SPECIAL REPORT 93-16

CRREL

Beaufort Sea Coastal Fish Studies

Overview and Bibliography

Robert K. Harris

June 1993

Abstract

Arctic fish are an important subsistence resource for the people living on the North Slope of Alaska. Many research efforts have investigated and monitored fish populations for the purpose of minimizing the impact of oil development on the fish. Many of these studies are in reports to various government agencies and may not be easily accessible. This report provides a general overview of the fish research done and lessons learned in the Alaskan Arctic for use by agencies involved in permitting future development. It allows access to the literature by listing other arctic fish bibliographies and providing species-specific bibliographies. The work focused on eight fish species identified as having ecological, subsistence or recreational value: arctic char (*Salvelinus alpinus*), arctic cisco (*Coregonus autumnalis*), arctic (polar) cod (*Boreogadus saida*), broad whitefish (*Coregonus nasus*), burbot (*Lota lota*), grayling (*Thymallus* sp.), least cisco (*Coregonus sardinella*) and saffron cod (*Eleginus gracilis*).

For conversion of SI metric units to U.S./British customary units of measurement consult *Standard Practice for Use of the International System of Units (SI)*, ASTM Standard E380-89a, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

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US Army Corps of Engineers
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PREFACE

This report was prepared by Robert K. Harris during a 1990 summer fellowship and updated in the summer of 1992. The work was supported by the Cold Regions Research and Engineering Laboratory, Geological Sciences Branch, and funded by the U.S. Army Research Office Scientific Services program administered by Battelle Laboratory (Contract No. DAAL03-86-D-001). The author thanks Darryl Calkins for his interest in this project. Ronald Smith and A.J. Paul of the University of Alaska commented on early drafts of the manuscript.

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ROBERT K. HARRIS

INTRODUCTION

Arctic fish are an important subsistence resource for the people living on the North Slope of Alaska. The development of the Prudhoe Bay oil fields continues to have potential impacts on the area's fish resources. An understanding of fish habitat use throughout the fishes' life history and of the seasonal energy flow through the food web was needed. Research efforts to investigate and monitor the fish resource were undertaken to minimize the impact of oil development on the fish. Many of these studies are in reports to various government agencies and may not be easily accessible. Attempts to collect the information have been made with the creation of a databank (Slaybaugh et al. 1989) and several synthesis reviews (Barnes et al. 1984, Craig 1984, Norton 1989).

The purpose of this report is to provide a general overview of the fish research done and lessons learned in the Alaskan Arctic for use by agencies involved in permitting future development. This report will allow access to the literature by listing other arctic fish bibliographies and providing species-specific bibliographies. The work focused on eight fish species identified as having ecological, subsistence or recreational value: arctic char (*Salvelinus alpinus*), arctic cisco (*Coregonus autumnalis*), arctic (polar) cod (*Boreogadus saida*), broad whitefish (*Coregonus nasus*), burbot (*Lota lota*), grayling (*Thymallus* sp.), least cisco (*Coregonus sardinella*) and saffron cod (*Eleginus gracilis*). A computer search of the Oceanic Abstracts, Aquatic Sciences and Fisheries Abstracts, and BIOSIS Previews databases covering the years 1970–1990 provided the basic material for the bibliography. Additional material from other sources was added when it reached the author's attention. Since many of these fish species have holoarctic distributions, no attempt was made to limit the search geographically, with the hopes that lessons learned in other areas may prove beneficial.

AN OVERVIEW OF RESEARCH ON THE FISH OF THE BEAUFORT SEA

The coastal oceanography of the Alaskan Beaufort Sea is dominated by the Mackenzie River, to the east of Prudhoe Bay. The Mackenzie River also supports a more diverse fish fauna than Prudhoe Bay. Sixty-two fish species have been recorded in coastal waters of the Alaskan Beaufort Sea; of these, nine species are common in brackish waters, two species in marine offshore waters, and one species in both environments (Craig 1984). Craig (1984, 1989) reviewed Beaufort Sea coastal fish habitats. Freshwater systems were included because of their contribution of anadromous fish to coastal waters.

The near-shore and offshore waters are very different habitats. The near-shore waters are warm, brackish and often turbid due to freshwater inputs from the river systems. Anadromous fish use this zone extensively in the summer during feeding migrations. The offshore waters are colder, clear and more saline because of their marine origin. Fish show distinct preferences by moving in response to the temperature–salinity gradients that result (Fechelm et al. 1983). Craig (1984) felt three factors tend to influence anadromous fish assemblages in Beaufort Sea coastal waters: distance from freshwater sources of origin, migration timing, and daily responses to salinity and temperature fluctuations.

Freshwater habitats

North Slope streams can be divided into three groups (Craig 1984):

- Coastal plain streams west of the Colville River, which do not have mountain headwaters;
- Mountain streams between the Colville and Mackenzie rivers with headwaters in the Brooks Range (including the Colville River); and
- The Mackenzie River complex.

The fish populations of these stream types are very different. The coastal plain streams support populations of whitefish, ciscoes and, to a limited extent, salmon. Coastal plain streams lack headwater springs that are found in the mountain streams; headwater springs provide overwintering habitat and are needed for spawning by some species such as the arctic char. The Colville and Mackenzie are the largest drainages on the North Slope, and they contain the most anadromous species and the largest populations.

In the fall, anadromous fish move up the freshwater streams to overwinter and spawn. Lakes, deep channels or perennial springs associated with larger North Slope rivers are used by these fish for overwintering and spawning sites (Craig 1984). Each species has its own specific substrate type and size requirements for spawning. The eggs of salmonid and coregonid fish incubate throughout the winter in streambed gravels. For successful egg survival a constant supply of oxygenated groundwater is needed (Craig 1989). The length of time young fish spend in the river is species dependent. Young fish leave the river to feed in coastal waters during the summer.

Brackish near-shore habitats

Arctic and least cisco, arctic char, arctic cod, broad and humpback whitefish, and fourhorn sculpin (*Myoxocephalus quadricornis*) were 90% of the fish caught in the brackish water area along the coast (Craig 1984). Turbid and warm river runoff water enters the near-shore zone during spring breakup. This river water pushes the colder, clearer and more saline marine water offshore. Since river water is less dense than marine water, the river water rides up and over the marine water, forming a typical estuarine wedge. As the river water mixes with the marine water, it becomes more saline and brackish. As a result, complex horizontal and vertical salinity and temperature gradients can occur. Anadromous and marine fishes will locate themselves within these gradients depending on their salinity and temperature preferences. Least ciscoes and broad and humpback whitefish are most abundant in the freshest water along the mainland. Arctic ciscoes and char, with larger tolerances, have wider distributions (Craig 1984).

Since the near-shore area is shallow, the prevailing winds determine the location and depth of the water masses in this zone. Easterly winds along the coast push the brackish water away from the shore out over the marine water, extending the estuarine wedge and making the water shallower near the shore. Westerly winds along the coast compress the estuarine wedge by pushing the marine and brackish water nearer the shore, and the nearshore water becomes deeper. The brackish water is typically 5–10°C, has a salinity of 10–25 ppt and is 2–10 km wide and 2–9 m deep (Craig 1984).

As the flow rate begins to drop and the rivers start to freeze in the fall, the marine water and associated fish move to the near-shore area. The anadromous fish reenter the river systems to overwinter and spawn. As the winter progresses and near-shore waters freeze, the bottom water becomes increasingly saline. The ice is 2 m thick by the end of the winter.

Marine habitats

There are few studies on the marine fish in the Alaskan Beaufort Sea. The studies that are available have focused on the arctic cod, a key marine species because of its abundance, wide distribution and trophic position (Frost and Lowry 1984). Studies in the Canadian High Arctic showed that arctic cod were found at ice edges feeding on invertebrate species. The arctic cod, in turn, were important forage fish for upper trophic levels (Bradstreet 1982, Bradstreet and Cross 1982). In the Beaufort Sea near-shore region, arctic cod are found in the marine waters of the estuarine wedge, where they feed on the abundant food that is concentrated there (Moulton and Tarbox 1987). The interface between the fresh and marine water is an important nursery and feeding area for young arctic cod. Development in this area could have an impact on the population. Information on different reproductive stocks appears to be lacking. Arctic cod are small, early maturing (three years), short-lived fish (Craig et al. 1982) with a wide distribution and high population turnover rate, suggesting to Craig (1984) that oil development may have a low impact on this species.

Habitat alterations

Anadromous fish in the Alaskan Beaufort Sea area have specific habitat requirements for spawning, feeding and overwintering. The fish migrate to different locations for each of these activities, and each of these locations is important for fish survival. Depending on the species and activity, fish show specific preferences for substrate type, salinity, temperature, groundwater input, oxygen level and depth. Habitat alterations, such as gravel removal, dredging, solid-fill causeways, water removal or dumping, in any of the locations could impact one or more fish population.

Anadromous fish populations in the Beaufort Sea region may be limited by the small number of suitable overwintering habitats that are available (Craig 1989, Schmidt et al. 1989). The overwintering sites may be where the anadromous fish populations are most vulnerable to environmental disturbance (Craig 1989). Anadromous fish overwinter in spring-fed streams and groundwater sources, deep pools (which may become oxygen depleted, resulting in fish kills; Schmidt et al. 1989), river deltas (primarily the Mackenzie and Colville), lakes and coastal waters (Craig 1989). Studies suggest that overwintering habitat for fish can be created by flooding gravel pits created during gravel removal operations (Hemmings 1988, 1989). Winter ice 2 m thick forms in the Prudhoe Bay area, but the deep ponds created by flooding gravel pits have substantial areas of under-ice water. Changing the vertical nature of the gravel pit sides and creating a shallow littoral zone enhances productivity and increases the amount of food for fish.

Development that hinders anadromous fish movements could have a serious impact on fish populations. Fish are known to move between the Mackenzie and Colville rivers (Gallaway et al. 1983, Fechhelm and Fissel 1987). Tag recoveries showed movement between the Hulahula River (char) and the Endicott study area (Cannon et al. 1987). Young-of-the-year arctic cisco from the Mackenzie River are transported into Alaskan waters by the coastal current and five years later recruit into the Colville River fishery. The mature arctic cisco return to the Mackenzie River to spawn (Fechhelm and Fissel 1987). Coastal development that impedes or blocks this movement of fish along the coast could affect the Colville River fishery, subsistence fisheries and the Mackenzie River spawning stocks.

The water along the Prudhoe Bay coast tends to be transported along the shore from east to west, with a strong wind-driven component. The construction of the West Dock Waterflood Causeway in Prudhoe Bay and the Endicott Causeway in the Sagavanirktok River delta (two solid-fill causeways) altered this current, changing the local temperature and salinity regimes (Craig and Griffiths 1981, Cannon and Hachmeister 1987, Fechhelm et al. 1989). Brackish water moving toward the west hits the east side of the causeways and is deflected seaward. Water on the west side of the causeways becomes more marine in character. West Dock had water temperatures 2.4°C lower and salinities 10 ppt higher on the west side than on the east (Craig and Griffiths 1981). This marine water then moves toward the west, giving a downstream effect. A tagging study of large arctic and least ciscoes suggested that West Dock did not block fish movements (Craig and Griffiths 1981). Further study by Fechhelm et al. (1989) suggested that when winds blow from the east the hydrographic regime is modified to such an extent that eastward movement of ciscos may be delayed or blocked. The Endicott studies also suggested that the causeways impede fish movement, both physically and by changing the water regime. The effect was greatest on young fish, which may be blocked (Cannon and Hachmeister 1987).

Craig (1984) felt that individual small-scale industrial use or development may not affect fish populations but that cumulative effects on the system, acting through direct mortality or habitat alteration, might affect the fish. Cannon and Hachmeister (1987) thought that effects from the West Dock and Endicott Causeways were independent enough that the effects were additive in nature rather than compounded. It appears that the causeways may have divided the area from Storkersen Point to Foggy Island Bay into three separate regions for young fish.

Trophic dynamics (near-shore habitat)

In the Arctic, fish migrate between different habitats for different reasons. Overwintering, reproduction and feeding are all important activities. The arctic feeding season is a short important time for an organism to get the energy resources that are needed to carry it through the rest of the year. Development that interferes with the timing of feeding or the amount of feed available could have a negative impact on arctic fish populations.

In Simpson Lagoon there was a high degree of dietary overlap between the fish and birds during the summer (Craig et al. 1984). Oldsquaw ducks (*Clangula hyemalis*) are the most important near-shore consumers during the summer (Craig et al. 1984). In the summer the fish and birds are feeding primarily on the mysids *Mysis litoralis* and *M. relicta* and the amphipod *Onisimus glacialis* (Craig et al. 1984). These epibenthic invertebrates feed primarily on diatoms, small crustaceans and peat. Isotope studies indicate that 90% of the carbon making up these invertebrates comes from primary production and 10% from peat (Schell et al. 1982). Advection of phytoplankton and immigration of mysids and amphipods into the lagoon occurs (Craig et al. 1984). The immigration rate is apparently fast enough that food has not been limiting, judging from the high degree of dietary overlap and low amount of resource partitioning that occurs. In the winter there was less dietary overlap, and there was more partitioning of food resources (Craig et al. 1984).

In freshwater habitats during the winter there was a high degree of dietary overlap between fish species (Craig et al. 1984), which may have reflected the availability of food species. Schell (1983) used isotope techniques to examine the importance of different carbon sources in Alaskan North Slope food webs. In freshwater habitats carbon from peat is heavily used by organisms. Overwintering fish feed on benthic aquatic invertebrates that are feeding on peat. At the end of the overwintering period, grayling were 32% and least cisco 20% peat carbon. During the open water season the percentage of peat carbon decreases as the fish feed on different food sources. Carbon isotopic variation in oldsquaw ducks depended on season and age. Birds, soon after leaving the tundra breeding lakes, were up to 63% peat carbon, while birds in marine environments had little peat carbon and were isotopically similar to marine fish. Marine organisms utilized the current year's primary production and were isotopically different from organisms using peat carbon (Schell 1983). Less than 10% of the carbon utilized by near-shore marine organisms came from peat (Craig et al. 1984). The peat carbon represents a "fossil fuel subsidy" (Schell 1983) in the Arctic that is useful to some aquatic invertebrates, overwintering fish and breeding ducks.

Frost and Lowry (1984) studied the offshore marine environment. Their calculations indicated that annual fluctuations in primary production could lead to food competition. Bowhead whales feed on larger copepods than Arctic cod, so some partitioning of food resources does occur (Frost and Lowry 1984). Arctic cod were responsible for 94% of the annual food consumption by vertebrates in the Alaskan Beaufort Sea (Frost and Lowry 1984). More information on the influence of marine offshore fish and bird populations on the trophic dynamics of the Alaskan Arctic is needed.

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13. ABSTRACT (*Maximum 200 words*)

Arctic fish are an important subsistence resource for the people living on the North Slope of Alaska. Many research efforts have investigated and monitored fish populations for the purpose of minimizing the impact of oil development on the fish. Many of these studies are in reports to various government agencies and may not be easily accessible. This report provides a general overview of the fish research done and lessons learned in the Alaskan Arctic for use by agencies involved in permitting future development. It allows access to the literature by listing other arctic fish bibliographies and providing species-specific bibliographies. The work focused on eight fish species identified as having ecological, subsistence or recreational value: arctic char (*Salvelinus alpinus*), arctic cisco (*Coregonus autumnalis*), arctic (polar) cod (*Boreogadus saida*), broad whitefish (*Coregonus nasus*), burbot (*Lota lota*), grayling (*Thymallus* sp.), least cisco (*Coregonus sardinella*) and saffron cod (*Eleginus gracilis*).

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