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A REVIEW OF COASTAL PLAIN FISH SURVEYS AND THE RESULTS OF 1986 FISH SURVEYS OF SELECTED COASTAL LAKES AND STREAMS, ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA

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A REVIEW OF COASTAL PLAIN FISH SURVEYS AND THE RESULTS OF 1986 FISH SURVEYS OF SELECTED COASTAL LAKES AND STREAMS, ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA

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Abstract

A review of fish surveys of Beaufort Sea drainages, north slope lakes and nearshore waters of the Arctic National Wildlife Refuge is presented. Also, fish surveys of nine lakes and six streams within the coastal plain of the refuge were conducted during early July, 1986. Sample sites were selected based upon their proximity to potential oil and gas development, suitability as water sources, and potential to support fish populations. Significant fish populations were not discovered at any of the sites, although ninespine sticklebacks *(Pungitius pungitius)* were found in three lakes and three streams, and a single Arctic grayling *(Thymallus arcticus)* was captured in the Katakturuk River. The abundance and distribution of Arctic freshwater fishes in the Arctic Refuge coastal plain are probably limited primarily by the lack of suitable overwintering habitat.

Table of Contents

List of Tables

List of Figures

Introduction

The Alaska National Interest Lands Conservation Act (ANILCA) of 1980 created new national park, monument, and refuge areas within Alaska, expanded some existing areas, and set forth a number of provisions for special studies and management planning. Section 1002(c) of the ANILCA provided for baseline studies on the coastal plain of the Arctic National Wildlife Refuge to assess fish and wildlife populations and their habitats, and to assess impacts of human activities, especially those related to oil and gas exploration and development (U.S. Fish and Wildlife Service 1982). Five years of baseline biological studies were completed on the refuge's coastal plain along with surface geological studies and two winter seismic surveys. A final report synthesized the fish and wildlife baseline studies and related information (Garner and Reynolds 1986). An analysis of all resource data was made and a legislative environmental impact statement was prepared for the United States Congress (Clough et al. 1986). Oil and gas potential in the area was deemed high. In 1987 Congress began deliberations on whether to open the area to oil and gas exploration and production.

Fish resources are one of the biological concerns should oil development occur on the coastal plain. Gravel removal, stream crossings, water withdrawal, and the potential of contaminant spills can have adverse effects on fish. Determining species distribution and abundance are the first requirements in affording them protection. The first intensive survey and inventory of fish in the refuge was completed in association with the proposed Arctic Gas Pipeline (Ward and Craig 1974). Most subsequent work was conducted by the U.S. Fish and Wildlife Service.

This report summarizes the results of all major known fishery surveys in the northern portion of the refuge. It also includes original fish survey data from 9 lakes and 6 streams within the coastal plain that had not previously been sampled, or which had received only limited sampling. The lakes sampled are all thaw-lake type (Carson and Hussey 1962). Of the streams, Carter Creek, Fish Creek and the Niguanak River are tundra streams. The Katakturuk River and the Jago River drain mountain-foothill areas, and both receive perennial spring waters. Marsh Creek primarily drains coastal foothill terrain.

Review of Fisheries Surveys

The major coastal plain drainages within the Arctic Refuge have been sampled for fish (Figures 1-3). Twenty-five fish species have been documented from the area's coastal and inland waters (Table 1). Craig (1984) lists 62 species of fish utilizing the coastal waters of the Alaskan Beaufort Sea including all fish species found within the coastal plain of the refuge, except lake trout and Bering wolffish. A total of seven species have been documented in coastal plain streams (Table 2), while six freshwater/anadromous and one marine species (Arctic flounder) have been collected in lakes (Figures 2 and 3).

Prior to the passage of the ANILCA few fisheries studies had been completed in the Arctic Refuge coastal plain. The first known scientific fisheries study in the area was a cursory fisheries survey of refuge coastal waters conducted by the Alaska Department of Fish and Game in the summer of 1970, in which these areas were found to be used primarily by Arctic char, Arctic grayling, fourhorn sculpin, and Arctic flounder (Roguski and Komarek 1972). Grayling, however, were found only in lagoons with low salinities. A few years later, Ward and Craig (1974) sampled and compiled information on areas near the routes of the proposed gas pipeline from Prudhoe Bay to the Canadian border. They found Arctic char, least and Arctic cisco, fourhorn sculpin, Arctic grayling, round and broad whitefish, Arctic flounder, Arctic cod, and ninespine stickleback in their survey of lagoons and river mouths off the refuge's coast.

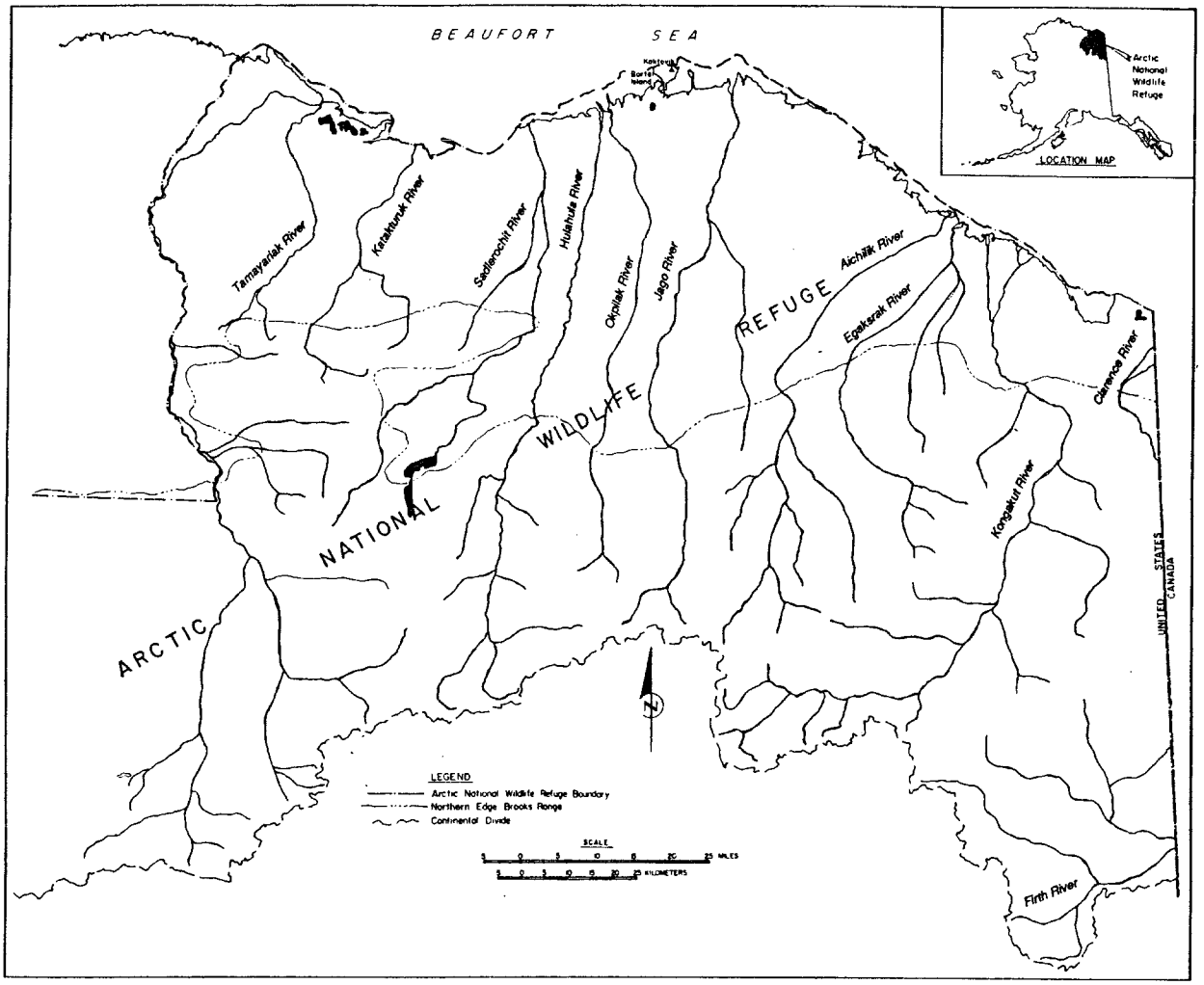

FIGURE 1. — Location of Arctic National Wildlife Refuge and major coastal plain stream drainages on the refuge.

TABLE 1. — List of fish species reported from the coastal plain of the Arctic National Wildlife Refuge.

Anadromous	
Arctic char	*Salvelinus alpinus*
Arctic cisco	*Coregonus autumnalis*
Broad whitefish	*Coregonus nasus*
Chum salmon	*Oncorhynchus keta*
Least cisco	*Coregonus sardinella*
Ninespine stickleback	*Pungitius pungitius*
Pink salmon	*Oncorhynchus gorbuscha*
Rainbow smelt	*Osmerus mordax*
Freshwater	
Arctic grayling	*Thymallus arcticus*
Burbot	*Lota lota*
Lake trout	*Salvelinus namaycush*
Round whitefish	*Prosopium cylindraceum*
Marine	
Arctic cod	*Boreogadus saida*
Arctic sculpin	*Myoxocephalus scorpioides*
Arctic flounder	*Liopsetta glacialis*
Bering wolffish	*Anarhichas orientalis*
Capelin	*Mallotus villosus*
Fourhorn sculpin	*Myoxocephalus quadricornis*
Kelp snailfish	*Liparis tunicatus*
Pacific herring	*Clupea harengus*
Pacific sand lance	*Ammodytes hexapterus*
Pallid eelpout	*Lycodes pallidus*
Saffron cod	*Eleginus gracilis*
Stout eelblenny	*Lumpenus medius*
Slender eelblenny	*Lumpenus fabricii*

TABLE 2. — Documented occurrence of freshwater and anadromous fish species in coastal plain drainages, Arctic National Wildlife Refuge.

Streams	Species						
	GR	AC	NSB	PS	RWF	CS	BB
Canning River	X	X	X	X*	X	X*	X
Tamayariak River	X		X				
Katakturuk River	X*	X*	X				
Marsh Creek		X*					
Sadlerochit River	X	X	X	X*			
Hulahula River	X	X					
Okpilak River	X						
Jago River			X				
Niguanak River			X				
Aichilik River	X	X					
Egaksrak River	X	X					
Kongakut River	X	X					
Clarence River		X					

Abbreviations: GR - Arctic grayling; AC - Arctic char; NSB - ninespine stickleback; PS - pink salmon; RWF - round whitefish; CS - chum salmon; BB - burbot.

* - Rare; based on single or few fish.

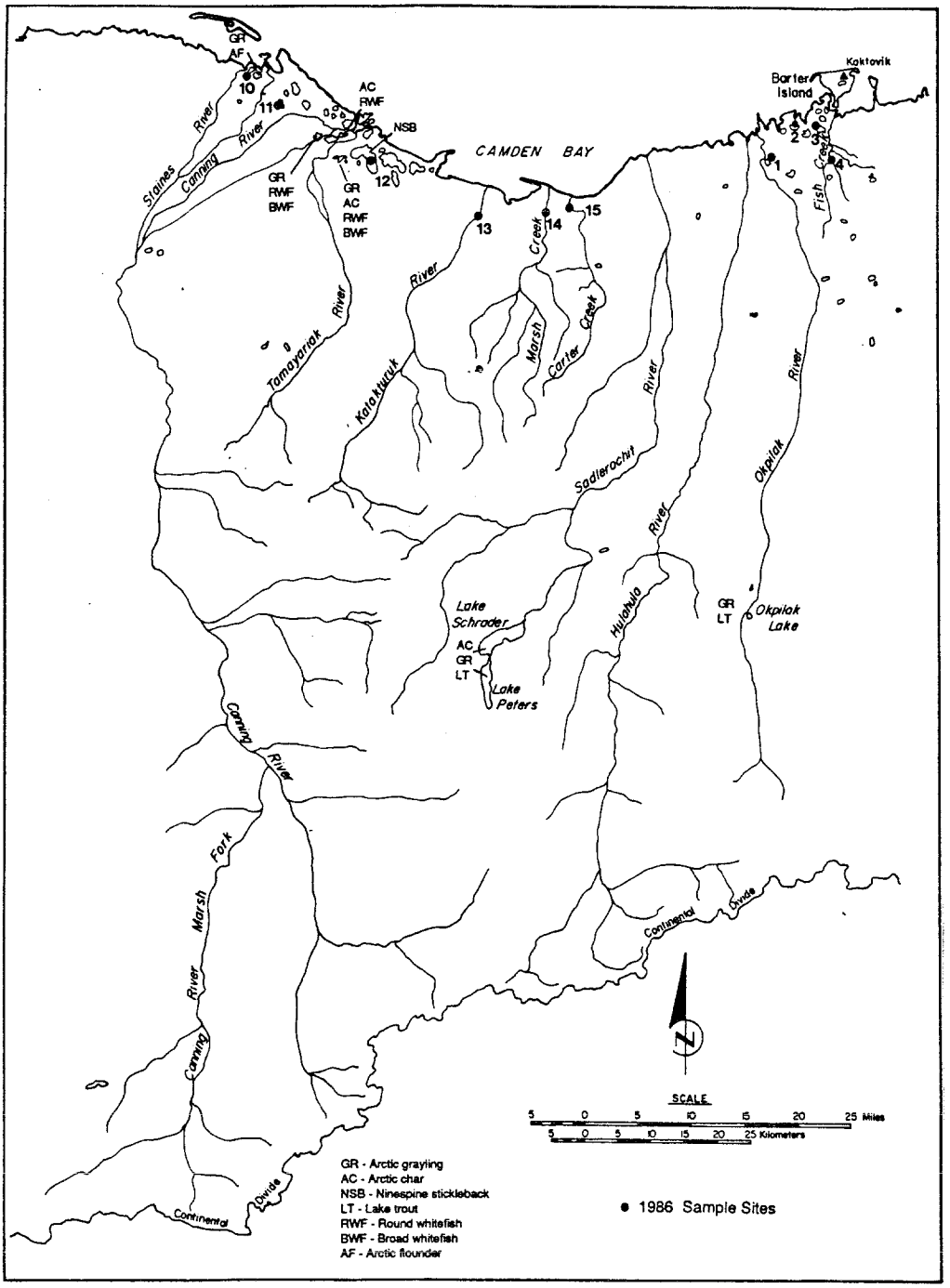

FIGURE 2. — Fish species occurrences in lakes, and locations of fish survey sample sites on the Arctic National Wildlife Refuge coastal plain west of Barter Island, July 1986.

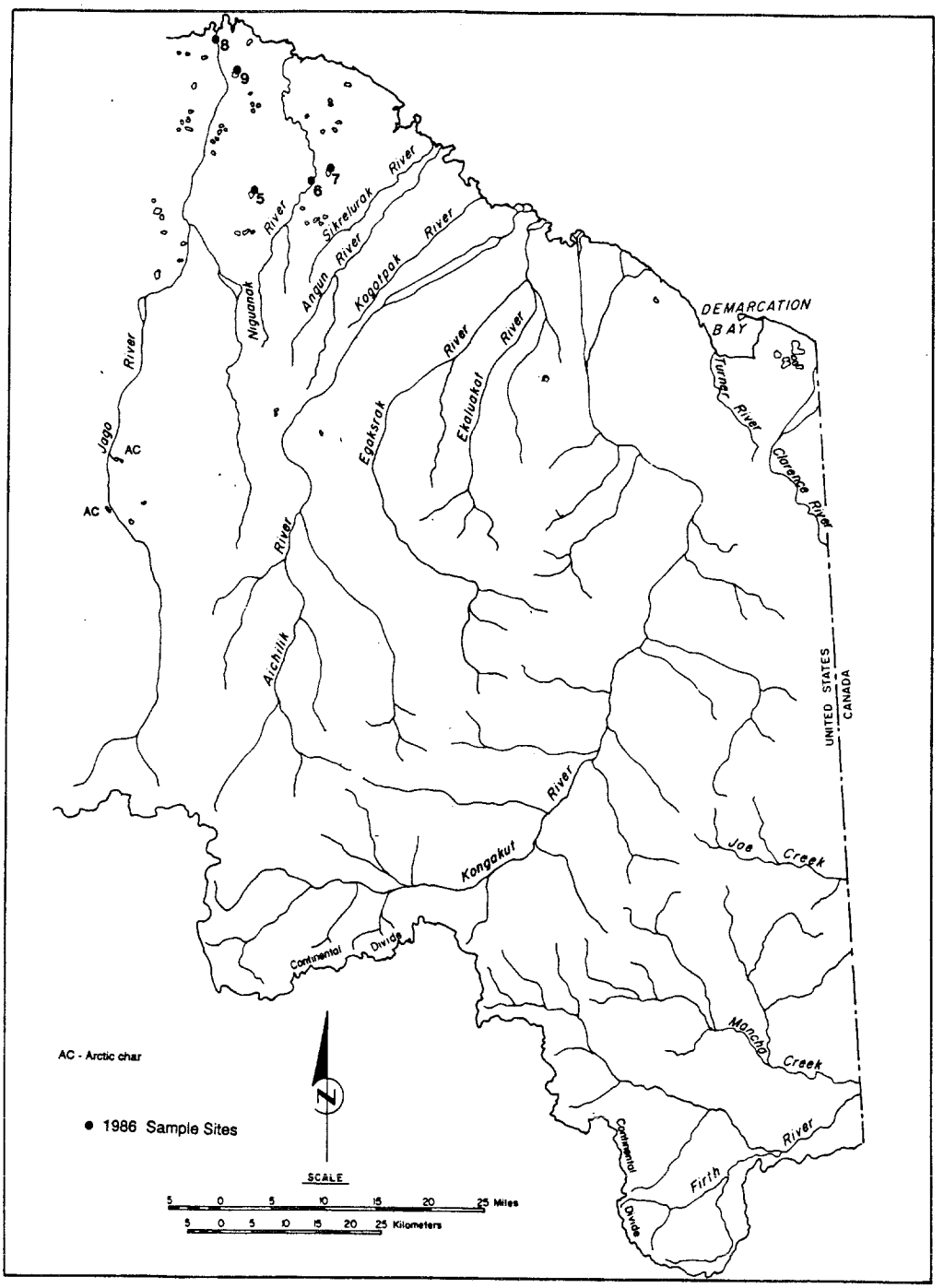

FIGURE 3. — Fish species occurrences in lakes, and locations of fish survey sample sites on the Arctic National Wildlife Refuge coastal plain east of Barter Island, July 1986.

Griffiths et al. (1977) conducted investigations in Kaktovik Lagoon near Barter Island in 1975. Arctic char, Arctic and least cisco, Arctic flounder, fourhorn and Arctic sculpins, Arctic cod, stout and slender eelblennies, capelin, ninespine stickleback, and snailfish were reported. Craig (1983) monitored the effects of a dredging operation in Kaktovik Lagoon. Sampling on August 9 and 10, 1983 yielded catches of fourhorn sculpin, Arctic char, Arctic cisco, Arctic flounder, and saffron cod.

Surveys were conducted in Angun and Beaufort Lagoons from July 25 to August 5, 1982 (Griffiths 1983). The primary fish species caught included Arctic char, Arctic cisco, fourhorn sculpin, and Arctic flounder. Also taken were least cisco, Arctic grayling, rainbow smelt, ninespine stickleback, saffron cod, and capelin.

West and Wiswar (1985) reported catching primarily Arctic char, Arctic cisco, fourhorn sculpin, least cisco, saffron cod, and Arctic flounder while sampling Beaufort Lagoon in 1984. Rainbow smelt, Arctic cod, unidentified eelpouts, and ninespine stickleback were also reported. In 1985, Wiswar and West (1986) found Arctic char, fourhorn sculpin, Arctic flounder, Arctic cisco, saffron cod, least cisco, Arctic grayling, unidentified eelpouts and rainbow smelt (listed in order of abundance) in continuation of the previous year's sampling in Beaufort Lagoon.

Summer fyke net sampling by Wiswar et al. *(In Preparation a)* in Oruktalik Lagoon in 1986 yielded catches of 13 species dominated by Arctic cisco (the bulk of these being young-of-the-year and juveniles), fourhorn sculpin, Arctic cod, capelin, Arctic char, and least cisco. A similar survey of Camden Bay in 1987 (Wiswar et al. *(In Preparation b)* found similar species composition, but differences in relative abundance. Catches were dominated by Arctic cod, capelin, Arctic cisco, fourhorn sculpin, Arctic char, Arctic flounder, and least cisco. One species new to the refuge and the Beaufort Sea was found during that survey with three captures of the Bering wolffish *(Anarhichas orientalis)*.

Coastal sampling continued in 1988 with fyke net and gill net surveys of Camden Bay, and fyke net surveys of Kaktovik and Jago Lagoons and Pokok Bay (Fruge et al. *In Preparation*). A total of 18 species were collected, with Arctic cod, Arctic cisco, fourhorn sculpin, and Arctic char being dominant.

Attention has also been focused on area streams. Ward and Craig (1974) surveyed 20 streams on the coastal plain of the refuge. Arctic char were found in the Hulahula, Egaksrak, and Clarence Rivers. Arctic grayling were found in the Tamayariak and Sadlerochit Rivers and both Arctic char and Arctic grayling were found in Sadlerochit Springs and the Aichilik, Egaksrak, and Kongakut Rivers. No fish were found in the Katakturuk, Akutoktak, Okpilak, Jago, Okerokovik, Niguanak, Kogotpak, and Turner Rivers or in Kalokut and Putugook Creeks. Furniss (1975) reported Arctic char and Arctic grayling to be abundant in the Kongakut River during a survey in late August.

Craig (1977a) sampled the Canning River from late May to mid-September in 1972 and 1973 and found primarily Arctic char, Arctic grayling, and round whitefish. Ninespine stickleback, burbot, broad whitefish, Arctic cisco, least cisco, Arctic flounder, and fourhorn sculpin were also reported in the drainage, but with rare occurrence or limited distribution. The cisco, broad whitefish, sculpin, and flounder were found only near the river mouth in coastal inshore areas.

Craig (1977b) reported Arctic grayling and stream resident Arctic char in Sadlerochit Springs from sampling in 1972-1975. Wilson et al. (1977) synthesized existing information concerning winter water availability and fish overwintering areas across the Alaskan north slope, including the Arctic Refuge. Known overwintering areas for Arctic char and Arctic grayling included portions of the Canning, Sadlerochit, Hulahula, Aichilik, Egaksrak, and Kongakut Rivers. Overwintering areas for Arctic grayling were identified in the Tamayariak River.

Smith and Glesne (1983) reported results of surveys on five Beaufort Sea drainages in the refuge. From investigations in 1981 and 1982 on the Canning River they caught Arctic char, Arctic grayling, round whitefish, chum salmon, pink salmon, burbot, and ninespine stickleback. The salmon were probably wanderers from other stream systems. Studies conducted in 1982 reported Arctic grayling and ninespine stickleback in the Tamayariak River and Arctic grayling and Arctic char in the Aichilik River. One Arctic char and one ninespine stickleback were

caught in the Katakturuk River. A single pink salmon was caught in the Sadlerochit River along with resident Arctic char, Arctic grayling, and ninespine stickleback.

Daum et al. (1984) sampled eight streams in 1983. The Okpilak and Akutoktak (an Okpilak tributary) Rivers were found to have Arctic grayling. Two ninespine sticklebacks were found near the mouth of Okpirourak Creek on the Jago River. No other fish were caught in the Jago River. No fish were captured during sampling efforts in the Angun and Niguanak Rivers or in Carter Creek. One anadromus Arctic char was captured in Marsh Creek. Of 2,788 fish captured on the Hulahula River, 2,740 were Arctic char and the remainder were Arctic grayling.

West and Wiswar (1985) caught Arctic grayling in the Tamayariak and Akutoktak Rivers and in Itkilyariak Creek during a telemetry study of overwintering areas. Both Arctic char and Arctic grayling were found during studies on the Hulahula and Aichilik Rivers.

Wiswar et al. (1986) radio-tagged Arctic grayling in the Tamayariak River, Itkilyariak Creek, and Akutoktak River. Overwintering areas were discovered in the mainstem Canning River and its lower delta, the Sadlerochit River, the Kekiktuk River, Schrader Lake, and the Hulahula River. A 1985 survey along most of the mainstem Kongakut River revealed widely-distributed Arctic grayling and anadromous Arctic char (Deschermeier et al. 1986).

In terms of fishery habitat types, least attention has been focused on refuge coastal plain lakes. Ward and Craig (1974) surveyed 12 coastal lakes near the Canning River delta in summer, of which 4 contained fish, including Arctic char, Arctic grayling, round whitefish, Arctic flounder, and broad whitefish. Craig (1977a) reported lake trout in two small lakes in the Canning River drainage west of the refuge boundary, but the species has not been collected from corresponding Canning River lakes on the refuge.

Lake trout, Arctic char, and Arctic grayling were reported in Peters and Schrader Lakes at the headwaters of the Sadlerochit River by Smith and Glesne (1983). Daum et al. (1984) caught lake trout and Arctic grayling in Okpilak Lake, a landlocked lake in the Okpilak River drainage. Those authors also reported that two of three lakes in the foothills of the Jago River drainage had resident Arctic char populations.

The subsistence fishery of the village of Kaktovik has also been the subject of several investigations. Furniss (1974) examined the summer subsistence fishery at Barter Island and found the catch to consist of Arctic char and Arctic cisco. Arctic char were also being caught in April 1974 in a subsistence fishery on the Hulahula River through holes in the ice (Furniss 1975). Griffiths et al. (1977) estimated the 1975 harvest of Arctic char and Arctic cisco from the Kaktovik fishery to be 2951 kg (6500 lb).

A subsistence inventory of traditional uses of fish and wildlife and hunting and fishing areas used by the residents of Kaktovik was completed by Jacobson and Wentworth (1982). The results given were generally obtained by personal interviews with village residents and were not verified by field sampling. Fish species listed as having been traditionally caught included: Arctic char, Arctic cisco, least cisco, broad whitefish, round whitefish, burbot, Arctic grayling, chum salmon, pink salmon, Arctic flounder, fourhorn sculpin, lake trout, Arctic cod, rainbow smelt, northern pike *(Esox lucius)*, and Alaska blackfish *(Dallia pectoralis)*. However, northern pike and Alaska blackfish have never been documented in fisheries surveys in the refuge coastal plain and were probably misidentified.

A survey was conducted in July and August of 1985 to gather data on the Kaktovik subsistence fishery and on tag recaptures from the Endicott fish monitoring program near Prudhoe Bay (Nelson et al. 1986). Arctic char and Arctic cisco were targeted in the domestic gillnet fishery, but a few Arctic flounder and fourhorn sculpin were also caught. Char, Arctic and least cisco, fourhorn sculpin, and Arctic cod were also captured in fyke net sampling during the survey. Recaptures of Arctic char and Arctic cisco, tagged originally near Prudhoe Bay, were made. Char previously tagged in the Hulahula River and at Beaufort Lagoon were also recaptured at Kaktovik.

Methods

Nine lakes and six streams within the refuge's coastal plain were chosen for investigation in 1986 (Table 3; Figures 2 and 3). Sample sites were selected primarily based upon their proximity to most likely areas of future oil and gas development as identified by Clough et al. (1986) and areas of recent proposals for oil and gas exploration activities. Within these areas of possible oil and gas development, specific sample sites were selected based upon their subjectively-assessed potential as fish habitat and potential for serving as industrial water sources in the future. One of the nine lakes (Site 12) and five of the six streams (Sites 6, 8, 13, 14, 15) had been previously sampled (Ward and Craig 1974; Smith and Glesne 1983; Daum et al. 1984), though not necessarily at the exact sites sampled in this survey.

All surveyed lakes were assumed to be of the thaw-lake type described by Carson and Hussey (1962). Since reliable measurement of maximum lake depth was not possible in most of the lakes due to the presence of ice, this parameter was predicted according to a relationship described by Carson and Hussey (1962), based upon the maximum fetch distance parallel to the prevailing wind direction (approximately WSW-ENE). This distance was determined by Carson and Hussey (1962) to be a major determinant of lake depth. Fetch distances were measured to the nearest 100 meters on 1:63,360-scale topographic maps.

All sampling was conducted July 2-5, 1986. Access to the sites was by helicopter. Fish were sampled in lakes using gill nets to sample the larger and minnow traps to sample the smaller individuals. The gill nets were 40 ft (12 m) total length consisting of equal length sections of 1, 1.5, 2, and 2.5 inch (2.5, 3.8, 5.0, and 6.4 cm) mesh. Two gill nets were set overnight in each lake. The minnow traps used were of metal, cylindrical/funnel design, measuring 12 in (30.5 cm) in length and 8 in (20.3 cm) in diameter. The funnel openings were approximately 0.75 in (2 cm) and the mesh size was 0.25 in (6.4 mm). Three minnow traps baited with preserved salmon eggs were set overnight per lake. The cumulative effort for all gear averaged 20 hours per lake. A gasoline-powered electrofishing unit (Smith-Root Model 15-A) was used to sample fish in streams. Voltage utilized ranged between 200-1200, at frequencies ranging from 15-120 pulses per second.

Surface water temperature was measured with a conventional field thermometer. Conductivity was measured with a Yellow Springs Instruments Model 33 temperature/salinity/conductivity meter. Conductivity readings were internally corrected to 25°C by the meter. Hardness and alkalinity were measured in terms of calcium carbonate ($CaCO^3$) with a HACH® hand-held digital titrator and HACH® chemical reagents. Although pH readings were taken several times at each site with a HACH® Model 17200 Mini-pH meter, the results are not presented because the meter readings changed rapidly after standardization and were considered unreliable. The percent ice cover was subjectively estimated while hovering over the site in a helicopter.

Results

A total of 13 ninespine sticklebacks and 1 Arctic grayling were caught during 180.5 hours of gillnet and trap effort and 2.5 hours of electrofishing (Table 4). Ninespine sticklebacks were found in Fish Creek (Site 4), the Niguanak River (Site 6), the Jago River (Site 8), and in three unnamed lakes (Sites 9, 10, and 12). A single Arctic grayling was captured while electrofishing in the Katakturuk River (Site 13). These were the first reports of these species at the respective sample sites except that ninespine sticklebacks had been previously reported in the Jago River (Daum et al. 1984).

Ice cover ranged from approximately 0 to 99% on the lakes sampled but was 75% or greater on all but two lakes. This made setting nets difficult and prevented accurate measurements of maximum lake depths. Using the fetch distance to depth relationship described by Carson and Hussey (1962), 6 of the lakes were estimated to be between 0.3 and 1.5 m and 3 of the lakes were estimated to be in excess of 1.8 m (Table 5).

TABLE 3. — Locations of sample sites on the Arctic National Wildlife Refuge coastal plain, July 1986.

Site Number	Name	Latitude	Longitude
1	Unnamed Lake	70° 00' 40" N	143° 56' 10" W
2	Unnamed Lake	70° 03' 26" N	143° 49' 42" W
3	Unnamed Lake	70° 03' 16" N	143° 44' 0" W
4	Fish Creek	70° 02' 6" N	143° 41' 11" W
5	Unnamed Lake	69° 52' 38" N	143° 09' 54" W
6	Niguanak River	69° 53' 36" N	142° 55' 42" W
7	Unnamed Lake	69° 54' 10" N	142° 51' 38" W
8	Jago River	70° 05' 23" N	143° 18' 39" W
9	Unnamed Lake	70° 02' 12" N	143° 13' 29" W
10	Unnamed Lake	70° 08' 0" N	145° 58' 21" W
11	Unnamed Lake	70° 05' 19" N	145° 51' 13" W
12	Unnamed Lake	70° 01' 16" N	145° 30' 27" W
13	Katakturuk River	69° 57' 32" N	145° 01' 35" W
14	Marsh Creek	69° 57' 27" N	144° 48' 38" W
15	Carter Creek	69° 57' 30" N	144° 43' 42" W

TABLE 4. — Catch and effort statistics from 15 sites in the Arctic National Wildlife Refuge, July 1986.

Site Number	Name	Date	Net/Trap Effort (hrs)	Electrofishing Effort (min)	Catch*
Lakes					
1	Unnamed lake	7/2/86	17.0	----	0
2	Unnamed lake	7/2/86	17.0	----	0
3	Unnamed lake	7/2/86	18.0	----	0
5	Unnamed lake	7/3/86	23.0	----	0
7	Unnamed lake	7/3/86	23.0	----	0
9	Unnamed lake	7/3/86	22.0	----	1 NSB
10	Unnamed lake	7/4/86	21.5	----	1 NSB
11	Unnamed lake	7/4/86	19.5	----	0
12	Unnamed lake	7/4/86	19.5	----	3 NSB
Streams					
4	Fish Creek	7/3/86	-----	33	4 NSB
6	Niguanak River	7/4/86	-----	17	3 NSB
8	Jago River	7/4/86	-----	34	1 NSB
13	Katakturuk River	7/5/86	-----	27	1 GR
14	Marsh Creek	7/5/86	-----	22	0
15	Carter Creek	7/5/86	-----	18	0

* NSB - Ninespine stickleback; GR - Arctic grayling

TABLE 5. — Physical characteristics and water chemistry data for 15 sites in the Arctic National Wildlife Refuge, July 1986.

Site Number	Estimated Depth[1] (m)	Fetch[2] (m)	Temperature (°C)	Conductivity micromhos/cm[2]	Hardness (mg/l)	Alkalinity (mg/l)	Percent Ice Cover
Lakes							
1	1.2 - 1.5	800	4	55	9	13	75
2	1.8+	1300	3	100	16	19	90
3	1.8+	1100	5	100	26	31	10
5	1.2 -1.5	900	5	80	21	37	80
7	0.9 - 1.2	700	4	120	72	58	75
9	1.2 - 1.5	900	5	60	24	26	95
10	1.2 - 1.5	900	8	200	155	145	90
11	0.3 - 0.6	300	10	160	77	70	0
12	1.8+	2900	8	55	44	35	99
Streams							
4	–	–	10	50	26	32	0
6	–	–	9	92	106	58	0
8	–	–	10	110	65	70	0
13	–	–	10	148	189	102	0
14	–	–	12	165	132	81	0
15	–	–	15	108	67	77	0

[1]Calculated based upon relationship presented in Carson and Hussey (1962).
[2]To nearest 100 meters; as measured on 1:63,360-scale topographic maps.

Water temperatures in streams were generally 5°C warmer than in lakes (Table 5). Conductivity measurements ranged from 50 to 165 micromhos/cm^2 in streams and 55 to 200 micromhos/cm^2 in lakes. Comparing all sample sites (both lakes and streams), alkalinity and hardness values ranged from 13 to 145 mg/l and 9 to 189 mg/l respectively.

Discussion

The absence of fish from most of the lakes surveyed is probably due to insufficient water depths to support fish during winter or the lack of connections to river channels or the ocean. According to Carson and Hussey (1962) water in Arctic freshwaters freeze solid in winter to a depth of approximately 1.8 m (6 ft). Hobbie (1984) stated that fish are only found in ponds and lakes at least 1.7 m (5.6 ft) deep. Ninespine sticklebacks were only found in three of the nine lakes sampled: Sites 9; 10 and 12. At Site 9, the lake was within the floodplain of the Jago River, the Site 10 lake had a connection to the Beaufort Sea, and the Site 12 lake was the largest lake surveyed and was estimated to be deeper than 1.8 m.

Of the three streams found to contain ninespine sticklebacks (Fish Creek, Niguanak River, Jago River), it is uncertain whether the streams provide only summer habitat or contain resident populations. Fish overwintering sites in these streams have not been documented. The Arctic grayling found in the Katakturuk River is the first report of the species in that stream. Arctic char and ninespine stickleback have also been reported from this river, though both of these species are commonly found in coastal waters and could have entered from Camden Bay. Although Arctic grayling do not enter brackish water as readily as the other two species, coastal entry by Arctic grayling cannot be discounted based upon current data.

Similar surveys by other workers on the north slope have produced comparable results. Four of 12 lakes surveyed in the Canning River delta by Ward and Craig (1974) had fish. Of these four, one had an open channel to the Beaufort Sea, one had a connection to the Canning River, and the other two appeared relatively deep and could be influenced by the Canning River during periods of flooding. Netsch et al. (1977) surveyed 58 lakes on the coastal plain of the National Petroleum Reserve-Alaska (NPR-A). Sixteen of the lakes did not have fish; none of these were river connected, and all had maximum depths less than 2.1 meters.

Based upon the numerous fish surveys that have been conducted on the Arctic Refuge coastal plain, Arctic char, Arctic grayling and ninespine stickleback are the most commonly-occurring freshwater fish species. Nearshore coastal waters are inhabited by a variety of fish during summer and provide important migratory zones and feeding areas. The Canning River has the highest diversity of freshwater fish and is the only stream within the refuge's coastal plain that supports major species other than char, grayling, and stickleback.

The lack of suitable overwintering habitat is probably the greatest limiting factor affecting the abundance and distribution of Arctic freshwater fishes. This most likely accounts for the apparent absence of fish from a number of lakes and streams on the refuge's coastal plain. Overall, lacustrine habitat suitable for sustaining year-around fish populations on the coastal plain of the Arctic Refuge appears to be limited. Lakes are not as numerous in the area as they are west of the Canning River, and those which do exist are generally shallow. A few deeper lakes may sustain some fish species. River or ocean-connected lakes, such as those in the Canning River delta, may support seasonal fish use. Overwintering potential of these lakes, and of the delta area itself, has not been examined and should be studied further.

Some refuge streams, particularly the smaller ones but also some of the more significant ones, such as the Katakturuk, Jago, and Niguanak Rivers, appear to support only ninespine sticklebacks in any numbers. Reasons for this may include lack of suitable spawning, feeding, rearing or overwintering habitat in these streams for the other more common coastal plain species. Ninespine sticklebacks, being a euryhaline species, probably disperse widely

along the coast during summer, utilizing a number of streams that may not provide suitable habitat for other fishes, at least during the mid- to late summer sampling period. That sticklebacks do not appear in large numbers anywhere is probably evidence that they are likewise restricted by lack of suitable habitat, most likely overwintering areas.

Theoretical depths for the lakes sampled in this study indicated that the shallowest lake was the one with the least amount of ice cover, and the deepest was the one with the most extensive ice cover. This is consistent with the observations of Carson and Hussey (1962) and Prescott (1963) that shallower lakes on the north slope tend to thaw more quickly than deeper lakes. The other lakes were intermediate in ice cover, with the exception of Site 3. That lake had only 10% ice cover, despite the fact that other lakes of comparable fetch and estimated depth had 90% ice cover. One possible explanation for this anomaly is that the lake is shallower than expected based upon fetch.

Results of water chemistry data on 15 lakes and streams in the refuge coastal plain indicate that most waters sampled are generally harder than lakes and streams west of the Colville River (Kalff 1968, Hobbie 1984). The majority of the waters sampled were medium hard to hard. Only two of nine lakes (Sites 1 and 2) were classified as soft, and three (Sites 2,3, and 10) showed indication of being chemically influenced by the ocean. The farthest inland of these was 3.1 km (1.9 mi). Kalff (1968) indicated that lakes as far as 10 km (6.2 mi) from the coast may be chemically influenced by the oceanic environment. Since water chemistry data from the present study are limited to one-time, single point source data, reliable conclusions cannot be drawn. Hobbie (1980) has shown that considerable variation in alkalinity may occur over the summer or even within a single day in Arctic lacustrine waters due to poor buffering capacity.

Because of the possibility of oil and gas development occurring in the Arctic Refuge coastal plain, and the likely need for year-around industrial water sources, the gathering of baseline information on fish presence and use, water chemistry, and other limnological characteristics of area waters should continue. Although lakes are not numerous on the Arctic Refuge coastal plain many have never been sampled. Potential lotic fish overwintering areas also require further study.

Lakes which have not been previously surveyed should first be screened using a remote-sensing technique to estimate lake depth. Satellite imagery data could be utilized, taking advantage of the fact that shallower lakes thaw earlier than deeper lakes (Mellor 1982). The deeper lakes discerned with this procedure could then be further scrutinized using side-looking airborne radar (SLAR) or direct fathometer readings. The SLAR technique has been utilized in western Arctic Alaska to study lake bathymetry (Mellor 1982), but has not been applied to Arctic Refuge waters. This technique may also lend itself to identification of deeper lotic areas which may be utilized for fish overwintering. More intensive biological and chemical sampling could then be focused on those lakes and stream areas that appear to be deep enough to support resident or overwintering fish populations.

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