**Fisheries**

**Overview**

The eastern North Slope in Alaska is endowed with limited freshwater options for fish. As a result, there are only a few species that occupy the freshwater habitats that are available. Lake density is very low in the 1002 Area, east of the Canning River drainage, but increases progressively to the west (White et al. 2008; Arp and Jones 2009). Several mountain streams cross the 1002 Area between the Canning and Aichilik rivers (Craig and McCart 1975). These streams flow during summer with snowmelt, rainfall, perennial springs, and for some streams, melting glaciers (Craig and McCart 1975; Rabus and Echelmeyer 1998; Kane et al. 2013), however, only the perennial springs provide flow during winter (Craig and McCart 1975). Craig (1989a) estimated that winter habitat in the area was only about 5% of what was available for fishes during summer.

The nearshore environment in the southern Beaufort Sea, adjacent to the 1002 Area, is a mix of open coast and lagoons bounded by barrier islands. In summer, water along the coast becomes brackish and relatively warm because of flow from the Mackenzie River and other rivers along the eastern Arctic coastline (Craig 1984; Hale 1991; Dunton et al. 2006). The lagoons are relatively shallow, the amplitude of the tides is very small (≤30 cm), barrier islands restrict flow to some extent, and the environment becomes much less salty and much warmer than sea water outside the barrier islands. The lagoons are very productive environments for marine and anadromous species during summer. In winter, in part because of reduced flow between lagoons and the sea, and in part because of ion exclusion during ice formation, some lagoons become hypersaline environments that get even colder than normal sea water under ice. As winter approaches and the lagoons begin freezing up, anadromous fishes return to freshwater environments and marine fishes eventually retreat to offshore environments.

Freshwater species present in the 1002 Area include Dolly Varden *S. malma*, Arctic grayling *Thymallus arcticus*, round whitefish *Prosopium cylindraceum*, burbot *Lota lota*, and ninespine stickleback *Pungitius pungitius* (Fruge and Palmer 1994). Round whitefish and burbot are present in the Canning River but nowhere else in the 1002 Area (Craig 1977c; Fruge and Palmer 1994). Dolly Varden are present in three life history forms: anadromous populations in which most members rear in freshwater rivers for 2–4 years then begin migrating to sea to feed each summer; residual dwarf males of the anadromous populations that choose to stay in freshwater rivers rather than migrate to sea; and dwarf resident populations that exist in isolated lakes or perennial springs (McCart and Craig 1973; Craig 1977c; Craig 1978). Arctic grayling occur in some lakes and also in rivers with perennial springs that are used for overwintering habitat (Craig and McCart 1974; Fruge and Palmer 1994). Ninespine stickleback occur as both freshwater residents and as anadromous forms. They are common in lakes and the lower reaches of many rivers and streams throughout the 1002 Area.

Anadromous species known to occur in or adjacent to the 1002 Area include Dolly Varden, ninespine stickleback, Arctic cisco *Coregonus autumnalis*, broad whitefish *C. nasus*, humpback whitefish *C. clupeaformis*, least cisco *C. sardinella*, chum salmon *Oncorhynchus keta*, pink salmon *O. gorbuscha*, Chinook salmon *O. tshawytscha*, and rainbow smelt *Osmerus mordax* (Craig 1984; Fruge and Palmer 1994; Brown 2008). Dolly Varden and ninespine stickleback are the only anadromous species in this group that maintain populations within the rivers of the 1002 Area. Dolly Varden are known to migrate long distances along the coast during their summer feeding forays, east to the Mackenzie River and west to the Colville River or beyond (Kruger et al. 1999), and some individuals migrate into offshore waters as well (Courtney et al. 2018). Arctic cisco have natal origins in the Mackenzie River but disperse as juveniles to coastal habitats including the Colville River delta, where many overwinter in brackish environments (Galloway et al. 1983; Fechhelm et al. 2007). Rearing Arctic cisco make annual feeding migrations along shore during summer and eventually return to the Mackenzie River to spawn. Broad whitefish, humpback whitefish, and least cisco that are encountered in nearshore environments adjacent to the 1002 Area have natal origins in either the Mackenzie River to the east or the Sagavanirktok or Colville rivers to the west (Craig 1984). Salmon species that occur in nearshore waters adjacent to the 1002 Area or in rivers within the 1002 Area are thought to be strays from southern Chukchi or northern Bering Sea populations, although some believe that self-sustaining chum salmon populations may exist in the Mackenzie River drainage (Stephenson 2006; Irving et al 2009). Rainbow smelt are known to spawn in the Mackenzie and Colville rivers as well as in the Kuk River drainage farther west (Craig 1984). Dolly Varden and Arctic cisco are the primary food fishes for people in north east Alaska (Craig 1989b; Pederson and Linn 2005).

There are about 12 species of marine fishes that are commonly encountered in nearshore brackish environments adjacent to the 1002 Area, only four of which are relatively abundant during the summer season (Craig 1984; Brown 2008). These are fourhorn sculpin *Myoxocephalus quadricornis*, Arctic flounder *Pleuronectes glacialis*, saffron cod *Eleginus gracilis*, and Arctic cod *Boreogadus saida*. While anadromous species tend to migrate along shore in the southern Beaufort Sea, marine species are thought to follow a very different migratory pattern; moving towards shore and into shallow water during summer and away from shore and into deeper water during winter (Craig 1984). It is not uncommon to find these four common marine species in brackish environments during summer, or even in the very lower reaches of the rivers in the area.

**Species accounts**

Some of the fish species of ecological and/or subsistence value in or adjacent to the Arctic NWR are discussed below. Information about distribution, life history characteristics, and subsistence use is presented when available.

**Broad whitefish** *Coregonus nasus* are large, primarily benthic-feeding whitefish found in many Arctic and sub-Arctic waters of Asia and North America (McPhail and Lindsey 1970; Morrow 1980). They are present but uncommon in the nearshore waters of the Beaufort Sea adjacent to the 1002 Area (Craig 1984; Brown 2008). Broad whitefish populations may exhibit either anadromous or freshwater resident life histories (Reist and Bond 1988; Chudobiak 1995; Brown et al. 2007). Because rivers flowing through the 1002 Area do not support spawning or overwintering habitats for broad whitefish, they spawn and overwinter in aquatic habitats in the lower Sagavanirktok River and farther west, or in the Mackenzie River and farther east (Craig 1984, 1989a; Reist and Bond 1988). Therefore, all broad whitefish encountered in or adjacent to the 1002 Area are anadromous fish foraging in nearshore and estuarine habitats of the Beaufort Sea and occasionally in the lower reaches of the larger rivers (Ward and Craig 1974; Craig 1984; Brown 2008).

Age at maturity for broad whitefish ranges from about five years old for the earliest maturing populations, such as those in the Peel (VanGerwen-Toyne et al. 2008) and Yukon (Carter 2010) rivers, to about eight years old for the latest maturing populations, such as those in the Selawik River in western Alaska (Brown 2004) and in the Teshekpuk Lake region in northern Alaska (Moulton et al. 2007). Broad whitefish spawn in flowing water over gravel in late October and November (Chang-Kue and Jessop 1997; Shestakov 2001; Carter 2010), which is three to four weeks later than other whitefish species. They survive spawning and may spawn multiple times during their lives. Once mature, spawning may be annual (Tallman et al. 2002) or less frequently (Prasolov 1989; Brown 2004). Broad whitefish are capable of living for 20 years or more (Brown 2004; VanGerwen-Toyne et al. 2008), and the oldest individuals in a population may exceed 30 years (Bond and Erickson 1985; Reist and Bond 1988). Broad whitefish are a very good food fish (McPhail and Lindsey 1970; Morrow 1980) and are harvested at times in nearshore waters adjacent to the 1002 Area (Pedersen and Linn 2005).

**Humpback whitefish** *Coregonus clupeaformis* are medium size, primarily benthic-feeding whitefish that are widely distributed in rivers, lakes, and estuaries of northern North America (McPhail and Lindsey 1970). Many similar forms have been described across North American and Asia and substantial taxonomic debate continues regarding appropriate species designations (Lindsey 1963; Alt 1979; Bodaly et al. 1988; Bernatchez and Dodson 1994). McPhail and Lindsey (1970) considered humpback whitefish to be part of a complex of three species that included *C. clupeaformis*, *C. pidschian*, and *C. nelsoni*, distinguished based on slight differences of modal gill raker counts on the first gill arch. A recent meristic, morphometric, and genetics analysis of the three humpback whitefish forms across North America concluded that the complex should be considered a single species, *C. clupeaformis*, differentiated at the subspecies level (McDermid et al. 2007). Humpback whitefish encountered in Alaska have traditionally been classified as *C. pidschian* in interior (Alt 1979) and Arctic habitats (Craig 1984), while in Canada they have been classified as *C. clupeaformis* (Bryan 1973; Craig 1984; Reist and Bond 1988). All humpback whitefish forms are referred to here as *C. clupeaformis*, per McDermid et al. (2007).

Humpback whitefish are rare in the nearshore waters of the Beaufort Sea adjacent to the 1002 Area (Craig 1984; Brown 2008). Similar to the situation with broad whitefish, spawning and overwintering habitats of humpback whitefish are in the lower Sagavanirktok River and farther west and in the Mackenzie River and farther east, so humpback whitefish encountered in or near the 1002 Area are anadromous fish foraging in nearshore and estuarine habitats of the southern Beaufort Sea.

Age at maturity for humpback whitefish range from about age 5 for the earliest maturing populations, such as those in southern Hudson Bay in eastern Canada (Morin et al. 1982) and in the Kuskokwim River (Harper et al. 2007), to age 11 for a much later maturing population in Dease Inlet in western Arctic Alaska (Moulton et al. 1997). River spawning humpback whitefish spawn in flowing water over gravel in late September and early October (Stein et al. 1973; Alt 1979; Brown 2006; Harper et al. 2009). Lake resident populations spawn over rock, gravel, and sand substrates between mid-October and late December, much later than river spawning populations (Bidgood 1974; Bryan and Kato 1975; Anras et al. 1999). Humpback whitefish in some populations may spawn two or more years in a row (Brown 2006, 2009), while in other populations alternate year spawning may be more common (Lambert and Dodson 1990; Moulton et al. 1997). Humpback whitefish are capable of living for 20 years or more (Moulton et al. 2007; Harper et al. 2007; VanGerwen-Toyne et al. 2008) and the oldest individuals within a population often exceed 30 years (Barnes and Power 1984; Howland et al. 2001; Brown and Fleener 2001). Humpback whitefish are considered to be a good food fish. They have been exploited in commercial food fisheries in North America more than any other whitefish species (Bodaly 1986; Ebener 1997; Tallman and Friesen 2007) and are routinely harvested in subsistence fisheries in Alaska and northwestern Canada (Corkum and McCart 1981; Georgette and Shiedt 2005).

**Least cisco** *Coregonus sardinella* are relatively small, pelagic-feeding whitefish found in many Arctic and sub-Arctic waters of Asia and North America (McPhail and Lindsey 1970; Morrow 1980). They have been documented in estuaries, rivers, and lakes from various locations in Alaska and northwest Canada (Alt 1980; Mann and McCart 1981; Reist and Bond 1988; Moulton et al. 1997; Seigle 2003). Because rivers within the 1002 Area do not support spawning or overwintering habitats for least cisco, they spawn and overwinter in aquatic habitats in the Sagavanirktok River and farther west, or in the Mackenzie River and farther east (Craig 1984, 1989a; Reist and Bond 1988). Therefore, least cisco encountered in or adjacent to the 1002 Area are anadromous fish foraging in nearshore and estuarine habitats of the southern Beaufort Sea (Craig 1984; Brown 2008).

Age at maturity for least cisco varies throughout Alaska, with interior and Kuskokwim River fish maturing as early as age 3 (Brown and Fleener 2001; Harper et al. 2007; Brown 2009), age 5 in the Selawik region (Brown 2004), and age 7 in Arctic Alaska (Moulton et al. 1997). Least cisco as old as 25 years or more have been reported (Mann 1974; Moulton et al. 1997). Least cisco are known to undertake extensive spawning migrations from lower drainage or estuarine rearing habitats to spawning habitats that may be several hundred kilometers upstream (Reist and Bond 1988; Brown et al. 2007). Spawning is thought to be either annual (Brown 2004) or less frequent (Mann 1974; Moulton et al. 1997), taking place from late September to early October (Kepler 1973; Mann 1974; Alt 1980). Eggs are broadcast in flowing water over gravel for riverine populations (Alt 1980, 1983; Brown 2009). Isolated populations in lakes are evidently capable of spawning in the absence of flowing water (Doxey 1991), however, actual spawning habitats within lakes have not been identified. Least cisco are harvested in subsistence fisheries as human or dog food but they are generally captured incidentally to other larger whitefish species (Georgette and Shiedt 2005; Moulton and Seavey 2005).

**Arctic cisco** *Coregonus autumnalis* are relatively small, pelagic-feeding whitefish, with a near circumpolar distribution in Arctic waters (McPhail and Lindsey 1970; Moskalenko 1971). Populations have been documented in several large rivers in northern Europe and Asia, and in the Mackenzie River in northwestern Canada. All evidence indicates that Arctic cisco observed in Alaskan waters originate in the Mackenzie River drainage in Canada (Galloway et al. 1983; Fechhelm et al. 2007; Zimmerman et al. 2013), where several spawning populations have been identified (McLeod and O’Neil 1983; Dillinger et al. 1992). Juveniles disperse throughout the Beaufort Sea coastal waters of northwest Canada and Alaska for rearing and feeding (Fechhelm and Fissil 1988; Fechhelm and Griffiths 1990; Fechhelm et al. 2007). Overwintering habitats include brackish environments in the Sagavanirktok and Colville River deltas in the west and the Mackenzie and Anderson River deltas in the east (Craig 1984; 1989a; Fechhelm et al. 2007). Arctic cisco encountered in nearshore habitats adjacent to the 1002 Area are either foraging or if mature, are migrating from overwintering habitats in the Colville River delta back to the Mackenzie River to spawn (Craig 1989a; Fechhelm et al. 2007; Brown 2008).

Arctic cisco are fully anadromous and are not known to exist as freshwater residents (Reist and Bond 1988). Age at maturity, based on minimum ages of Arctic cisco sampled from spawning migrations in the Mackenzie River drainage, has been estimated at seven to eight years (Stein et al. 1973; Van Gerwen-Toyne et al. 2008). Arctic cisco are capable of spawning more than once and some may live for as long as 20 years or so (Reist and Bond 1988; Van Gerwen-Toyne et al. 2008). The spawning migration into the Liard River, in the upper Mackenzie River drainage, entails an upstream migration of over 2,000 km (McLeod and O’Neil 1983). During summer, Arctic cisco are one of the most abundant species in nearshore waters of the Beaufort Sea, including areas adjacent to the 1002 Area (Craig 1984; Brown 2008), and one of the primary species taken in the Kaktovik subsistence fishery (Griffiths et al. 1977; Pedersen and Linn 2005).

**Round whitefish** *Prosopium cylindraceum* are a relatively small, primarily benthic-feeding whitefish common in northern North America and northeastern Asia (McPhail and Lindsey 1970). While anadromous populations of round whitefish exist in certain coastal drainages (Morin et al. 1982), most round whitefish populations are freshwater resident forms, occupying freshwater rivers and lakes (Morrow 1980; Stewart et al. 2007). Round whitefish are present in several drainages and lakes on the North Slope of Alaska (McCart et al. 1972; Alt 1976), but within the 1002 Area they occur only in the Canning River and not farther east (Ward and Craig 1974; Craig 1977c; Smith and Glesne 1983).

Age at maturity for round whitefish ranges from as young as age 3 for early maturing populations, such as those in southeast Canada (Morin et al. 1982), to age 8 or older for later maturing populations such as those in the northeast Asia (Gudkov 1999) and in the upper Chandalar River drainage (Craig and Wells 1975). Spawning for riverine round whitefish takes place in flowing water over gravel in late September and October (Craig and Wells 1975; Zyus’ko et al. 1993). Lake resident populations spawn over a mixed substrate composed of rocks, gravel, and mud in November or December (Normandeau 1969; Bryan and Kato 1975, Haymes and Kolenosky 1984). Round whitefish may spawn every year following maturity, as suggested by Craig and Wells (1975), but most reports suggest that spawning takes place less frequently (Jessop and Power 1973; Zyus’ko et al. 1993; Gudkov 1999). Round whitefish are capable of living for 20 years or more (Craig and Wells 1975; Plumb 2006) and the oldest individuals within a population may exceed 30 years (Gudkov 1999). Round whitefish have been exploited as a food fish for many years in the Laurentian Great Lakes (Mraz 1964; Fleischer 1992). They are occasionally harvested in subsistence fisheries in Alaska but are usually a minor component of the catch (Pedersen and Linn 2005).

**Dolly Varden** (*Salvelinus malma*) is a coldwater species distributed on the Arctic coast of North America from the Mackenzie River west and south through Alaska to British Columbia and on the western side of the Pacific from the Chukotsk Peninsula of Russia south to Japan and Korea (Scott and Crossman 1973; Reist et al. 1997; DeCicco 1997). Previous to 1997, Dolly Varden in northern Alaska were often referred to as Arctic char (*Salvelinus alpinus*), although for many decades there has been an understanding that there were morphological differences between char to the east of the Mackenzie River and those to the west (McCart 1980). Reist et al. (1997) conducted detailed morphology and genetics analyses and formally established anadromous char in northern Alaska and northwest Canada as Dolly Varden.

Dolly Varden are widely distributed within the northern part of the Arctic NWR and several rivers flowing through the 1002 Area support spawning populations including the Canning (Craig 1977c), Hulahula (Daum et al. 1984; Brown et al. 2014), and Aichilik (Craig and McCart 1974; West and Wiswar 1985) rivers. In addition, several isolated resident populations have been documented in springs and lakes in the Canning (McCart and Craig 1973; Craig 1977c), Sadlerochit (Craig 1977b; Wiswar 1994), and Jago (Daum et al. 1984) River drainages. It should be noted that it isn’t clear at this point whether the lake resident char in the Jago River valley (Daum et al. 1984) are Dolly Varden or Arctic char.

Resident and anadromous forms of Dolly Varden exhibit a number of distinct life history characteristics (Craig and McCart 1974; McCart 1980). Resident fish rarely achieve seven years of age and typically do not exceed 250 mm in length (Craig 1977b; Craig 1978; Armstrong and Morrow 1980). Resident fish primarily feed on dipteran larvae and other macroinvertebrates, achieve sexual maturity between the ages of two and four, and with few exceptions, utilize spring habitat exclusively for all life history stages (Craig 1977b; McCart 1980). Alternatively, anadromous fish may live to 10 years of age or more and grow to over 800 mm in length (Armstrong and Morrow 1980; Craig and Haldorson 1981; Underwood et al. 1996). Sexual maturity may be attained as early as 4 years for certain precocious individuals, although the majority of anadromous fish don’t mature until 6 or 8 years at lengths of 400 mm or greater (McCart 1980; Underwood et al. 1996). First migration to sea occurs between the ages of 2 and 5 years, with the majority of individuals migrating at 3 to 4 years (Yoshihara 1973; McCart 1980; Underwood et al. 1996). In late spring or early summer, Dolly Varden migrate to brackish, nearshore coastal areas of the Beaufort Sea from overwintering habitats in deep pools and spring-fed areas in coastal rivers (Craig 1989a; Fechhelm et al. 1997; Jarvela and Thorsteinson 1997). While at sea, individuals move extensively along the Arctic coast within mixed-stock aggregates feeding heavily upon mysid shrimp and amphipods with some incidence of piscivory (Craig 1984, 1989a; Krueger et al. 1999). Additionally, recent satellite telemetry data indicate that at least some Dolly Varden migrate as much as 60 km or more offshore, a migratory phenomenon that was previously unknown (Courtney et al. 2018). Anadromous Dolly Varden return to freshwater in late summer or early fall to spawn and overwinter (Craig 1984; Craig 1989a). Catch data indicate that the majority of returning spawners are female, suggesting different rates of mortality among the sexes. However, because virtually all individuals of the anadromous populations that remain resident are male (Furniss 1975; Craig 1978; McCart 1980), and those residual males can be very numerous on spawning grounds, it is thought that they account for the proportional differences between males and females observed returning from the sea. Spawning is thought to occur most often in non-consecutive years with mature females building redds within spring-fed areas of tributary streams and rivers where males compete for access (Furniss 1975; McCart 1980). Genetic structure within drainage systems indicates that spawning fish display a high level of fidelity to natal drainages (Everett et al 1997; Krueger et al. 1999; Crane et al. 2005). Some individuals are known to overwinter in non-natal drainages during nonspawning years (McCart 1980; Brown et al. 2014). Fry emerge from nests under ice cover in May and June and are believed to remain in close proximity to spawning beds throughout the first year of life (McCart 1980).

Anadromous Dolly Varden are the primary species caught in subsistence fisheries by residents of Kaktovik, in a winter fishery at Fish Hole 2 on the Hulahula River and in coastal areas during the summer (Craig 1989b; Pederson and Linn 2005). There is also evidence of recreational use and harvest on some of the more popular rivers that flow through the 1002 Area (Arvey 1991; Jennings et al. 2010)

**Arctic char** (*Salvelinus alpinus*) inhabit freshwater and marine habitats and exhibit a circumpolar distribution within the Holarctic (Johnson 1980; Reist et al. 1997). While both anadromous and freshwater-resident forms are present within Alaska, only lake-resident populations exist within the Arctic NWR (Reist et al. 1997). Within North Slope drainages, populations have been documented in a few lakes within the upper Canning and Sagavanirktok River drainages (McCart et al. 1972; Craig 1977c) and in Peters and Schrader lakes in the upper Sadlerochit River drainage (Ward and Craig 1974; Craig 1977c). It is also possible that isolated lake-resident char in the Jago River drainage are Arctic char but meristic data necessary to make that determination is not available (Daum et al. 1984). At this time, Arctic char have not been documented in waterbodies within the 1002 Area.

Arctic char body size and growth varies dramatically among areas, but in general, lake-resident Arctic char are smaller and grow at slower rates relative to anadromous forms (Craig 1977c). For example, lake-resident Arctic char in Big Lake, located in the headwaters of the Canning River, were found not to exceed 190 mm in length, while populations in adjacent lakes reached sizes upwards of 400 mm (Craig 1977c). Sexual maturity is attained between the ages of 3 and 8 with maximum ages greater than 10 years (Craig 1977c). Spawning is thought to occur during fall in deeper portions of lacustrine habitats to avoid ice scouring (Armstrong and Morrow 1980). Individuals feed non-selectively on insect larvae, amphipods, planktors, and fish where available (Craig 1977c; Armstrong and Morrow 1980). No data regarding abundance or harvest are currently available.

**Lake trout** (*Salvelinus namaycush*) inhabit deep, coldwater lakes and are widely distributed throughout northern North America from the Alaskan peninsula east across Canada to Nova Scotia and south to northern New York (Scott and Crossman 1973). Within the Refuge, lake trout are present in some coastal and headwater lakes where suitable overwintering habitat exists (Scott and Crossman 1973). On the North Slope, lake trout have been documented in Elusive Lake in the Sagavanirktok River drainage, two unnamed coastal lakes in the Canning River drainage, and Okpilak, Wahoo, Peters, and Schrader lakes (Ward and Craig 1974; Daum et al. 1984; Bendock and Burr 1985; West and Fruge 1989). At this time, Lake trout have not been documented in waterbodies within the 1002 Area.

Lake trout are long-lived (40+ years) and can reach sizes upwards of 1,000 mm fork length (Furniss 1974; Craig and Wells 1975; Morrow 1980). Individuals feed on invertebrates early in life, eventually shifting to a piscivorous diet as gape expands with increasing body size. Forage likely consists of any co-occurring fish species, with documented consumption of Arctic char, ninespine stickleback, slimy sculpin, Arctic grayling, and whitefish (*Coregonus* spp.) in Alaska (Burr 1990; McDonald and Hershey 2006; Swanson et al. 2010). Lake trout become sexually mature between the ages of 5 and 13 with the majority of individuals maturing at 7 or 8 years (Craig and Wells 1975; Morrow 1980). In general, lake trout spawn in the fall over large boulder or rubble substrate at depths less than 13 m (Scott and Crossman 1973). Time of and length at emergence varies depending on habitat conditions with eggs typically requiring a 4 to 5 month incubation period (Martin 1957).

The Schrader Lake population of lake trout was estimated to contain roughly 7,000 individuals in 1995, with the majority of fish ranging between 390 and 500 mm in length (Lubinski et al. 1999). Lake trout from Peter and Schrader lakes are harvested in subsistence fisheries by residents of Kaktovik (Craig 1989b; Pederson and Linn 2005). Elusive Lake, located in the Ribdon River drainage supports a small lake trout sport fishery, however no specific sport harvest data could be found for Refuge waters (Bendock and Burr 1985; Jennings et al. 2010).

**Chum salmon** (*Oncorhynchus keta*) are distributed on the western coast of North America from southern California to the Arctic and in Asia from Siberia south to Japan (Scott and Crossman 1973). Chum salmon are semelparous and anadromous, with adults typically ranging between 550 and 650 mm in length (Horne-Brine et al. 2009). Fry emerge from gravel nests in early spring and shortly thereafter begin to disperse to the marine environment. At sea, juveniles prey upon various copepods and amphipods until growth permits the consumption of fish (Salo 1991). Individuals return to freshwater to spawn in natal tributaries beginning in summer and fall between the ages of two and six, with the majority of fish returning as four and five year olds (Gilk et al. 2009; Horne-Brine 2009). On the spawning grounds, females construct gravel nests where eggs are deposited and subsequently covered with gravel (Morrow 1980).

Within North Slope waters of the Arctic NWR, chum salmon have been captured in low numbers in the Sadlerochit, Sagavanirktok, and Canning rivers as well as nearshore coastal areas (Smith and Glesne 1983; Craig and Haldorson 1986; Brown 2008). Some believe that self-sustaining chum salmon populations may exist in the Mackenzie River drainage while others consider all encountered in the Beaufort Sea to be strays originating from more southerly drainages (Craig and Haldorson 1986; Irvine et al. 2009b). Residents of Kaktovik infrequently harvest chum salmon in subsistence fisheries in nearshore areas surrounding Barter Island in the southern Beaufort Sea (Pedersen and Linn 2005).

**Chinook salmon** (*Oncorhynchus tshawytscha*) are distributed along the west coast of North America from southern California to Point Hope, Alaska and in Asia from Siberia south to Japan (Scott and Crossman 1973). Within the northern part of the Arctic NWR, Chinook salmon are rarely encountered in nearshore environments and have not been captured in any of the rivers, despite occasional catches in the Colville River to the west and Mackenzie River to the east (Craig and Haldorson 1986; Stephenson 2006; Irvine et al. 2009a). Chinook salmon are anadromous, semelparous, and the largest of the Pacific salmon species. Adults commonly reach lengths of 430 to 860 mm but may grow to upwards of 1000 mm on occasion (Horne-Brine et al. 2009). Fry emerge in spring and usually spend the first year of life in freshwater habitats feeding on aquatic and terrestrial invertebrates (Wipfli 2009). Smolts migrate to sea in spring where growth rates subsequently increase as individuals shift to a primarily piscivorous diet (Bradford et al. 2009). In the ocean, the majority of Chinook salmon occupy habitats in the southern Bering Sea where they spend between one and five years before returning to natal freshwater streams to spawn in mid-July to late August (Healey 1991). On the spawning grounds, females construct gravel nests in flowing water where eggs are deposited and covered with substrate.

**Arctic grayling** (*Thymallus arcticus*) reside in lakes and rivers of northern North America from Hudson Bay to the western shores of Alaska and in Asia from Siberia to North Korea (Scott and Crossman 1973). In Beaufort Sea drainages of the Arctic NWR, including those flowing across the 1002 Area, Arctic grayling are widespread and abundant (Garner and Reynolds 1986; Craig and Wells 1975). Sexual maturity is attained between the ages of four and eight with individuals typically reaching 300 to 350 mm in length and between 450 and 750 grams in weight (McCart et al. 1972; Craig and Poulin 1975; Morrow 1980). Spawning occurs annually shortly after break up in early spring in small river and lake tributaries over areas of sandy gravel (Bishop 1971). When stream habitat is not available, spawning may also occur in larger substrates in rivers and lakes (Scott and Crossman 1973). Males are territorial on the spawning grounds however no nest is constructed (Kratt and Smith 2006). The incubation period is relatively short and juvenile fish emerge from the substrate roughly 9 to 21 days following spawning, depending on water temperature (Morrow 1980; Kratt and Smith. 1977). Adults feed on aquatic and terrestrial invertebrates and may undertake extensive inter- and intra-drainage movements between overwintering sites (deep pools, lakes, spring-fed areas) and summer feeding habitats following reproduction (Craig and Poulin 1975; West et al. 1992). Arctic grayling are, at least for short periods, tolerant of saline conditions, as individuals are sometimes captured in estuarine waters during inter-drainage movements in coastal systems (West et al. 1992). Additional biological information regarding Arctic grayling inhabiting North Slope rivers and lakes within the Arctic NWR are present in a number of publications (Furniss 1975; Garner and Reynolds 1986; Deschermeier et al. 1986; Wiswar 1991, 1992, 1994; West et al. 1992). Recreational harvest is likely to occur throughout the Refuge, although, no specific data are available (Jennings et al. 2010).

**Burbot** (*Lota lota*) inhabit deep areas of rivers and lakes of the circumpolar north extending south into some temperate areas of Europe, Asia, and North America (Morrow 1980). Within North Slope waters of the Arctic NWR, burbot have been documented in lakes and main-stem areas of the Canning River, including the segment along the western boundary of the 1002 Area (Ward and Craig 1974; Craig 1977c; Smith and Glesne 1983) and in the Sagavanirktok River but not in any other rivers or lakes within the 1002 Area (Bendock 1980; Bendock and Burr 1985). Burbot are rarely observed in nearshore environments (Craig 1984).

Burbot typically reach lengths of 400 to 550 mm and weigh between 0.5 and 1 kg, however, individuals greater that 1,500 mm and weighting over 30 kg have been reported (Chen 1969; Evenson 1990). Most individuals are sexually mature by the age of seven (earlier in southern latitudes) and spawn under the cover of ice between the months of November and February (Chen 1969). Spawning may not be an annual event and generally takes place over gravel and sand substrate in relatively shallow areas of rivers and lakes (Chen 1969; Breeser et al. 1988). Eggs and sperm are released simultaneously by a mating pair with fertilized eggs settling into spaces in the substrate and developing over the next one to two months without parental care. Juvenile burbot feed on insect larvae and other invertebrates until roughly the third or fourth year after which they feed primarily on fish (Chen 1969). Seasonal movements ranging from a few kilometers to over 250 kilometers have been reported within riverine populations most likely associated with the connection of spawning and foraging habitats (Percy 1975; Breeser et al. 1988; Evenson 1990).

**Ninespine stickleback** (*Pungitius pungitius*) are distributed in North America from Cook Inlet, Alaska, north to the Arctic Ocean and southeast through Canada terminating on the Atlantic Coast of New England (Scott and Crossman 1973; Morrow 1980). Within North Slope waters of the Arctic NWR, ninespine stickleback are present in the lower reaches of most of the major drainages including those that flow through the 1002 Area (Ward and Craig 1974; Craig 1977a; Wilson et al. 1977; Bendock and Burr 1985). Furthermore, ninespine stickleback are commonly found in coastal brackish lagoons (Griffiths et al. 1977; West and Wiswar 1985; Wiswar et al. 1995; Brown 2008) and coastal lakes where they are often the only species present (West and Fruge 1989; Trawicki et al 1991; Wiswar 1994).

Ninespine stickleback are tolerant of salinities < 20 ppt and may move between fresh and saltwater throughout the year as access and conditions permit (Wooton 1984). Individuals attain sexual maturity by the age of two, seldom live beyond the age of five, and typically reach 65 mm in length with some as large as 90 mm (Scott and Crossman 1973; Heins et al. 2003). Spawning occurs in freshwater between the months of May and July in shallow areas containing aquatic vegetation (Wooton 1984). Males construct nests from algae and small debris where females deposit eggs. After fertilization, males protect nesting areas from predators and fan oxygenated water over the clutch of eggs. Young emerge roughly a week to a month later at which time males continue to provide care by preventing them from straying from nursery areas. Little is known regarding seasonal movements, however, spawning individuals likely move from shallow (littoral, tributary, or slough habitat) to deep (river deltas, coastal areas, lake bottoms) areas in fall (Wooton 1984). Ninespine stickleback prey on aquatic insects and small crustaceans and are an important prey item of predatory fish and birds (Palmer 1962; Morrow 1980). Additional biological data on ninespine stickleback are available in numerous publications (Yoshihara 1972; Ward and Craig 1974; Craig 1977a; Griffiths et al. 1977; Wilson et al. 1977; Bendock and Burr 1985; West and Wiswar 1985; West and Fruge 1989; Trawicki et al 1991; Wiswar et al. 1995; Jarvela and Thorsteinson 1999; Brown 2008). While they are commonly found in most North Slope coastal habitats of the Refuge, catch rates vary dramatically among areas and years.

**Arctic cod** (*Boreogadus saida*) is a marine species distributed throughout the entire northern polar basin, around Greenland and Iceland**,** into Hudson Bay, and in the North Bering Sea (Cohen et al. 1990). Arctic cod are commonly encountered and sometimes abundant in nearshore coastal areas adjacent to the Arctic NWR in the southern Beaufort Sea (Craig et al. 1982; Brown 2008).

Arctic cod prefer cold (0-6°C), saline (20-30 ppt) habitats but are at least temporarily tolerant of fluctuating temperatures, salinities, and turbidities as they are found in both in-and off-shore marine areas, estuaries, and occasionally in in the lower reaches of coastal rivers (Lowry and Frost 1981; Craig et al. 1982; Cohen et al. 1990). Adults typically range between 60 and 170 mm in length with some individuals reaching 250 mm (Craig et al.1982). Sexual maturity is attained between the ages of two and three with maximum ages of six to seven years (Lear 1979; Craig et al.1982). During late summer and fall, Arctic cod may aggregate into large schools and move into nearshore coastal areas that are transitioning from estuarine to marine conditions (Craig et al 1982; Hop et al. 1997). Seasonal movements and schooling behavior may be associated with spawning, foraging, predator avoidance, or habitat availability as Arctic cod are often found associated with the edges of pack ice (Welch et al. 1993; Hop et al. 1997). Spawning occurs under ice between the months of November and March, presumably close to shore (Lowry and Frost 1981; Craig et al. 1982). Arctic cod prey on amphipods, copepods, and mysid shrimp and are an important prey item for many species of marine mammals, birds, and fish (Palmer 1962; Craig et al. 1982; Craig et al. 1984; Frost and Lowry 1984).

Arctic cod may be the most abundant and widely distributed fish species in the Beaufort Sea (Lowry and Frost 1981; Craig et al. 1982; Craig 1984). Catch data suggest Arctic cod are more abundant in coastal areas west of the Arctic NWR with one estimate, during the summer of 1978 in Simpson lagoon, numbering in the millions (Craig et al. 1982; Jarvela and Thorsteinson 1999). Within waters adjacent to the Arctic NWR, catch rates of Arctic cod are variable within and among years and areas but tend to increase during late summer and fall (Griffiths et al. 1977; Fruge et al. 1989; West and Fruge 1989; Underwood et al. 1995; Wiswar et al. 1995; Jarvela and Thorsteinson 1999; Brown 2008). There is some evidence that Arctic cod are harvested in subsistence fisheries in Kaktovik and Jago lagoons by residents of Kaktovik (Griffiths et al. 1977).

**Saffron cod** (*Eleginus gracilis*) is a marine species distributed throughout the North Pacific from the Yellow Sea in Asia to Southeast Alaska and north in the Arctic Ocean from eastern Siberia to northwestern Canada (Morrow 1980; Cohen et al. 1990). Saffron cod are widely distributed in the Beaufort Sea including coastal areas adjacent to the Arctic NWR (Wiswar and West 1987; Fruge et al. 1989; Wiswar et al. 1995; Brown 2008).

Saffron cod inhabit both in- and off-shore marine and estuarine areas and are occasionally found in the lower reaches of coastal rivers (Morrow 1980). Average adult lengths range between 250 and 350 mm, with some individuals reaching up to 500 mm (Craig and Haldorson 1981). Sexual maturity is attained between the ages of two and three, with maximum ages reported between 10 and 12 years old (Cohen et al. 1990). Fish tend to move inshore in fall and winter to spawn, then move offshore in spring and summer to feed in deeper habitats (Morrow 1980). Forage consists of mysid shrimp, amphipods, and decapods, with larger individuals ingesting fish (Ellis 1962; Craig and Haldorson 1981)

Biological data pertaining to saffron cod are largely limited to catch data and are available for nearshore areas of the Beaufort Sea adjacent to the Arctic NWR (Griffiths 1984, Wiswar and West 1987; Fruge et al. 1989; Wiswar et al. 1995; Brown 2008) and in other locations (Bendock 1977**;** Craig et al. 1985**;** Griffiths et al. 1998; Fechelm et al. 2006). Catch rates vary substantially among years and areas.

**Fourhorn sculpin** (*Myoxocephalus quadricornis*) is a marine species distributed throughout the circumpolar north from the Baltic Sea, east across northern Siberia to the Arctic coast of Canada and south to Norton Sound, Alaska (Andriyashev 1954; Morrow 1980). Fourhorn sculpin are often abundant in nearshore coastal areas of the Beaufort Sea adjacent to the Arctic NWR (Griffiths et al. 1977; West and Wiswar 1985; Wiswar and West 1987; Underwood et al. 1995; Wiswar et al. 1995; Jarvela and Thorsteinson 1999; Brown 2008).

Fourhorn sculpin rarely descend below 15-20 meters in depth and inhabit cold nearshore marine and estuarine coastal areas year-round, occasionally moving into the lower reaches of coastal streams and rivers (Griffiths et al. 1977; Morrow 1980). Adults typically reach 280 mm in length but may grow to 365 mm and live to 14 years of age (Andriyashev 1954; Percy et al. 1974; Griffiths et al. 1975). Sexual maturity is attained between the ages of three and nine with the majority of fish mature by the age of six (Griffiths et al. 1975; Griffiths et al. 1977). Spawning is thought to occur in winter, although evidence of summer spawning also exists (Goldberg et al. 1987), with males excavating shallow depressions in soft substrate where females deposit eggs (Westin 1969). After fertilization, males remain in close proximity to the nest site, cleaning and fanning oxygenated water over the eggs. Young emerge two to three months later, depending on water temperature, and move into shallow waters close to shore (Westin 1970). Seasonal on- and off-shore movements by adults may be common with individuals feeding on invertebrates such as mysids, amphipod, isopods, and occasionally small fish (Griffiths et al. 1975; Griffiths et al. 1977).

Biological data pertaining to fourhorn sculpin are largely limited to catch data and are available for nearshore areas of the Beaufort Sea adjacent to the Arctic NWR (Griffiths et al. 1977; West and Wiswar 1985; Wiswar and West 1987; Underwood et al. 1995; Wiswar et al. 1995; Jarvela and Thorsteinson 1999; Brown 2008) and in other locations (Percy et al. 1974; Griffiths et al 1975; Craig and Haldorson 1981; Jarvela and Thorsteinson 1999). While catches vary among years and areas, fourhorn sculpin are typically one of the most abundant marine species in nearshore areas of the Arctic NWR.

**Arctic flounder** (*Pleuronectes glacialis*) is a marine species distributed from Queen Maude Gulf in Arctic Canada west along the coast of North America to Siberia and south to Bristol Bay, Alaska (Andriyashev 1954; Morrow 1980). Fishbase (Froese and Pauly 2017), a world-wide, web-based, fish taxonomy guide, classifies Arctic flounder as *Liopsetta glacialis* while the American Fisheries Society classifies the species as *Pleuronectes glacialis* (Page et al. 2013). We use the American Fisheries Society classification here. Arctic flounder are found throughout nearshore coastal areas of the Beaufort Sea adjacent to the Arctic NWR (Griffiths et al. 1977; Wiswar 1986; Jarvela and Thorsteinson 1999; Brown 2008).

Arctic flounder typically remain close to shore, inhabiting shallow brackish water habitats and river deltas, occasionally entering rivers and delta lakes (Craig 1977c; Wilson et al. 1977). Adults range between 150 and 250 mm in length, attain sexual maturity between the fourth and fifth years, and generally live to between 9 and 12 years of age, however, specimens as old as 19 have been reported (Andriyashev 1954; Griffiths et al. 1975; Griffiths et al 1977; Bendock 1979; Morrow 1980). Spawning is thought to occur in coastal areas between January and March but possibly as late as May in some areas (Andriyashev 1954; Morrow 1980). Young emerge roughly 40 days after fertilization depending on water temperature (Aronovich et al. 2003). Seasonal on- and off-shore movements are thought to occur with forage consisting mainly of amphipods, mollusks, crustaceans, and small fish (Griffiths et al. 1975; Morrow 1980; Wiswar 1986).

Relative to Arctic cod and fourhorn sculpin, Arctic flounder are less frequently captured, but still common in nearshore areas of the Beaufort Sea coast (Percy et al. 1974; Griffiths et al 1975; Craig and Haldorson 1981; Jarvela and Thorsteinson 1999; Fechelm et al. 2006), including areas adjacent to the Arctic NWR (Griffiths et al. 1977; Wiswar 1986; Underwood et al. 1995; Jarvela and Thorsteinson 1999; Brown 2008). In addition, Arctic flounder are infrequently captured in subsistence fisheries by the residents of Kaktovik in waters surrounding Barter Island (Pedersen and Linn 2005).

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