Fish life history, diets, and habitat use in the Northwest Territories: freshwater sculpin species

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FISH LIFE HISTORY, DIETS, AND HABITAT USE IN THE NORTHWEST TERRITORIES: FRESHWATER SCULPIN SPECIES

by

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ABSTRACT

Arciszewski, T., Gray, M.A., Hrenchuk, C., Cott, P.A., Mochnacz, N.J., and Reist, J.D. 2015. Fish life history, diets, and habitat use in the Northwest Territories: freshwater sculpin species. Can. Manuscr. Rep. Fish. Aquat. Sci. 3306: vii + 41 p.

The freshwater sculpins of the Northwest Territories (NWT) are represented by the Slimy Sculpin (*Cottus cognatus*), Spoonhead Sculpin (*C. ricei*), and the Deepwater Sculpin (*Myoxocephalus thompsonii*). These sculpin species all are small-bodied, benthic, coolwater fishes that require clean substrates for spawning. Their diets appear to be general and are dependent on prey size, abundance, and availability near the bottom, and therefore rely little on drifting invertebrates in streams. Temperature is a key factor in determining sculpin presence and overall health, and may be a concern for sculpins if the NWT waterbodies experience rising water temperatures in the future as a result of climate change. Presumably, as long as sculpins are able to find deeper coolwater refugia, changes in density would not likely be seen unless water temperatures were sustained above 15° C. Large knowledge gaps exist and directed research on sculpins in Northern Canada is needed. Activities that introduce fine sediments into aquatic habitats could negatively affect sculpin species as with any other benthivorous aquatic biota. The Slimy Sculpin is becoming a widely used monitoring species because they are often more abundant and have a limited home range relative to larger bodied fishes. Life histories of all three sculpin species in the NWT are likely similar to their southern North American conspecifics, although this should not be assumed given the differences in biotic and abiotic variables in northern environments.

Key words: diet, life history, habitat use, Northwest Territories, habitat use, Cottidae, Slimy Sculpin, Spoonhead Sculpin, Deepwater Sculpin

RÉSUMÉ

Arciszewski, T., Gray, M.A., Hrenchuk, C., Cott, P.A., Mochnacz, N.J., and Reist, J.D. 2015. Cycle biologique du poisson, régimes alimentaires et utilisation de l'habitat dans les Territoires du Nord-Ouest : espèces de chabots d'eau douce. Can. Manuscr. Rep. Fish. Aquat. Sci. 3306: vii + 41 p.

Les chabots d'eau douce des Territoires du Nord-Ouest (T.N.-O.) sont représentés par le chabot visqueux (*Cottus cognatus*), le chabot à tête plate (*C. ricei*) et le chabot de profondeur (*Myoxocephalus thompsonii*). Ces espèces de chabots sont des poissons benthiques d'eau tempérée de petite taille qui ont besoin de substrats propres pour le frai. Leur régime alimentaire semble être relativement général et dépend de la taille des proies, de leur abondance relative et de leur disponibilité. Les chabots dépendent peu des invertébrés dérivant dans les cours d'eau. La température est un facteur clé pour déterminer la présence et la santé générale du chabot, et pourrait être une source de préoccupation si les T.N.-O. connaissent une hausse de la température de l'eau dans l'avenir en raison du changement climatique. Vraisemblablement, tant et aussi longtemps que les chabots sont en mesure de trouver refuge dans des eaux froides plus profondes, il est peu probable que l'on remarque des changements liés à la densité, à moins que les températures de l'eau ne se maintiennent au-dessus de 15 °C. Il faut mener des recherches sur les chabots dans le nord du Canada. Les activités qui introduisent des sédiments fins dans les habitats aquatiques pourraient avoir une incidence négative sur les espèces de chabots ainsi que sur tout autre biote aquatique benthivore. Le chabot visqueux sert de plus en plus souvent d'espèce de surveillance parce qu'il est souvent plus abondant, et que son domaine vital est plus limité que les poissons de plus grande taille. Le cycle biologique des trois espèces de chabots présents dans les T.N.-O. est plutôt semblable à celui de leurs congénères du sud de l'Amérique du Nord, bien que cela ne devrait pas être présumé, étant donné les différences dans les variables abiotiques et biotiques dans les milieux nordiques.

Mots clés : régime alimentaire, cycle biologique, utilisation de l'habitat, Territoires du Nord-Ouest, Cottidae, chabot visqueux, chabot à tête plate, chabot de profondeur

1.0 INTRODUCTION

The Family Cottidae consists of over 300 species across 70 genera that are found in both marine and fresh waters. Although most sculpin species are marine, there are three freshwater sculpin species reported in the Northwest Territories (NWT): Slimy Sculpin (*Cottus cognatus,* Richardson 1836), Spoonhead Sculpin (*C. ricei,* Nelson 1876), and Deepwater Sculpin (*Myoxocephalus thompsonii,* Girard 1851) (Sawatzky et al. 2007). This report reviews the literature for life history, diet, and habitat requirements of these three species. Scientific and anecdotal information from other sculpin species is also included where relevant.

Not surprisingly there is an extreme paucity of information on sculpins in the north when compared to other areas (e.g., the Laurentian Great Lakes basin), and therefore this report relies heavily on life history information gathered about these species from areas other than Arctic and sub-Arctic regions. Clearly there is a strong need for research to better understand how these three sculpin species may be affected by current and future developments, and to determine how well the information from southern areas relates to the NWT.

Of all the freshwater North American sculpin species, the Slimy Sculpin and Mottled Sculpin (*C. bairdi*) are the most extensively studied, likely due to their broad geographic distribution; spanning much of the continent. This report provides pertinent information on all three NWT sculpin species, however research has been focused predominantly on the Slimy Sculpin, and so discussions of cottid life history characteristics concern mostly this species. Although many of the previous reviews are valuable resources (e.g. Scott and Crossman 1973, Richardson et al., 2001, Evans et al., 2002), they suffer from the same information shortcomings that exist for other rarer species, and as a result often use data from closely related species to fill in knowledge gaps. For instance, spawning patterns of Slimy and Mottled sculpins are fairly well-studied, but this is not the case for either Spoonhead or Deepwater sculpins. We have tried to limit extrapolating information from one species to another however; in some cases there may be similar habits among the cottids discussed herein as appropriate.

2.0 COTTIDS OF THE NORTHWEST TERRITORIES

2.1 DISTRIBUTION

The Slimy Sculpin is widely distributed across North America (Figure 1), ranging from Virginia, Labrador, and Ungava in the east, through all of the provinces and territories, and into Alaska in the west (Scott and Crossman 1973). The range of Slimy Sculpin also extends into eastern Siberia (Scott and Crossman 1973). Slimy Sculpin does not occur within Nova Scotia, the Cypress Hills region of Saskatchewan, southern Alberta, and most of the lower portions of the coastal British Columbia drainages (Scott and Crossman 1973). The knowledge of the range of this species continues to expand; for example it has been recently reported from western Prince Edward Island by Gormley et al. (2005). Slimy Sculpin occurs throughout the mainland NWT, but is absent from the Arctic islands (Sawatzky et al. 2007).

The Spoonhead Sculpin is mainly restricted to Canada, the exception being within the United States portion of the Laurentian Great Lakes basin (Figure 1; Houston 1990; Scott and Crossman 1973). Historically, Spoonhead Sculpin ranged from the St. Lawrence River, westward through Alberta and the NWT (Scott and Crossman 1973). Populations of Spoonhead Sculpin within the Laurentian Great Lakes began to decline in the 1960's, but there are some reports of recovery in some areas of Lake Michigan (Potter and Fleischer 1992). In the Alberta foothills and neighbouring prairie provinces, Spoonhead Sculpin is primarily stream-dwelling (Nelson and Paetz 1992). Although found within the Mackenzie and Thelon River basins (south-eastern Yukon, NWT, and Nunavut), there are no validated records of Spoonhead Sculpin within Alaska (McPhail and Lindsay 1970; Scott and Crossman 1973). Information regarding the Spoonhead Sculpin is often restricted to presence or absence data due to the difficulties of collecting habitat information at significant depths in lakes and because of their nocturnal activity (Houston 1990; Potter and Fleischer 1992). In the NWT, Spoonhead Sculpin occurs in the Mackenzie, Liard, Slave, and Thelon drainages, in Great Slave Lake, but has not been recorded in Great Bear Lake (Sawatzky et al. 2007). Also, confusion and misidentification as Slimy Sculpin likely hinders our understanding of this species.

The Deepwater Sculpin has a more restricted geographical range than many other congeneric species (Figure 1).This species is considered to be a "glacial relict" (Scott and Crossman 1973). Originally inhabiting Arctic marine or brackish water, this species was pushed southward as ice sheets advanced during the Pleistocene ice age, and left in postglacial lakes upon glacial retreat (Scott and Crossman 1973; Sheldon et al. 2008). Current Deepwater Sculpin distribution is likely related to post-glacial dispersal through glacial lakes and the Champlain Sea (Kontula and Vainola 2003; Sheldon et al. 2008). In Canada, Deepwater Sculpin occurs in deep, cold lakes in western Quebec through Ontario, Manitoba, Saskatchewan, and NWT (Scott and Crossman 1973; COSEWIC 2006). In the United States this species is limited to Michigan and Minnesota (Scott and Crossman 1973). Within the Laurentian Great Lakes Deepwater Sculpin is rarely captured in Lake Huron (Houston 1990), are in decline in Lake Michigan

(Pothoven et al. 2011), and they were thought to be extirpated from lake Ontario, but have recolonized, and were thought to never be present in lake Erie (Lantry et al. 2007). The distribution of Deepwater Sculpin in the NWT is patchy; they are known to occur in Great Slave and Great Bear lakes, Lac la Marte, as well as the Husky Lakes, which is connected to the Beaufort Sea (Sawatzky et al. 2007).

Sheldon et al. (2008) never found Spoonhead and Deepwater sculpins in the same lakes and suggested that there may be some competitive exclusion occurring outside of the Great Lakes. However, Cott et al. (2011) found all three species co-occurring in three medium-sized (365-547 ha, 32-34.5 maximum depth) lakes located 30 km north of Yellowknife.

2.2 SPECIES DESCRIPTION AND DISTINCTION

The three freshwater sculpin species found in the NWT have physiological, anatomical, and morphological features that are characteristic of a benthic lifestyle. These Cottids lack scales, have no swim bladder, are dorso-ventrally flattened, have a broad flattened head, and are posteriorly tapered (Figure 2). One of the dominant anatomical features of the sculpin is the large wing-like pectoral fins. When extended laterally the pectoral fins generate negative lift, thus allowing the fish to maintain their position in flowing waters (Webb et al. 1996). Coombs et al. (2007) found that in laboratory flume studies using digital particle image velocimetry, Mottled Sculpin pectoral fins simultaneously created a hydrodynamic footprint of the fish's' presence that may be detected by the lateral line of nearby fish. The pectoral fins may also be used for display purposes by males during courtship (Savage 1963), intraspecific competition, for fanning the incubating eggs in the nest, or when a fish is threatened by a predator.

As different species of sculpin share many features, identification can be difficult in areas where several species overlap, for example in the lower Columbia River in British Columbia (McPhail 2007). Although identification is difficult and requires practice, several features can be used to distinguish among Slimy, Spoonhead, and Deepwater sculpins in those areas where they are sympatric, such as the Mackenzie River basin (Figure 2). The features used to distinguish among these three species are summarized in Table 1.

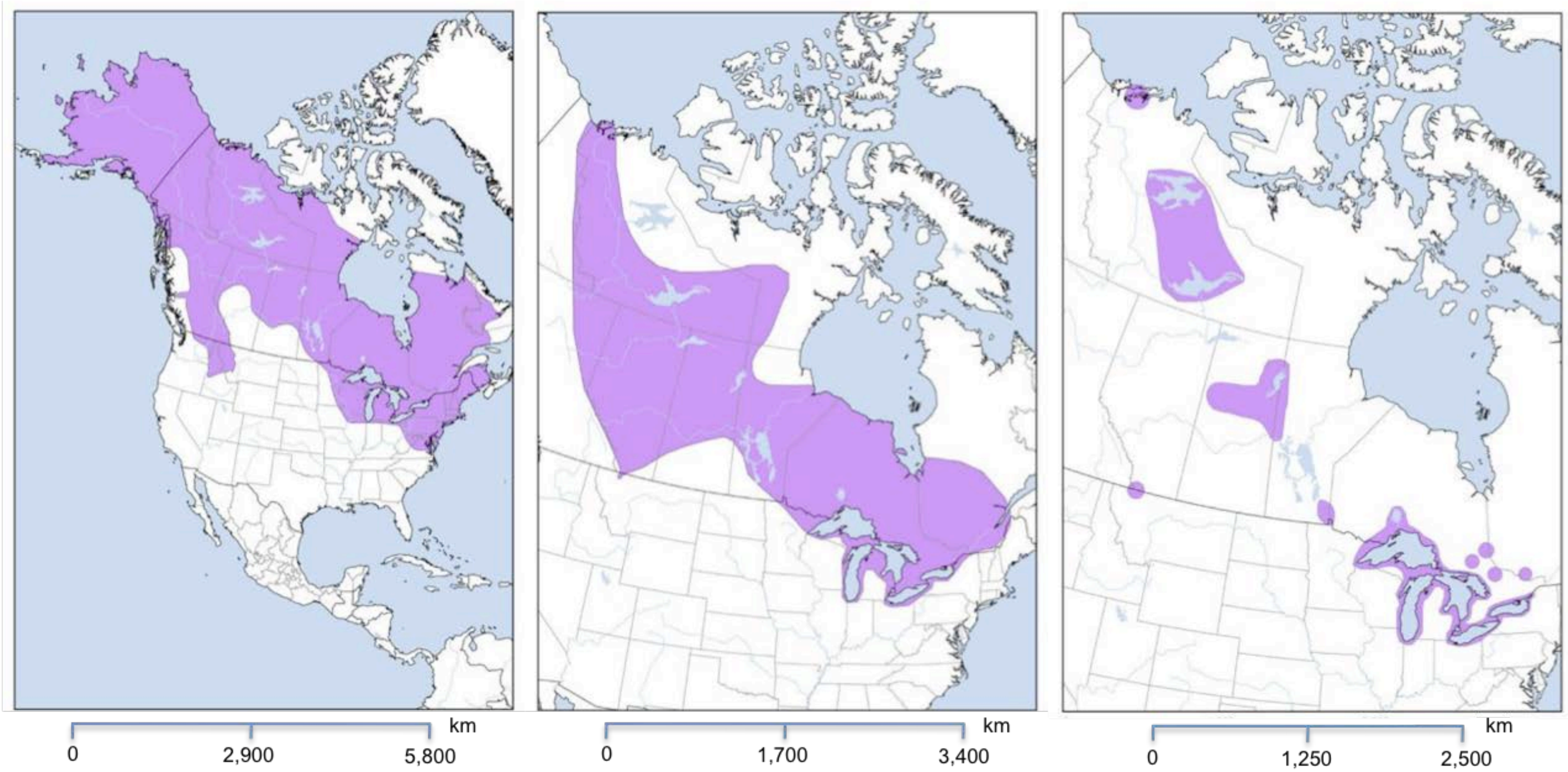

Figure 1. North American distributions for Slimy Sculpin (left), Spoonhead Sculpin (middle), and Deepwater Sculpin (right). Printed with permission of Montana Natural Heritage Program and Montana Fish, Wildlife and Parks, 2010. (Accessed on November 18, 2014, from http://FieldGuide.mt.gov/speciesDetail.aspx?elcode=AFC4E04020); originally adapted from Lee et al. (1980) and Scott and Crossman (1973).

Figure 2. Photos of Slimy Sculpin (top), Spoonhead Sculpin (middle), and Deepwater Sculpin (bottom). Photo credits: Doug Watkinson, Fisheries and Oceans Canada.

Table 1. Key morphological features of Slimy, Spoonhead, and Deepwater Sculpin (*compiled from multiple sources*).

Feature	**Slimy Sculpin**	**Spoonhead Sculpin**	**Deepwater Sculpin**
chin pores	2	1	0
pelvic rays	3-4 soft	4 soft	3 (4 rare), 1 spine
pectoral rays	12-15	14-16	15-18
lateral line	incomplete	complete	complete
body surface	smooth	prickles	disk-like tubercles on upper body length
preopercular spines	2-3, top large	3, top curved	4 (2 upwards, 2 downwards)
dorsal fins (all have 2)	meet and touch	meet and touch	complete separation
other key distinctions	first dorsal fin is dark at the bottom	very flat head	small eye diameter relative to head size, operculum isthmus is under chin

3.0 FEEDING

3.1 FEEDING BEHAVIOUR

Sculpins are an important link between benthic and pelagic food webs (Sierzen et al. 2003; O'Brien et al. 2009; Jacobs et al. 2010). In the past, sculpin species have been labelled as obligate benthivores (Brandt 1986a), but recent evidence of cannibalism, piscivory, and oophagy (i.e., egg consumption), as well as stable isotope evidence of a pelagic diet has been reported suggesting that they are facultative benthivores (Cuker et al. 1992; Miller et al. 1992; Mirza and Chivers 2002; Black et al. 2003; Pfister 2003; Janssen et al. 2006). Sculpin selectively forage (Hershey 1985; Cuker et al. 1992), with the types of invertebrates they consume depending on the local invertebrate community, prey size-distribution, prey behaviour, their accessibility (e.g. density, mobility, and concealment), and the gape of the fish (Hershey 1985; Hershey and Dodson 1985; Kohler and McPeek 1989; Biga et al. 1998). Hondorp et al. (2011) found feeding selectivity in co-occurring Deepwater and Slimy sculpins, with *Mysis* and *Diporeia* spp[1]. being the preferred prey items, respectively. Deepwater Sculpin also tended to select larger prey than Slimy Sculpin (Hondorp et al. 2011).

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[1] Note: The taxonomic status of "glacial relect" freshwater Amphipods previously called *Pontoporeia hoyi* (=*P. affinis*) has been under periodic review, and currently may consist of several species of the genus *Diporeia* spp. (Bousfield 1989, Cavaletto et al. 1996).

The dorsocranial placement of the eyes is a unique feature of most Cottids (Houston 1990), and suggests a role in both prey detection and predator avoidance (Hondorp 2006). Freshwater sculpin have dorsal eyes and strike upwards to capture food (Hondorp 2006).

Sculpins use the sensory cues of mechanoreception (involving the lateral line), vision, tactile, and chemoreception to locate food. These feeding cues are thought to be used to locate specific food items or where conditions favour one particular mode of detection. For example, light is likely less important than mechanoreception for sculpin species that live in deep water (Brandt 1986a), and chemoreception is important for immobile food items like fish eggs (Dittman et al. 1998; Mirza and Chivers 2002). Nocturnal feeding behaviour suggests that these fish rely mostly on non-visual cues, such as chemosensory, tactile, or vibrational information, to locate food items like fish eggs (Dittman et al. 1998; Mirza and Chivers 2002) or concealed invertebrates (Hoekstra and Janssen 1985).

Nightfall seems to trigger sculpin feeding in shallow lakes (Broadway and Moyle 1978). For instance, Slimy Sculpin in Lake Ontario forage at night in water less than 35 m deep, but showed no diel pattern at 75 m, a depth at which very little light reaches (Brandt 1986a; Holeck et al. 2008). Deepwater and Slimy sculpins in Lake Michigan did not show a daily feeding cycle at 80m depth, perhaps because of the absence of diel light cycles which govern prey activity (Kraft and Kitchell 1986). A distinct nocturnal feeding behaviour for Slimy Sculpin was reported in depth integrated samples (5-95m) in Lake Superior (Selegby 1988). Potter and Fleischer (1992) only caught Spoonhead Sculpin at night, and suggested their nocturnal activity as a predator avoidance strategy.

Movement of prey may be an important cue for sculpins. More active predatory chironomids were selectively cropped by Slimy Sculpin in Toolik Lake, Alaska (Cuker et al. 1992), possibly having been detected through lateral line mechanoreception. In laboratory experiments blinded Mottled Sculpin detected moving inert items that had no chemical cues by using their lateral line system (Hoekstra and Janssen 1985). These blinded fish also had difficulty detecting prey when the pores of the lateral line were artificially obstructed (Hoekstra and Janssen 1985). There may, however, also be species differences in the mechanisms for detecting prey. Mechanoreception may be less well-developed in Deepwater Sculpin, where subjects rarely attacked stationary prey in laboratory tests, while Slimy Sculpin subjects showed no such inhibition (Hondorp 2006).

Chemical reception, or chemoreception, may be important in the detection of specific food items like fish eggs. The chemical signature of food items such as eggs, may however, fade with time. Foote and Brown (1998) suggested that predation by Slimy Sculpin on Sockeye Salmon (*Oncorhynchus nerka*) eggs in an Alaskan lake likely occurred within 24 h of deposition in the redds, before the eggs were water hardened. Further experiments using Mottled Sculpin also suggested that the feeding rate on water-hardened eggs is low (Biga et al. 1998).

Chemoreception may also be important in the avoidance of predators. Chivers et al. (2001) found that Slimy Sculpin avoided areas with large Brook Trout (*Salvelinus fontinalis*), but did not avoid areas when only small Brook Trout were present, when the sculpin could visually assess the predation threat. Conversely sculpin avoided all areas with any size trout when they could only use chemical cues.

Relative to other boreal fishes in the NWT, sculpins have good hearing at lower frequency ranges, and hearing is likely important in foraging and predator avoidance. In an assessment of the hearing potential of eight fish species found in the NWT Mann et al. (2007), found that the Spoonhead Sculpin had fairly sensitive hearing at 100-200 Hz, similar to Longnose Sucker (*Catostomus catostomus*), a species with good hearing, but did not hear well at higher frequencies (400-1600 Hz), similar to Broad Whitefish (*Coregonus nasus*), a species with poor hearing capabilities.

3.2 FEEDING RATE

Feeding rate may be linked to the size of the consumer. Foote and Brown (1998) found that although sculpins of all sizes consumed fish eggs, larger sculpins consumed proportionally more Sockeye Salmon eggs than did smaller sculpins. Miller et al. (1992), however, found no evidence of a relationship between length of a sculpin and its egg feeding rate. This discrepancy may be related to the stomach volume of different sized fish (Biga et al. 1998) but could also be related to the age of the eggs since they harden and enlarge over time. The processes of egg hardening and enlargement may reduce the chemical signature of the eggs and make them less appetizing to the fish. Souring of eggs over time may also occur, but chemical contamination of eggs does not disrupt their consumption by sculpins (Savino and Henry 1991).

Although sculpins prefer the cover offered in areas of streams and lakes with complex piling of cobbles with many interstitial spaces, this strategy can also mitigate their consumption of food (Fitzsimmons et al. 2006). For example, sculpins have been found entering the redds of salmonids to predate eggs (Mirza and Chivers 2002), but complex redds with small interstitial spaces may provide some relief from sculpin feeding pressure, especially if only small, gape-limited sculpin can infiltrate the redds (Biga et al. 1998).

High sculpin densities can affect the feeding rates of individuals. In laboratory studies Fitzsimmons et al. (2006) reported that consumption of fish eggs by Slimy Sculpin was not additive as numbers of feeding sculpin was increased. Although sculpins may be affected by intraspecific social hierarchies and competition, neither feeding rates nor availability of shelter were affected by the presence of other potential competitors such as the Northern Crayfish (*Orconectes virilis*) (Miller et al. 1992).

3.3 SLIMY SCULPIN FEEDING

The Slimy Sculpin is the most thoroughly studied freshwater sculpin species. In some waterbodies it is the most abundant species and densities can be as high as 6-8 individuals per m^2 (M. Gray, pers. comm.). As is typical for northern fish populations, Slimy Sculpin tend to grow more slowly and live longer but reach smaller maximum size than those in more southerly latitudes. (Craig and Wells 1976; Hershey and McDonald 1985). In surveys of mountain streams in the south and central Mackenzie Valley, NWT, Slimy Sculpin dominated the stream fish community in terms of numbers, representing 70.4% (Mochnacz and Reist 2007a), and 67.5% (Mochnacz and Reist 2007b) of the catches respectively.

3.3.1 Feeding in lakes

In the Laurentian Great Lakes, Slimy Sculpin found in both shallow and deep water eat opossum shrimp (*Mysis* sp.), amphipods (*Diporeia* spp. and *Gammarus* sp.), and other invertebrates (Brandt 1986a, Cuker et al. 1992; Bergstrom and Mensinger 2009; French et al. 2010). In the Great Lakes, Slimy Sculpin consume proportionally more mysids and amphipods (Owens and Weber 1995; Brandt 1986a) than other invertebrates. A decline in the populations of *Diporeia* spp. following the invasion of dreissenid mussels (Dermott and Kerec 1997; Madenjian et al. 2002) in the Laurentian Great Lakes may have caused a dietary shift to mysids in recent years (Owens and Dittman 2003; Walsh et al. 2008). A diet study in Lac de Gras, NWT found that chironomids, and more specifically the sub-family Orthocladiinae, were the predominant food item in Slimy Sculpin stomachs (C. Fraikin, Golder Associates, unpubl. data).There were no major differences between sex or life stage in the occurrence of prey items in the stomachs of Slimy Sculpin in Lac de Gras. Slimy Sculpin captured in lakes also consumed fish eggs. Slimy

Sculpin consumed Lake Trout eggs in a Lake Michigan mid-lake reef complex (Houghton et al. 2010). Foote and Brown (1998) estimated that 16% of Sockeye Salmon eggs in Iliamna Lake, Alaska were consumed by Slimy Sculpin during the fall Salmon spawning period.

Depth of habitat occupancy may strongly influence Slimy Sculpin diet (Brandt 1986a). Slimy Sculpin in Lake Ontario consumed more *Diporeia* spp. in shallower areas (55 m) compared to more mysids in deeper water (95 m) (Owens and Weber 1995). Although depth may be an important factor in prey availability, there may also be high variability in feeding patterns related to lake circulation that may complicate specific depth and diet relationships (Houghton et al. 2010). In Alexie Lake, NWT, Slimy Sculpin occupied the same food web niche as Spoonhead Sculpin, but were at a lower trophic position than that of Deepwater Sculpin. Both Slimy and Spoonhead sculpins derived their energy intermediate between nearshore and offshore sources (Figure 3). Alexie Lake has a maximum depth of 32 m (Cott et al. 2011) so is therefore entirely within the depth range of all three sculpin species.

Lake dwelling Slimy Sculpin show size selectivity of prey items. Slimy Sculpin from Lake Michigan consumed amphipods (*Diporeia spp.*) that were between 5 and 7 mm (Kraft and Kitchell 1986), irrespective of their own body size. An additional study in Lake Michigan also found that intermediate-sized amphipods (2-7 mm) were consumed by all Slimy Sculpins (Hondorp 2006). In Toolik Lake, Alaska, Slimy Sculpin consumed proportionally more small (≤7 mm) chironomids (Hershey 1985; Hanson et al. 1992). Further study in Toolik Lake, indicated that the smallest free-living chironomids (≤3.5 mm) and tube dwelling chironomids were unaffected by sculpin predation (Cuker et al. 1992). Cuker et al. (1992) also found that sculpins fed selectively on predatory chironomids and that motility of prey increased their risk of predation. Studies in Toolik Lake suggest that sculpins preferentially consumed free-living, predatory chironomids between 3.5 and 7 mm. Larger chironomids found in Toolik Lake may burrow deeper into the sediments which reduces their predation risk (Hershey and McDonald 1985).

Consumption of intermediate-sized prey may be the result of a trade-off between vulnerability and detectability by sculpins (Hondorp 2006), rather than a preferential selection. Although sculpins may select intermediate-sized prey, their growth rate may also be higher in areas with larger prey (Zimmerman and Vondracek 2006). An additional trade-off between energy expenditure during foraging and energy gained during consumption and digestion may occur for some populations. For instance, although many researchers have found that sculpins of many sizes will selectively crop the same size of invertebrates, others have found a link between body size of Slimy Sculpin and prey size. Owens and Weber (1995) found a positive relationship between fish size and prey length, suggesting a link to mouth size or stomach volume and prey size (Biga et al. 1998).

Slimy Sculpin can influence lake invertebrate community structure through their feeding patterns. In field enclosures, sculpins at ambient densities reduced the biomass of caddisflies by 50% and predatory chironomids larvae by 30%, compared to areas without sculpins (Cuker et al. 1992). Other researchers found that particular invertebrate crops in northern lakes were associated with the presence of Slimy Sculpin, suggesting top-down control (Goyke and Hershey 1992; O'Brien et al. 2004). The presence of Mottled Sculpin was even found to influence the behaviour of baetid mayflies, which spent less time moving between food patches above the substrate in the presence of sculpins (Kohler and McPeek 1989).

Sculpin size may be an important factor in the physical access to food items. In laboratory aquaria with large substrates, larger Mottled Sculpin were predominantly epibenthic, while smaller individuals were found in the interstitial spaces (Biga et al. 1998). This suggests that if there are differences in the distribution of prey items among the microhabitats of lake and river substrates, then accessibility by sculpins into deeper interstitial spaces can also influence their diet.

Slimy Sculpin home ranges are relatively small (~10 m measured in streams; Gray 2003; Cunjak et al. 2005) and their diets reflect this. In Toolik Lake, Alaska, Slimy Sculpin that were captured within the 3 m rocky littoral margin consumed proportionally more organisms than were found in that habitat; Slimy Sculpin captured in the mud-bottom profundal zone ate proportionally more organisms from that habitat (Cuker et al. 1992). The home ranges of sculpin found in lakes is also likely smaller than large piscivores (Minns 1995; Harvey and Kitchell 2000).

3.3.2 Feeding in streams and rivers

In streams, mayflies, chironomids, amphipods, snails, caddisflies, and other invertebrates are frequently consumed by sculpins (Zimmerman and Vondracek 2007). In a study in the Mackenzie River basin, Slimy Sculpin consumed oligochaetes, stoneflies, caddisflies, mayflies, and nematodes (Hatfield et al. 1972). The rate of consuming particular organisms may not be related to their local abundance (Hershey and Dodson 1985), but rather the size of sculpin in streams is likely an important determinant in prey selection. Smaller (and presumably younger) Slimy Sculpin in a Minnesota stream fed on dipterans, such as chironomids, and larger sculpins consumed amphipods and caddisflies (Petrosky and Waters 1975).

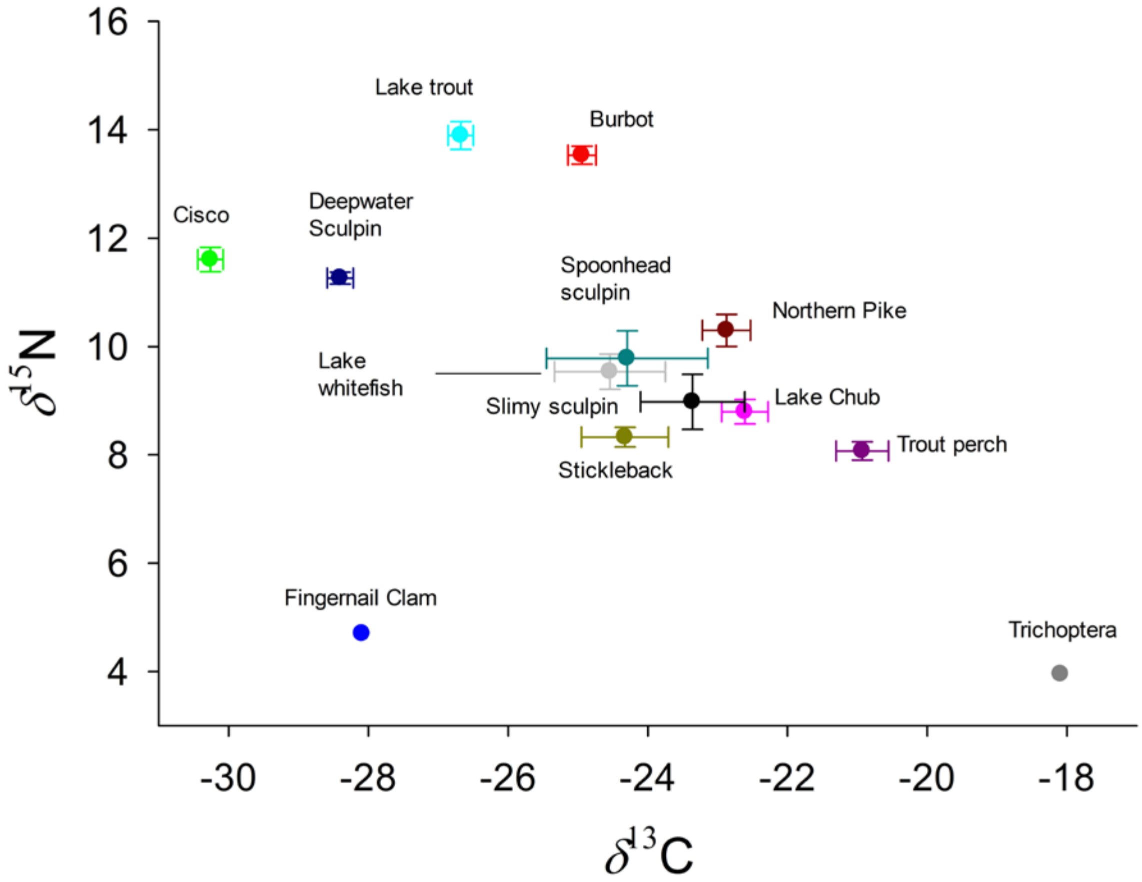

Figure 3. Food web position of various biota in Alexie Lake, NWT. Data from Cott et al. (2011) and M. Guzzo unpublished.

Riverine Slimy Sculpin often consume fish eggs. Bennett and Janz (2007) reported that in Saskatchewan streams the diet of Slimy Sculpin did not vary greatly with season, but in the spring fish eggs were found in their stomachs. Fish eggs may, therefore, be a seasonally important source of energy for sculpin in both lakes and rivers. As in lakes, Slimy Sculpin in riverine environments are likely gape-limited opportunistic feeders, and will prey on small fish if the opportunity presents itself (Figure 4).

The availability of prey organisms in streams can be different than that of lakes, but there is often much overlap. Drift of prey items in streams increases their availability and represents a key difference in fish food items. Drift of invertebrates can either be intentional as a dispersal mechanism, or unintentional, such as dislodgement during a high flow event (Brittain and Eikeland 1988). Although invertebrate drift is an important food source for fishes in streams, sculpin may not fully utilize this resource. Mottled Sculpin are not likely to feed on drifting invertebrates (Dahl and Greenberg 1996; Dahl 1998). In a study in a Minnesota stream, the highest size frequency of amphipods found in the drift were not consumed in large numbers by Slimy Sculpin (Newman and Waters 1984). In their study, Slimy Sculpin selectively cropped amphipods that were between 4 and 12 mm, and that were likely epibenthic (Newman and Waters 1984).

Figure 4. A large Slimy Sculpin, collected in a Yukon stream, attempting to swallow a juvenile Arctic Grayling. Photo: Steve Gotch, DFO Whitehorse, Yukon.

Although researchers have suggested that sculpins exert strong top-down control on invertebrates in lakes, the pattern is less clear in streams (Zimmerman and Vondracek 2007). Dahl and Greenberg (1996) suggested that benthivorous fish are more likely to influence the resident prey abundance than drift feeders, such as trout. Although this generalization may be reasonable, the results of river feeding studies are variable. Flecker (1984) found that Mottled Sculpin and Potomac Sculpin (*C. girardi*) did not influence the prey abundance in study streams. However, other investigators have found a reduction in the density of invertebrates in the presence of sculpins. Englund and Olsson (1996) found that the density of benthic invertebrates was reduced by up to 50% in cages with Bullhead (*Cottus gobio),* a European sculpin species. Ruetz et al. (2004) found that sculpins did reduce the invertebrate crop in enclosures, but exerted a weak top-down influence on the benthic community in streams. Dahl (1998) found a general consumption pattern of benthic organisms and strong control by *C. gobio* in Swedish streams. Local habitat attributes, such as substrate complexity, most likely affect the influence of feeding by sculpin populations on the benthic community (Biga et al. 1998).

Because sculpins typically have a small home range, they tend to consume invertebrates from their local environment. Slimy Sculpin collected at ten different sites along a single 4th order river (Little River, New Brunswick) were statistically differentiated by both stable carbon and nitrogen isotopes suggesting distinct and localized diets (Gray et al. 2005). In the Saint John River near Edmundston, New Brunswick, stable isotopes of Slimy Sculpin differed between sites on both lateral and longitudinal scales of only 50m when the sites were separated by an anthropogenic discharge (Galloway et al. 2003; Arciszewski 2007). A more mobile fish species that feeds over a broader area and environments would not display such distinct isotopic signatures.

3.4 SPOONHEAD SCULPIN FEEDING

Spoonhead Sculpin, in general, is a poorly studied species. Once common in the Great Lakes, this species began to decline in the 1960s, but are reappearing in some areas (Potter and Fleischer 1992; Oyadomori and Auer 2004). Little direct information is available on their diet (Houston 1990; Bergstrom and Mensinger 2009), and much of the diet information presented for Spoonhead Sculpin is based on the diet of other sculpin species (see Scott and Crossman 1973).

Although there is much similarity in the diet of different Cottids, there is often segregation in sympatric populations (Kraft and Kitchell 1986). In a specific study on this topic, there was substantial overlap of diet in small benthic fishes, including Slimy and Spoonhead Sculpin collected in the Laurentian Great Lakes (Bergstrom and Mensinger 2009). An additional study in Lake Superior also suggested that there was substantial overlap in the diet of Deepwater, Slimy, and Spoonhead sculpin (Selegby 1988). Burrowing amphipods (*Diporeia spp.*) and *M. relicta* were commonly selected by Spoonhead Sculpin (Selegby 1988); while very few chironomids were consumed by this species. The notion of diet overlap between Slimy and Spoonhead sculpin is supported with stable isotope analysis of fish from Alexie Lake, NWT. Figure 3 clearly illustrates that these two species are occupying the same food web position in this 32 m deep, oligotrophic, boreal-shield lake. In a study in the Mackenzie River basin, Spoonhead Sculpin consumed mainly plecopterans and dipterans (Hatfield et al. 1972).

3.5 DEEPWATER SCULPIN FEEDING

Deepwater and Slimy sculpin are sympatric in some areas of the Laurentian Great Lakes (Kraft and Kitchell 1986), as well as in Great Slave and Great Bear lakes, Lac la Marte and the Husky Lakes (Sawatzky et al. 2007). Deepwater Sculpin were found to co-occur with Slimy and Spoonhead sculpin in four small boreal shield lakes 30 km NE of Yellowknife (Cott et al., 2011). In Lake Michigan, Deepwater and Slimy Sculpin showed segregation of food items. At water depths between 75 and 91 m Deepwater Sculpin consumed *Diporeia spp.* and *M. relicta* whereas Slimy Sculpin consumed only *Diporeia spp.* (Kraft and Kitchell 1986). *Diporeia* spp. is likely the dominant food item for Deepwater Sculpin (Wojcik et al. 1986) and has been linked to increased energy density in the fish (Pothoven et al. 2011). In another study, researchers found that the amount of mysids and chironomids compared to *Diporeia spp.* in the diet of Deepwater Sculpin was inversely proportional to their occurrence in the habitat (O'Brien et al. 2009). This may be related to the seasonal increase in the abundance of mysids in September (O'Brien et al. 2009) but may also be affected by the distributional patterns of *Diporeia spp.* in the Great Lakes (Hondorp et al. 2005).

Like the Slimy Sculpin, some studies have found that feeding of Deepwater Sculpin did not appear to be selective by prey size (Kraft and Kitchell 1986; Hondorp et al. 2005). In Lake Huron, during the fall, Deepwater Sculpin consumed all sizes of *Mysis sp.*, *Diporeia spp.*, and chironomids regularly and sphaerid clams, ostracods, fish eggs, and occasionally small fishes (O'Brien et al. 2009). However, Hondorp (2006) reported that all Deepwater Sculpin selected amphipods that were between 6-7 mm and mysids that were >12 mm. This case of size selection of mysids by Deepwater Sculpin may have been related to the behaviour of the prey item. Mysids exhibit an escape behaviour, the velocity of which is not correlated with size; thus larger mysids with the same escape velocity as a smaller individual may have a higher predation risk (Hondorp 2006). Other researchers have found a relationship between the size of Deepwater Sculpin and prey selection. Small Deepwater Sculpin (50-99 mm) consumed *Diporeia spp.* and *M. relicta*, while sculpin larger than 100 mm consumed proportionally more *Diporeia spp.* (Brandt 1986b). These differences in prey selection may be related to ontogenic habitat shifts that occur with increasing depth for Deepwater Sculpin (Geffen and Nash 1992; Hondorp 2006).

Stable isotope analysis of Deepwater Sculpin collected in Alexie Lake, NWT, revealed that this species held a distinctly different food web position than the co-occurring Slimy and Spoonhead sculpins, which overlapped in their food web niches (Figure 3). The separation between the food web positions of these species is likely because, unlike

Slimy and Spoonhead sculpins that forage in nearshore areas, Deepwater Sculpin would be eating almost exclusively offshore food sources. Also, Deepwater Sculpin would likely be more dependent upon *M. relicta* than the other sculpin species. Although not shown on Figure 3, stable isotope analysis of *M. relicta* from Alexie Lake places them at approximately the same food web position as Ninespine Stickleback (M. Guzzo, University of Manitoba, *pers. comm.*). This would account for the elevated trophic position and offshore energy signal relative to Slimy and Spoonhead sculpins.

The diet of larval (10-21 mm total length) Deepwater Sculpin was dominated by copepods at sample locations throughout northern Lake Huron and the Detroit River. The diets of benthic age-0 fish (>25 mm total length) were more variable by site, but chironomids and Mysids were most prevalent (Roseman 2014).

4.0 PREDATORS

Most sculpin species are important links between benthic invertebrate and piscivorous food webs (Sierzen et al. 2003; O'Brien et al. 2009; Jacobs et al. 2010). In northern lakes, including Alaska and the NWT, their primary predators include Burbot (*Lota lota*) and Lake Trout (*Salvelinus namaycush*; Hanson et al. 1992; Lienesch et al. 2005; Keyse et al. 2007); these fish species were also identified as predators of sculpins in the Great Lakes (Brandt 1986b). Other researchers have reported predation of sculpins by Brown Trout (*Salmo trutta;* Zimmerman and Vondracek 2007), Brook Trout (Chivers et al. 2001), Alewife (*Alosa pseudoharengus*; Madenjian et al. 2002), and Yellow Perch (*Perca flavescens*; Janssen and Quinn 1985 as cited in Miller et al. 1992). Large sculpin also prey on smaller conspecifics (Pfister 2003). Sculpins and Ninespine Stickleback (*Pungitius pungitius*) were the most commonly occurring food item in the stomachs of Burbot collected from boreal shield lakes in the NWT, each occurring in 36% of stomachs with contents. Although the identifying characteristics of sculpin are quickly digested; one individual eaten by a Burbot was positively identified as a Deepwater Sculpin. In contrast, Burbot in Great Slave Lake most frequently selected Ninespine Stickleback (42%), Cisco (Coregonus spp.) (38%), followed by sculpin at 8% (P.A. Cott unpublished data).

As with other fish species, the abundance and distribution of predators may influence the distribution and diversity of sculpin. Lake Trout and Burbot predation pressure can limit sculpin abundance (Anderson 1985; Brandt 1986a; McDonald and Hershey 1992; Owens and Bergsted 1994). However, Slimy Sculpin do show behaviours to avoid predation using both visual and chemical cues to initiate escape or maintain concealment (Chivers et al. 2001).

Slimy Sculpin may also alter the use of habitat types in lakes in response to the occurrence of predators. Slimy Sculpin may increase their use of shoreline habitat and occupy areas with soft sediments when the densities of prey, such as chironomids, are high and predator abundance is low (McDonald and Hershey 1992). Hanson et al. (1992) showed that in Arctic lakes where Burbot and Lake Trout were absent Slimy Sculpin were more commonly found in deeper areas with fine sediments. In contrast, they found that in lakes containing these predators, Slimy Sculpin were distributed at the interface between the deeper soft sediments where chironomids were abundant, and shallower rocky shorelines where shelter was abundant (McDonald et al. 1982; Hanson et al. 1992). The role of darkness in enhancing the camouflage of an already cryptic fish may also be an important strategy used by sculpins to avoid predators that rely on visual cues (Mazur and Beauchamp 2003).

When young Spoonhead Sculpin hatch they are protected from predation by a dense covering of prickles on their bodies. Lake Trout and Burbot were historically noted as main predators of Spoonhead Sculpin in the Laurentian Great Lakes (Deason 1939). Deason (1939) found as many as 33 individuals in one Lake Michigan predator, but noted that the average stomach contents were usually less than 10.

5.0 HABITAT REQUIREMENTS

As discussed above, freshwater sculpins may occur in both lakes and rivers. The diversity of these habitats suggests that there are different life history strategies between lotic and lentic environments. For example, Slimy Sculpin can be found in the swift waters of streams (Galloway et al. 2003) and deep areas of the Laurentian Great Lakes (Kraft and Kitchell 1986), while Deepwater Sculpin are restricted to lakes (Sheldon et al. 2008). Habitat preferences of sculpin are generally better understood in rivers than lakes.

In rivers, sculpins predominantly inhabit erosional areas with fast water and large substrate. However, they can also be found in areas with slower flow and patches of coarse gravels and cobble. Sculpins are most efficiently captured using active techniques (e.g., electrofishing), and are generally concealed under and amongst gravel, cobble, and rubble substrates. Little is known about the specific habitats of sculpins found in lakes. Sculpins are, however, generally captured using a combination of passive techniques (e.g., traps) and active techniques (e.g., trawls). The techniques used in lakes and the depths that are sampled make it difficult to determine the exact habitats used by lake sculpins. Much of the study of the habitat of sculpin in lakes has focussed on depth preferences, rather than factors such as water currents and substrate.

5.1 HABITAT OVERLAP OF SPECIES

Depth distributions of Slimy, Spoonhead, and Deepwater sculpins overlap in some areas. Madenjian et al. (2005) studied the habitat overlap of Slimy and Deepwater sculpins within Lake Michigan. They found no significant negative association between the two species, suggesting that there is little inter-specific competition despite their habitat overlap (Madenjain et al. 2005), or that there is some spatial separation (Madenjian and Bunnel 2008). Kraft and Kitchell (1986) suggested that Slimy and Deepwater sculpins have slightly different feeding behaviours and can coexist within the same habitats. Slimy, Spoonhead, and Deepwater sculpins have similar depth distributions within Lake Superior, ranging from 15-115 m (Selgeby 1988). Within Lake Ontario, depth distributions of Deepwater Sculpin overlapped with those of Slimy Sculpin at 40-80 m (Brandt 1986a), but the depth range of the species overlap may vary with time of year or life stage (Kraft and Kitchell 1986). Slimy, Spoonhead, and Deepwater sculpins were collected from four medium-sized lakes in the NWT where the maximum depth of the deepest lake was <35 m (Cott et al. 2011). As the maximum depths of these lakes are within the known depth distributions of all three sculpin species (Scott and Crossman 1973), it is reasonable to assume that habitat overlap occurs among species.

5.2 SLIMY SCULPIN HABITAT REQUIREMENTS

Slimy Sculpin are found in both lakes and rivers, and have been extensively studied within the Laurentian Great Lakes. Slimy Sculpin habitat preferences likely differ between the two water body types, based on the inherent physical differences between lakes and rivers. However, in both lakes and rivers Slimy Sculpin have small home ranges (Harvey and Kitchell 2000; Galloway et al. 2003; Gray et al. 2005).

5.2.1 Spawning habitat

Spawning of Slimy Sculpin occurs in the spring in temperate areas, the precise timing and location of spawning is influenced by temperature and the presence of appropriate substrate. Water temperatures between 6 and 10°C initiate spawning (Van Vliet 1964; Gray 2003; Keeler and Cunjak 2007; Majeski and Cochran 2009). In temperate regions these temperatures generally occur in late May and early June (Mohr 1984; Selgeby 1988), and would presumably be later in the NWT. Slimy Sculpin are considered lithophilous, requiring clean, stable, stony substrates (cobble and boulders) for spawning (Balon 1975; Mohr 1984; Keeler and Cunjak 2007; Majeski and Cochran 2009). Slimy Sculpin create nest sites by excavating holes beneath rocks (Van Vliet 1964).

5.2.1.1 Spawning in rivers

Slimy Sculpin spawning habitat in rivers includes cobble substrates in areas with high velocity (≥0.18 m/s; van Snik Gray and Stauffer 1999) and shallow water (<0.50 m; Gray 2003; Keeler and Cunjak 2007). However, substrate size and water velocity are the primary factors in the selection of a nest site (Mousseau and Collins 1987; Majeski and Cochran 2009). Flowing water reduces the accumulation of fine sediments and maintains dissolved oxygen around the eggs, and large substrate is generally more stable and less prone to shifting during high flow events (Edwards and Cunjak 2007).

Slimy Sculpin nests in Little River, New Brunswick were found by overturning rocks that showed signs of a recent excavation on the downstream side, and by using an electrofisher to collect and identify guarding males. In areas where guarding males were captured, the underside of large substrate was checked for egg masses (Gray and Munkittrick 2005). Guarding males are easily identified because they have dark pigmentation around the head and pectoral fins (Van Vliet 1964). The majority of nest sites were found underneath rocks with flat undersides at the downstream end of a riffle where the water velocities are swift, but are dampened at the top end of the subsequent run or pool habitat (M. Gray, pers. comm.). In the NWT, Slimy Sculpin spawn over bedrock, boulder, or rubble in clear or turbid water. Spawning occurs when water temperatures are between 3.5°- 8°C (Evans et al. 2002).

5.2.1.2 Spawning in lakes

Spawning of sculpins in lakes is poorly understood. Within the Laurentian Great Lakes, Slimy Sculpin may utilize deep offshore habitats for spawning (Goodyear et al. 1982), however, Mohr (1984) reported that they used shallow water for spawning within lakes in northern Ontario. Van Vliet (1964) reported that Slimy Sculpin in a northern Saskatchewan lake showed a preference for flat, shallow areas, with minimal current for nest sites and that these areas are often located adjacent to shore (Van Vliet 1964). The differences in these findings may be due to the habitat and other environmental features of those specific lakes. Slimy Sculpin may prefer to spawn in deeper areas when they are available, but the ultimate location may be more strongly influenced by the presence of large substrates needed for nest construction. Richards et al. (2001) suggest that Slimy Sculpin spawn in areas of current or wind action in <10 m depth of water over various substrates from boulder to sand.

5.2.1.3 Larvae and juveniles

The incubation period of Slimy Sculpin eggs may vary with water temperature, but has been reported as 28-29 days (Van Vliet 1964). Males will typically guard their nest during this period. Slimy Sculpin fry and yearlings are benthic in lakes and rivers (Madenjian and Jude 1985) and they stay in the paternally guarded nest sites for 3-6 days post-hatch (Evans et al. 2002). Following this larval period, young sculpin seek areas of minimal current (Van Vliet 1964). Young Slimy Sculpin appear to prefer gravel substrates (Van Vliet 1964) and shallower habitat than adults (van Snik Gray and Stauffer 1999), < 10 m in lakes (Richardson et al. 2001) and <60 cm in rivers (Evans et al. 2002). As fry develop into juveniles they undergo ontogenetic changes in habitat use and move to deeper water with this pattern continuing as the fish mature into adults (Brandt 1986a).

5.2.2 Physical and chemical habitat preferences

5.2.2.1 Temperature

Adult Slimy Sculpin can occur in a wide range of temperature (Van Vliet 1964; Wells 1968; Mohr 1984; Lessard and Hayes 2003), but are generally considered a coldwater species. The temperature range where Slimy Sculpin have been collected includes 15-30°C in Saskatchewan (Van Vliet 1964) and 13.0-18.7°C in Michigan (Lessard and Hayes 2003). Wells (1968) reported that Slimy Sculpin were most abundant in areas of Lake Michigan with temperatures ranging from 4.0 to 6.0°C and Gangemi (1992) documented them in streams with a mean temperature of 8.8°C. Lessard and Hayes (2003) reported collecting no Slimy Sculpin in sites with mean summer temperatures above 20°C within small streams in Michigan.

Otto and Rice (1977) tested temperature tolerance as well as behavioural changes that accompanied temperature gradients, such as avoidance, for Slimy Sculpin in laboratory conditions. They concluded that Slimy Sculpin have an upper lethal temperature of 26.5°C and an overall preferred temperature of about 10°C (Otto and Rice 1977). In a later study, Otto and Rice (1997) reported a lethal thermal limit for Slimy Sculpin of 22°C. Symons et al. (1976) reported an upper lethal water temperature of 25°C, a preferred temperature of 15°C, and suggested that sites with sustained water temperatures of > 19°C would be devoid of Slimy Sculpin. Gray et al. (2005) found an abrupt decline in Slimy Sculpin density at sites with a maximum mean daily water temperature of ≥ 19°C, and that all study streams with maximum daily water temperatures above 25°C had no Slimy Sculpin present.

An upper thermal limit of 30°C was found by Van Vliet (1964) at sites of field collections of Slimy Sculpin. The discrepancy between these studies may relate to the methodology of the laboratory studies or to conditions specific to the natural environments. The field studies conducted by Van Vliet (1964) may have collected fish that had access to coolwater refugia during periods of high ambient temperature. The lower lethal limit reported by Otto and Rice (22°C; 1977) may relate to intraspecific differences or to to differences in methodological approached by reaserchers. Although estimations of lethal and preferred temperatures vary, Slimy Sculpin are likely able to sense optimal temperatures and adjust their locations within the water column accordingly (Otto and Rice 1997; Symons et al. 1976). Duration of exposure to higher temperatures will certainly influence whether sculpin are able to remain in a local habitat. In the NWT during the summer Slimy Sculpin were collected in streams with water temperatures as high as 17.7ºC (Mochnacz and Reist 2007b).

5.2.2.2 Substrate size and water velocity

Across the North American range, the occurrence and abundance of Slimy Sculpin may directly relate to substrate type. Slimy Sculpin are most often found in habitats consisting of cobble to rubble substrates (Van Vliet 1964; Edson 1992; Gangemi 1992; Edwards and Cunjak 2007). Slimy Sculpin were found under rocks measuring a mean length, width, and height of approximately 16 x 11 x 5 cm, respectively (van Snik Gray and Stauffer 1999). Biga et al. (1998) found that twice as many Mottled Sculpin occupied artificial piles of rubble (10 to 22 cm) than gravel (5 to 10 cm). Larger substrate is typically more stable and may provide a more static environment that minimizes physical injury, such as crushing (Edwards and Cunjak 2007) and reduces predation pressure by enhancing concealment (Biga et al. 1998). Fewer adult Mottled Sculpin were found in streams with a high (>70%) proportion of fine sediments compared to streams with <30% fines (Mebane 2001) suggesting that substrate is important for the persistence of sculpin. In the NWT Slimy Sculpin were found in 2nd to 4th order streams in the southern (Dehcho Region) and central (Sahtu Settlement Area) regions. In the Dehcho Region Slimy Sculpin occupied habitat with substrates ranging from sand to cobble (Mochnacz and Reist 2007b), whereas in similar streams surveyed across the Sahtu Settlement Area this species was mainly found in habitat dominated by pebble to cobble substrate (Mochnacz and Reist 2007a).

Rivers and streams offer habitat features different from those in lakes, such as erosional areas. Within streams and rivers, Slimy Sculpin occupy habitats that erode small particles (Finger 1982) including runs, riffles, and glides (Danehy et al. 1998; Edson 1992; Gangemi 1992). The habitat types used by sculpin are found in streams with a gradient between 1 and 4% (Edson 1992; Gangemi 1992). Despite the fact that they are found in many areas of streams, Gangemi (1992) suggests that runs are likely preferred by Slimy Sculpin. Although sculpin are found in areas with swift water, substrate size is likely the most important feature of the erosional habitats that sculpin occupy; fast water may be a tolerable, rather than a preferred habitat feature. In mountainous areas of the NWT, Slimy Scuplin were collected in streams with velocities ranging from 0.01 m/s to 2.17 m/s (Mochnacz and Reist 2007a; 2007b).

5.2.2.3 Water depth

Slimy Sculpin occupy a large range of depths in both streams and rivers. They have been reported in lakes near the shore in less than 5 m of water (Selgeby 1988; Gorman et al. 2008). It is possible that Slimy Sculpin may enter shallow, near-shore areas in order to forage, which is followed closely by a retreat to deeper water when they are satiated (Mohr 1984). Slimy Sculpin have also been reported at depths of 210 m within Lake Superior, likely the greatest depth recorded (Selgeby 1988). Slimy Sculpin within Lake Superior and Lake Michigan are most abundant at about 70 m depth (Dryer 1966; Kraft and Kitchell 1986); however, density and abundance in Toolik Lake, Alaska, was significantly higher at 3.5 m than at any other depth (Toolik Lake maximum depth is 25 m; Bahr et al. 1996). Although Slimy Sculpin inhabit a variety of depths in the lakes, shallower maximum depth may limit their survival over the winter (Hershey et al. 2006).

Dryer (1966) reported that the depth distribution of Slimy Sculpin in lakes changes with season. Kraft and Kitchell (1986) reported that Slimy Sculpin were predominantly in water less than 75 m in June and 81 m in October in Lake Michigan. In contrast, Selgeby and Hoff (1996) reported that Slimy Sculpin move shallower as the season progresses from spring to fall; suggesting seasonal depth distribution may be context specific. Limited seasonal migrations of sculpin may also occur in streams, but lateral movement of sculpin may be more closely related to changing water levels than to season. Within NWT mountain streams Slimy Sculpin have been collected in water depths as little as 3 cm (Mochnacz and Reist 2007b).

5.2.2.4 Water chemistry

The link between water chemistry and habitat use by Slimy Sculpin is not well studied, but the continent-wide distribution of these fish suggests they do not have a narrow requirement of water chemistry characteristics. Generally, Slimy Sculpin are found in lakes and rivers with low dissolved organic carbon and high calcium concentrations (Matuszek et al. 1990). Slimy Sculpin are generally found in areas where the pH is between 6.8 and 8.4 and individuals avoid areas with pH less than 6.4 (Van Vliet 1964; Matuszek et al. 1990). Slimy Sculpin were found in a small NWT lake (20 ha, maximum depth of 7 m) with no inlet or outlet with late winter dissolved oxygen concentrations of < 3 mg/L (Cott et al. 2008). This suggests that these fish can withstand re-occurring extreme conditions.

5.3 SPOONHEAD SCULPIN HABITAT REQUIREMENTS

5.3.1 Spawning habitat

Spoonhead Sculpin are not well studied. Based on indirect evidence from observations of egg maturity and milt condition, spawning has been suggested to occur in late summer or early fall (Delisle and Van Vliet 1968, Scott and Crossman 1973); however, in Lake Superior spawning may occur in early to mid-May (Selgeby 1988). Very little is known about their specific spawning habitats. Spawning activity in rivers is similar to Slimy Sculpin. Spawning occurs at water temperatures between 4.5 and 6.0°C, females lay adhesive eggs on the underside of rocks in flowing waters, and males guard the egg masses during the incubation period of 2-3 weeks (Roberts 1988). In lakes, Spoonhead Sculpin are thought to spawn over sand to boulder substrates (Evans et al. 2002). Unlike the larvae of Slimy Sculpin which are benthic, larval Spoonhead Sculpin are pelagic and have a small yolk sac (Potter and Fleischer 1992).

5.3.2 Physical and chemical habitat preferences

5.3.2.1 Temperature

Selgeby (1988) reported temperatures between 3.2 and 17.0°C within Lake Superior in areas where Spoonhead Sculpin were captured. Lessard and Hayes (2003) suggested that temperature may be the most important factor that predicts Slimy Sculpin abundance, which may also hold true for other sculpin species, including the Spoonhead Sculpin.

5.3.2.2 Water depth

At its southern range, the Spoonhead Sculpin is generally restricted to deeper water than Slimy Sculpin (Dryer 1966). In large waterbodies, such as the Great Lakes, Spoonhead Sculpin densities are greatest between 46-90 m depths (Dryer 1966; Selgeby and Hoff 1996). They may be found as deep as 210 m (Selgeby 1988). In Lake Superior, Spoonhead Sculpin were collected at depths of 37-110 m (Deason 1939), and were collected in shallower waters in fall than in spring (Selgeby and Hoff 1996). In the north, Spoonhead Sculpin are found in shallower water, and may occupy small lakes and fast-moving water (Stewart and Watkinson 2004). Within the Athabasca River, Alberta, Spoonhead Sculpin are found in water 50-75 cm deep (Gibbons *et al.* 1998). Like both Deepwater and Slimy sculpins, Spoonhead Sculpin show some differences in seasonal depth distribution. Overall depth distribution may be affected by temperature and light availability (Houston 1990). In NWT, Spoonhead Sculpin occurred in lakes that were between 20 and 34.5m in maximum depth (Cott et al. 2011). The Spoonhead Sculpin specimens used for the hearing assessment in Mann et al. (2007) were collected in the East Channel of the Mackenzie Delta over silty-sand substrate in 1 m water depth (P.A. Cott pers. comm.).

5.4 DEEPWATER SCULPIN HABITAT REQUIREMENTS

5.4.1 Spawning habitat

Deepwater Sculpin are thought to spawn between the ages of two (males) and three (females; Black and Lankester 1981). The specific spawning period of Deepwater Sculpin is currently unknown (COSEWIC 2006), and spawning is generally confirmed through the collection of spent females. However, Black and Lankester (1981) reported that Deepwater Sculpin within Burchell Lake, Ontario had not spawned by mid-October. Selgeby (1988) suggested that Deepwater Sculpin spawn in mid-winter but have a protracted spawning period that extends from November to May. Spawning of Deepwater Sculpin likely occurs in deep water (Mansfield et al. 1983).

5.4.1.1 Larvae and juveniles

Larval Deepwater Sculpin were sampled in Lake Michigan by Geffen and Nash (1992). Although they hatch in deep water, larval fish are found at the surface and inshore during the spring (Geffen and Nash 1992). It is likely that larvae are pelagic and are brought to the surface by deepwater upwellings (Mansfield et al. 1983; Geffen and Nash 1992). By late summer, larval Deepwater Sculpin move into the lower water column, and are not found in areas of shallow water (15-50 m) by September (Geffen and Nash 1992). Larval Deepwater Sculpin may also show some temperature preference. Within Lake Michigan, they were not collected in areas with water temperatures less than 11° C (Mansfield et al. 1983). Juveniles (50-90 mm) live in shallower water than larger and older Deepwater Sculpin (Brandt 1986b). Deepwater Sculpin migrate to progressively deeper water as they grow and mature (Brandt 1986b). Larval Deepwater Sculpin collected in northern Lake Huron, Lake Michigan, and the Detroit River re-emerged in late March and remained pelagic for 40-60 days until they were about 25mm in total length and then became benthic (Roseman 2014). Concentrations of Deepwater Sculpin larvae in inshore zones (1.5 – 15 m) of northern Lake Huron suggest that such areas are important nursery habitats (Roseman and O’Brien 2013).

5.4.2 Physical and chemical habitat preferences

5.4.2.1 Temperature

Although temperature values may be site specific, in general Deepwater Sculpin show preference for cooler temperatures. Selgeby (1988) reported preferred temperatures of 3.0 to 7.3°C within Lake Superior. In Lake Michigan, adults were most abundant at depths of 73 to 137 m, and mainly occupied water colder than 4.5°C (Deason 1939).

5.4.2.2 Water depth

Water depth is likely the most thoroughly studied habitat characteristic of Deepwater Sculpin. This may be due to the fact that depth is relatively easy to measure, especially in studies that simply note presence or absence of the species. The Deepwater Sculpin lives on the bottom of the deepest lakes throughout its range (Stewart and Watkinson 2004), thus this species is often captured in deep bottom trawls (Wells 1968; Black and Lankester 1981; Madenjian and Bunnel 2008). Deepwater Sculpin appear to seek the deepest habitats available, and have been collected from the deepest part of Lake Superior in 407 m of water (Slegeby 1988). Although Deepwater Sculpin have been sampled at depths of 15 m (Selgeby 1988; Selgeby and Hoff 1996) they appear to be most abundant in areas greater than 70 m deep (Selgeby 1988). Deepwater Sculpin depth distribution may be seasonal, and they may be found in slightly deeper areas in the fall than in the spring (Kraft and Kitchell 1986). Geffen and Nash (1992) suggested that the population dynamics of Deepwater Sculpin appeared to be based on a dynamic spatial separation of different life-history stages, so that age classes are segregated along a depth gradient moving inshore and offshore on a seasonal basis. Gorman et al. (2012) found that Deepwater Sculpin were absent from shallow-water (≤ 40 m) bottom trawls in Lake Superior, but increased in numbers with depth, dominating the catch at depths of >160 m. Behind Cisco (*Coregonus* sp.), Deepwater Sculpin were the most important deep-water fish in terms of biomass in Lake Superior (Gorman et al. 2012). In the NWT, Deepwater Sculpin have been found co-occurring with Slimy and Spoonhead sculpins in four medium-sized lakes—ranging from 305 to 547 ha and 20 to 34.5 m of maximum depth respectively.

5.4.2.3 Water chemistry

Little is known about water chemistry and conditions related to Deepwater Sculpin. However, it is known that this species requires high levels of dissolved oxygen and is thus negatively affected by eutrophication (COSEWIC 2006). The usable benthic habitat of Deepwater Sculpin would be influenced by the oxygen levels at depth. By late summer the oxygen levels at the deepest portions of some lakes where Deepwater Sculpin have been found in the NWT had reduced to the point where those areas were likely unsuitable for this species (< 4 mg/l) (Cott et al. 2011).

6.0 THREATS TO SCULPIN SPECIES IN THE NORTH

The introduction of exotic species into northern sculpin habitats may affect their density and distribution. For example, the introduction and proliferation of zebra mussels (*Dreissena* spp.) elsewhere in North America has greatly affected aquatic communities by changing water clarity, zooplankton communities, benthic community structure, and fish foraging success (Beeky et al. 2004). Beeky et al. 2004 demonstrated that zebra mussels affect Slimy Sculpin communities by impeding foraging in some substrate types.

Several researchers have documented the effects of mining-derived metals on several species of sculpin (Dubé et al. 2005; Allert et al. 2009). Allert et al. (2009) concluded that sculpins may be a good indicator species for the effects of mining-derived metals on fish communities (Allert et al. 2009). Dubé et al. (2005) exposed Slimy Sculpin to metal mining effluent in artificial streams, and found this depressed growth and reduced survival. Similarly, habitat changes due to agricultural inputs may negatively affect Slimy Sculpin through decreasing reproductive success and young-of-the-year survival (Gray and Munkittrick 2005; Gray et al. 2005).

Water temperature was found to be a more significant factor for influencing Slimy Sculpin density, growth, and survival than sediment deposition (Gray et al. 2005). With increasing temperatures from climate change there may be some shifts in sculpin distributions, but the lag time will probably be much longer for Northern Canada regions where water temperatures are presently low. All three sculpin species would be expected to respond negatively to sustained warmer water temperatures, if they are not able to move to cooler water refugia during periods of higher temperatures. Warmer water temperatures would be expected to affect the sculpin in the order of ascending preferred water temperatures (Deepwater Sculpin→ Spoonhead Spulpin→ Slimy Sculpin). Given that Slimy Sculpin occupy shallower waters, this species could be affected most if streams and lakes in the NWT experience increasing water temperatures in the future.

7.0 SUMMARY

The Slimy, Spoonhead, and Deepwater sculpins of NWT are species that all prefer cool-water habitat and which exhibit a range of diet, habitat, and life history characteristics that make them an integral part of the aquatic ecosystems of the NWT. Where they co-exist they do not appear to be in direct competition but exhibit some diet and habitat overlap. They have short lifespans and small home ranges compared to larger, more mobile fish species commonly encountered in lakes and rivers of NWT. Although much of the research focused on the more common and ubiquitous Slimy Sculpin, it is likely that all three species require clean, cold, well-oxygenated water with larger cobble substrate for spawning.

Given the increased use of the Slimy Sculpin as a species for environmental monitoring in the NWT and other parts of Northern Canada (see Spencer et al., 2008; Arciszewski et al., 2010), further research on Slimy Sculpin in northern environments would be valuable. Sculpins appear to serve valuable roles in cycling energy in austere habitats such as deeper lakes or in mountain streams. Gaining more knowledge on these species would be beneficial to our understanding of arctic aquatic ecosystems, as it is apparent that in many cases, sculpins are the most common, or only fish species found in these systems.

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