation.

Table 12. Lacustrine habitat requirements data for the spottail shiner.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depth:								
0-1 meters	H			H	2,6			1,6
1-2 meters	H			H	2,6			1,6
2-5 meters	H			H	2,6			1,5,6
5-10 meters	M			M	2			1,5,6
10+ meters	M			M	2			1,6
Substrate:								
Bedrock				L				1
Boulder				L				1
Rubble	H	H		M	2	2		3
Cobble	H	H		M	2	2		3
Gravel	H	H		H	2,4	2		1
Sand	H	H		H	2,4,56	2		1,3
Silt				M				1
Muck (detritus)				L				1
Clay				L				1
Pelagic								
Cover:								
None								
Submergents	H	H		M	2,6	2		1,4
Emergents		H		M		2		1,4
Overhead								
In Situ								
Trees & Brush								

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Both Wells and House (1974) and Goodyear *et al.* (1982) noted that female spottail shiners deposit eggs in *Cladophora sp.,* which may provide important spawning habitat for this species.

Table 13. Lacustrine habitat requirements data for goldeye.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Kristensen and Sekerak (1976) reported that catches of goldeye fry were higher in areas where ragwort (*Senecio* spp.) was present and that goldeye catches tended to be low in areas where horsetail (*Equisetum* spp.) was present. Although no definitive studies on the importance of terrestrial and submergent vegetation have been conducted, certain vegetation species such as those mentioned above may provide key habitat features for young goldeye.

Table 14. Lacustrine habitat requirements data for Iowa darter.

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

[1]**Ratings are Nil (default), Low, Medium or High.**
[2]**Sources are numbered and references starting on page 128 of this report.**
[3]**Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults**

Comments and observations:
This species is intolerant of turbid and muddy waters and therefore may be highly affected in areas of resource development (Scott and Crossman 1973).
Iowa darters are commonly associated with aquatic vegetation throughout their life cycle particularly filamentous algae covering stones and plants (1,4,5,6).

Table 15. Lacustrine habitat requirements data for walleye.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depth:								
0-1 meters	H	H		H	1,3,4,5,6,8,11,13,15	3,5,15,16		1,4,14,18,19
1-2 meters	H	H		H	3,4,5,6,8,11,13,15	5,16		3,4,14,18,19,20
2-5 meters	M	H		H	4,5,6,13	5,16		2,4,9,14,17,18, 19
5-10 meters	L	M		M	5	16,19		2,4,9,14,17,17, 19
10+ meters				L				4,9,14,17,18,19
Substrate:								
Bedrock	L				6			
Boulder	H			M	3,5,6,8,11,13,20			1,7,13,19
Rubble	H			H	3,4,5,6,8,11,14,15			1
Cobble	L			H	6			4
Gravel	H	H		H	3,4,6,8,11,12,13,15,19,21	5		1,4,7
Sand	M	H		H	3,5,6,8,11,13,14,15	2,5,10		1,7
Silt				L				1
Muck (detritus)	L	H		H	6,8,11,15	5		1
Clay	L	H		M	5,11	5		1
Pelagic		M				3		
Cover:								
None								
Submergents	M	M		M	6,13,15	16		1,4,13,19
Emergents	M	M		M	6,13,15	16		13,16
Overhead				H				4,19
In Situ								
Submerged trees				M				13

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Walleye are very photosensitive and use banks, logs, and even turbidity to avoid sunlight (Ford *et al.* 1985).
Kristensen (1979) and Summers (1978) found that the distribution of young walleye was positively correlated with shoreline vegetation dominated by paper birch (*Betula papyrifera*) and willows (*Salix* spp.), sand or rock substratum and relatively warm water temperatures.
Although, walleye typically spawn in areas free of vegetation, Priegel (1970) noted that walleye preferred to spawn in marshes in association with vegetation over sand and gravel substrates.

Table 16. Lacustrine habitat requirements data for yellow perch.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Cooper *et al.* (1981) note the importance of nearshore areas and their role as nursery habitat for young perch.
Danehy *et al.* (1991) showed that improved growth in yellow perch was associated with structured habitat and that natural shoals may be important to local fish populations.

Table 17. Lacustrine habitat requirements data for northern pike.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depth:								
0-1 meters	H	H	H	H	2,8,9,14,15,16,17,18,22	2,9,11,13,14	8,14	4,6,8,14
1-2 meters	M	H	H	H	9,16,17	2,5,8,11,13,14	2,5,8,14	2,4,5,6,14
2-5 meters	L	L	L	H	9,16,17,19	5	2,5	2,4,5,6,8
5-10 meters	L			M	9,17,19		2,5	2,5,6
10+ meters				L				3,6,21,23
Substrate:								
Bedrock								
Boulder	M			H	9			12
Rubble	L				17			
Cobble	M				9			
Gravel	M			H	9			12
Sand	L	L	L	L	13	13	7	7,12
Silt	H	H	H	H	13,14,17,22	8,13,14	8	8
Muck (detritus)	H	H	H	H	2,13,17,22	2,3,8,13,14	1,2,3,8	2,4,6,8
Clay	H	H	H	H	2	2,3,8	1,2,3,8	8
Pelagic				H				3,4,5,23,24
Cover:								
None								
Submergents	H	H	H	M	2,9,14,15,16,18,22,23	2,3,8,9,10,11,13,14	1,2,3,8,14	2,4,5,6,8,14,19
Emergents	H	H	H	M	2,9,14,16,20	2,3,8,9	1,2,3,8	6
Overhead								
In Situ				L				14
Trees & Brush								

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Lawrence *et al.* (1977) noted that spawning does not occur in areas with cattails.
Both submergent and emergent vegetation types provide important habitat for pike throughout all life history stages (2,4,5,6,8,9,10,11,14,15,16,19).
Rawson (1932) noted that pike were found spawning around sedge hummocks in protected weedy regions, usually over very soft muskeg.

Table 18. Lacustrine habitat requirements data for deepwater sculpin.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Relatively very little information exists on the biology of this species due to the great depths in which it is found (Parker 1988; Scott and Crossman 1973).
Although no information on juvenile deepwater sculpin was located, it is assumed that they inhabit similar habitats as adults, following their transition to bottom habitats.

Table 19. Lacustrine habitat requirements data for slimy sculpin.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
McDonald and Hershey (1992) found that slimy sculpin inhabiting soft sediment substrates showed increased growth, indicating that these environments may be more productive.
Males select nest sites on the under side of stones and logs in shallow water > 1.5 m deep (3,8,10,13).
Within the NT, slimy sculpin were found in areas with current and wind action in waters < 10 m deep (7).

Table 20. Lacustrine habitat requirements data for spoonhead sculpin.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Relatively little is known of the biology of this species (Scott and Crossman 1973; Houston 1990). Eggs are deposited under stones or logs over rubble, boulder, gravel, sand or mud substrates at up to 270 feet in depth (4).

Table 21. Lacustrine habitat requirements data for pond smelt.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Pond smelt have been known to spawn over peat substrates amongst macrophytes in northern lakes (2).
Adults are pelagic (4) although no information on the habitat requirements for this portion of the life cycle were found.

Table 22. 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
Depth:								
0-1 meters	H	H	H		1,3,10,11	1	1	
1-2 meters	H	H	H		1,3	1	1	
2-5 meters	H	H	H		9	1,6	1	
5-10 meters		H	H			1,6	1	
10+ meters		H	H	H		1,5,6	1,5,12	1,5,13
Substrate:								
Bedrock								
Boulder	H	H			3	3		
Rubble	H	H			3,10,11	3		
Cobble	H	H			3,9,10,11	3		
Gravel	H	H			2,3,9,10,11,13	3		
Sand	H				3,9,10,11			
Silt	H				3			
Muck (detritus)	H	H			3	3		
Clay	H				3			
Pelagic		H	H	H		6,7	6	1,3,7,8,12,13
Cover:								
None								
Submergents	H				3,9			
Emergents	H				3			
Overhead								
In Situ	H				3,9			
Mussel shells					9			

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Adult rainbow smelt spawn over a wide variety of substrates including boulder, rubble, cobble, gravel, sand, silt, muck and clay (3,9,10,11,13).
Goodyear *et al.* (1982) note that spawning may take place in wave swept areas of lakes.
Conversely Ivanova and Polokova (1972) note that spawning usually takes place in protected areas with little wind or wave action.

Table 23. Lacustrine habitat requirements data for brook stickleback.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Brook stickleback may seek cover and have been observed burrowing into silty substrates in streams (Degraeve 1970) as well as under dead leaves, vegetative detritus and amongst rocks (5). Although no specific habitat requirements were found for juvenile fish, it is assumed that vegetation as in all other life history stages is an important habitat component.

Table 24. Lacustrine habitat requirements data for ninespine stickleback.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Although ninespine stickleback typically spawn in association with vegetation, they may also spawn in burrows constructed in mud substrates as well as between or under rocks (4,6).
No information on juvenile habitat use was located, this is attributed to that fact that this species matures in less than one year, and thus the juvenile life history is likely short.
Vegetation is a key habitat requirement throughout all life history stages (3,4,5,7,9,12,13,14).

Table 25. 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
Depth:								
0-1 meters	H	H	H	H	6,7,8,10,15,16	5,10,14,15	5,14,15	2,11,14,15
1-2 meters	H	H	H	H	6,7,8,10,15,16	5,10,14,15	5,14,15	2,11,14,15
2-5 meters	L			H	7,16			2,11
5-10 meters	L			M	7,16			2,11
10+ meters	L			L	4,7			2,13
Substrate:								
Bedrock								
Boulder								
Rubble	L			L	16			13,14
Cobble	L			L	16			11,13,14
Gravel	L			L	16			11,13
Sand	H				3,10,15,16			
Silt	H				16			
Muck (detritus)	H				3,4			
Clay	H	L	L	H	4,9	7	7	14
Pelagic				H				1,2,7,10,12
Cover:								
None	M				4,7,8,16			
Submergents	M	H	H	H	3,6,7,9,10,13	3,5,10	5	7,9,11,12,13
Emergents	M	H	H	H	3,6,7,9,10,13,14	3,5,10	5	7,9,11,12
Overhead				H				7
In Situ				H				7
Trees & Brush								

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Threespine stickleback are often associated with vegetation (8,9,11,12,13), in addition they may also occur in open water areas (1,2,8,10,12).
Very little information was found on the habitat requirements of young-of-the-year and juvenile threespine stickleback.
Males avoid nesting in water < 0.2 m deep (6,7), possibly to avoid damage from wave action (6).
Adult stickleback may be found in association with vegetation (8,9,10,13) or in open water (4,7,8).

Table 26. Lacustrine habitat requirements data for longnose sucker.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Longnose suckers were found in association with submerged pulpwood logs in a Maine reservoir (10).
Both young and juvenile longnose suckers were found to be associated with aquatic vegetation, which may provide important rearing habitat (1,3).
Longnose sucker spawn primarily in streams, although spawning may take place in lakes along rocky wave swept shorelines at depths of 15-30 cm (5,11,12).

Table 27. Lacustrine habitat requirements data for white sucker.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
White sucker were found in association with submerged pulpwood logs in a Maine reservoir (6).
Young white suckers may be found in association with vegetation (4).
White suckers typically spawn in streams (3,5,7), although they are known to spawn in shallows along the shoreline of lakes (3,4,7).

Table 28. Lacustrine habitat requirements data for (freshwater resident normal) Arctic char.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Juveniles are most often found in the benthic areas of lakes at depths > 5 m avoiding littoral and shallow benthic habitats which are often occupied by large conspecifics and potential predators (Johnson 1980; Klemetsen *et al.* 1989; Bjoru and Sandlund 1995; 4,18,24).
Similar to young-of-the-year juveniles seek cover amongst boulder, rubble and cobble substrates as well as in vegetation (3,13,24).
Adults make seasonal habitat shifts to pelagic habitats in the summer to feed on abundant zooplankton (1,4,6,12,14,18,20,21,24,30).

Table 29. Lacustrine habitat requirements data for (freshwater resident dwarf) Arctic char.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Adult dwarf char generally inhabit shallow littoral habitats 0-5 m in depth moving to the pelagic zone during late summer and fall (1,2,4,5,9).
Juveniles are most often found in the profundal zone in water > 5 m in depth (1,5).
No literature was found on the lacustrine habitat requirements of young dwarf arctic char, thus it was assumed that young-of-the-year select similar habitats as juveniles.

Table 30. Lacustrine habitat requirements data for Arctic grayling.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Within the Mackenzie River grayling were commonly found hiding under overhanging trees, darting up to feed on falling insects (2).
Arctic grayling are typically found in shallow water (3,7,10) primarily over rubble, cobble and gravel substrates (3,5,8).
Within the NT grayling have been reported to occur on rocky shorelines (Rawson 1951; McPhail and Lindsey 1970) and in association with streams in bays of lakes (Miller 1946).

Table 31. Lacustrine habitat requirement data for bull trout.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Lacustrine populations are primarily found in profundal and littoral areas of lakes (2,4,5). Connor *et al.* (1997) noted that bull trout were most often caught within 3 m of the bottom, and were most often observed at depths ranging from 22.5 to 40 m using hydroacoutstics.
Young bull trout may spend several years in their natal streams before entering lakes (Stelfox and Egan 1995; 1,4).

Table 32. Lacustrine habitat requirements data for the inconnu.

Habitat Features:	**Ratings[1]**				**Sources[2]**			
Categories[3]	S	Y	J	A	S	Y	J	A
Depth:								
0-1 meters								
1-2 meters				H				2
2-5 meters				H				2
5-10 meters				H				2
10+ meters				H				1
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel								
Sand								
Silt								
Muck (detritus)								
Clay								
Pelagic								
Cover:								
None								
Submergents								
Emergents								
Overhead								
In Situ								
Trees & Brush								

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Fuller (1955) notes that inconnu were rarely taken in water deeper than 30 m.
Rawson (1951) captured inconnu to depths of 75 m, with fish being most common in 2-10 m of water.
Although no information was found for young-of-the-year or juvenile inconnu, it is assumed that they would be found in similar habitats as other coregonid species at similar life stages.

Table 33. Lacustrine habitat requirements data for the lake herring (lake cisco).

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Spawning most often takes place over sand and gravel substrates (3,7,9,10,11,15).
Young-of-the-year show a preference for shallow water habitat in association with rocky substrates and vegetation (7,12).
No habitat requirements for juvenile lake cisco were found, although it is assumed once young-of-the-year move into deeper water areas they become pelagic and remain so until maturity.

Table 34. Lacustrine habitat requirements data for lake trout.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Juvenile lake trout may seek cover amongst boulders and woody debris (9).
Lake trout typically spawn in areas free of sand, silt, and detritus (20,22,23), although spawning over these substrates have been observed (2,10).
Lake trout have been shown to spawn in association with vegetation in some areas (15,19).
No preference for substrate was found for adult lake trout, and in general they seek cooler deeper waters in the summer (19,22,27,28).

Table 35. Lacustrine habitat requirements data for lake whitefish (freshwater resident).

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Both YOY and juvenile lake whitefish show a preference for weedy areas which provide cover (8,11,13,18,23).
YOY leave shallow water areas and move into deeper waters in the summer (10,16,17,23,24).
Spawning occurs in shallow water over a variety of substrates, with gravel being the most common (2,5,6,8,10,15,17,18,19,24,25).

Table 36. Lacustrine habitat requirements data for (freshwater resident) least cisco.

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

[1]**Ratings are Nil (default), Low, Medium or High.**
[2]**Sources are numbered and references starting on page 128 of this report.**
[3] **Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults**

Comments and observations:
Least cisco were reported to spawn over sand and gravel substrates (1,3,4) in shallow water areas. Young least cisco showed a preference for areas without vegetation, whereas juveniles preferred areas with vegetation (2).
The lacustrine habitat requirements for all life history stages of this species are poorly understood and further studies should performed to gain basic information on its biology and life history requirements.

Table 37. Lacustrine habitat requirements data for round whitefish.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Spawning typically takes place over gravel and rubble substrates (2,8,9), although spawning has been observed over sand and silt substrates in areas with emergent vegetation (2).
Round whitefish spawn primarily in lakes and on occasion will spawn in streams and rivers (1,2,4,5,7,8,9,10).
Young round whitefish are most often found over rock, sand and gravel substrates (Goodyear *et al.* 1982) although no specific substrate requirements were found for juveniles or adults.

Table 38. Lacustrine habitat requirements data for shortjaw cisco.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
The shortjaw cisco is a deepwater species and prefers depths from 55-144 m (4), although they are known to occur at depths to 183 m (7).
Spawning occurs over clay and sand substrates (3,4).
Very little information exists on the biology of this species and further studies should conducted in order to gain a better understanding.

Table 39. Lacustrine habitat requirements data for trout-perch.

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

[1]Ratings are Nil (default), Low, Medium or High.
[2]Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y- young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Trout-perch typically spawn over sand and gravel substrates often in association with vegetation (5,6,8).
Trout-perch hide under rocks during the day (Nelson and Paetz 1992;7), which might help explain why they are rarely observed or taken during daylight hours.

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<u>Northern redbelly dace</u> (Table 9)
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<u>Iowa darter</u> (Table 14)
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Arctic grayling (Table 30)
1. **Beauchamp, D.A.** 1982.

2. **Bendock, T.** 1979.

3. **Bishop, F.G.** 1967.

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<u>Inconnu</u> (Table 33)
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15. **Lawrence, M.** and S. Davies. 1978.

16. **Lindstrom, T.** 1970.

17. **Machniak, K.** 1975a.

18. **Morrow**. 1980.

19. **Nester, R.T.** and T.P Poe. 1984.

20**. Qadri, S.U**. 1961. Food and distribution of lake whitefish in Lac la Ronge, Saskatchewan. Trans. Am. Fish. Soc. 90: 303-307.

21. **Rawson, D.S.** 1947.

22. **Rawson, D.S.** 1951.

23. **Reckahn, J.A.** 1970.

24. **Scott** and Crossman. 1973.

25. **Slastenenko, E.P.** 1958.

Least cisco (freshwater resident) (Table 36)
1. **Lawrence, M.** and S. Davies. 1978.

2. **Mann, G.J.** 1974.

3. **McPhail** and Lindsey. 1970.

4. **Scott** and Crossman. 1973.

Round whitefish (Table 37)
1. **Becker.** 1983.

2. **Bryan, J.E.** and D.A. Kato. 1975.

3. **Goodyear** *et al.* 1982.

4. **Haymes, G.T.** and D.P. Kolenosky. 1984.

5. **Koelz, W.** 1929.

6. **Lawrence, M.** and S. Davies. 1978.

7. **McPhail** and Lindsey. 1970.

8. **Morrow**. 1980.

9. **Normandeau, D.A.** 1969.

10. **Scott** and Crossman. 1973.

Shortjaw cisco (Table 38)
1. **Becker.** 1983.

2. **Dryer, W.R.** 1966.

3. **Goodyear** *et al.* 1982.

4. **Houston, J.J.** 1988.

5. **Koelz, W.** 1929.

6. **Paterson, C.G.** 1969. Occurrence of *Coregonus artedii* and *C. zenithicus* in Barrow Lake, Alberta. J. Fish. Res. Board Can. 26: 1934-1939.

7. **Rawson, D.S.** 1951.

8. **Scott** and Crossman. 1973.

9. **Slastenenko, E.P.** 1958.

10. **Van Oosten, J.** 1937.

Trout-perch (Table 39)
1. **Becker.** 1983.

2. **Dahlberg, M.D.** 1981.

3. **Dryer, W.R.** 1966.

4. **Dymond, J.R.** 1926.

5. **Goodyear** *et al.* 1982.

6. **Magnuson, J.J.** and L.L. Smith. 1963.

7. **Nelson** and Paetz. 1992.

8. **Scott** and Crossman. 1973.