Fishery Information Service, Annual Report FIS-04-102, May 2011
U.S. Fish and Wildlife Service

Seasonal Migrations and Important Habitats of Humpback Whitefish, Broad Whitefish, and Least Cisco in the Selawik National Wildlife Refuge, as Determined with Radio Telemetry

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Abstract

Thousands of whitefish of three primary species in the subfamily coregoninae are harvested each year in the Selawik River delta in northwest Alaska. Yet, very little is known about the habitats they use or the movements they make in the region. Radio telemetry was used in this study to identify seasonal migrations and important habitats of humpback whitefish *Coregonus pidschian*, broad whitefish *C. nasus*, and least cisco *C. sardinella* tagged in the Selawik River delta. Transmitters were deployed in 64 humpback whitefish, 64 broad whitefish, and 32 least cisco during the two years of this study. Humpback whitefish were tagged in early June (early in the annual feeding period), 40 in the northern region of the Selawik River delta and 28 in the southern region. Broad whitefish were tagged during early June (n = 45) and in early August (n = 19), when broad whitefish were feeding in the delta. They were tagged in the northern (n = 36) and southern (n = 28) regions of the delta. Least cisco were tagged in early June, 16 in the northern region and 16 in the southern region. Transmitters deployed in 2004 (n = 96) were programmed to last for 13 months. Those fish have been tracked through a full year and are no longer transmitting. Transmitters deployed in 2005 (n = 64) were programmed to last for approximately 2 years. Those fish have been located during their first fall and winter time periods, and will continue to be tracked for another full year. During the first summer it became clear that there was very little interchange between fish tagged in the northern region of the delta and those tagged in the southern region. At least half of all tagged fish of each species were located during the fall spawning season, and fish that were not located were presumed to be in Selawik Lake or in Hotham Inlet, both large water-bodies that precluded comprehensive aerial survey coverage. Spawning areas for humpback whitefish were identified in upstream, gravel-substrate regions of the Selawik River drainage and nearby tributary streams. Broad whitefish spawning habitat was identified only in the Kobuk River. No least cisco spawning areas were identified. It is hypothesized that some areas of Selawik Lake with gravel or sand substrates may provide suitable spawning habitat for some fish of all three species. Ten humpback whitefish, 13 broad whitefish, and 12 least cisco tagged during 2004 were known to be alive in the Selawik River delta a year following tagging. Many others may also have been alive in Selawik Lake, Hotham Inlet, or other unsurveyed river drainages. Aerial survey data from spring and fall 2006 will be analyzed for additional information on survival, habitat fidelity, and spawning frequency of fish tagged during 2005.

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Introduction

Salmon *Oncorhynchus* spp. have been documented in the waters of the Selawik National Wildlife Refuge (Selawik NWR) in northwest Alaska (Figure 1), but they are not found there in abundance. As a result, local residents are dependent on other fish species to meet their subsistence needs. Northern pike *Esox lucius*, burbot *Lota lota*, and several whitefish species, subfamily coregoninae, are harvested throughout the region, with the combined harvest of whitefish thought to exceed all other fish (U.S. Fish and Wildlife Service 1993). Limited harvest records suggest that 15,000 to 30,000 fish of all whitefish species combined are harvested in the lower Selawik River each spring (U.S. Fish and Wildlife Service 1993; Ken Troyer, U.S. Fish and Wildlife Service, unpublished document). Georgette (2002) reported that major fishing activities occurred in both spring and fall, but no quantitative records of fall harvests have been collected, so estimates of the total annual harvest of whitefish species in the Selawik River are not available.

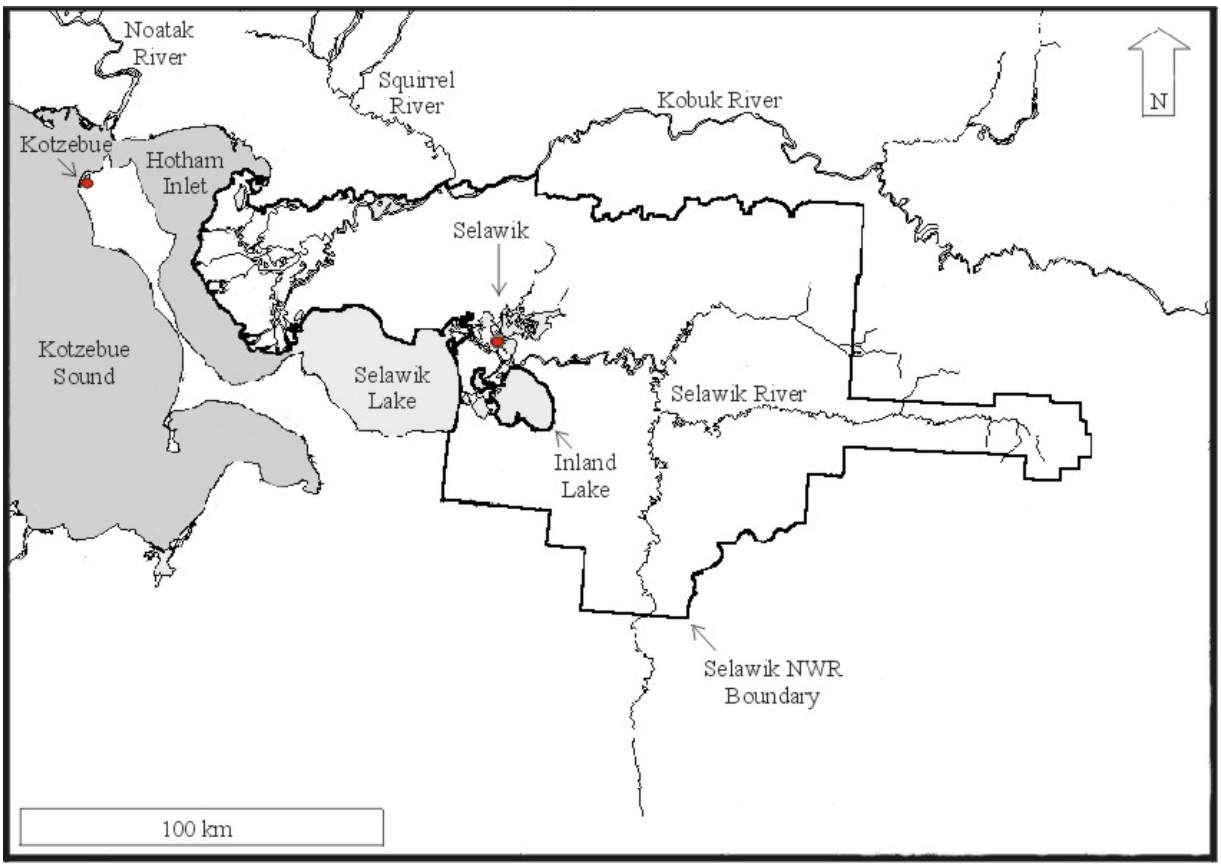

Figure1. The Selawik River drainage and surrounding area in northwest Alaska.

Five whitefish species have been reported in the Selawik NWR. Inconnu *Stenodus leucichthys* (sheefish), humpback whitefish *Coregonus pidschian*, and broad whitefish *C. nasus* are relatively large fish and are actively targeted in subsistence fisheries in the area. Least cisco *C. sardinella* and round whitefish *Prosopium cylindraceum* are relatively small fish. Some least cisco are taken in the fishery, but most pass unhindered through the large mesh gillnets that are commonly used (Brown 2004). Round whitefish are present in the upper reaches of the Selawik River

drainage, but are not common in the fishery, which takes place in the lower reaches of the drainage (U.S. Fish and Wildlife Service 1993).

Spawning, rearing, feeding, and overwintering habitats are extremely important to northern fish species including the whitefish. Known spawning habitats are generally gravel-substrate regions of swiftly flowing rivers (Alt 1969; Fleming 1996; Brown 2000; Underwood et al. 2000) to which mature fish from a wide geographic region migrate to spawn. This results in a large component of a fish population in one place at the same time. Humpback whitefish and least cisco spawn in late September or early October and the spawning time for broad whitefish is thought to be later, extending into November (Reist and Bond 1988). Good rearing habitats are those that maximize survival until recruitment to the spawning population. These are broadly distributed across the landscape, often in places quite distant from spawning areas and adult conspecifics (Chang-Kue and Jessop 1992; Gallaway et al. 1983). Most feeding is thought to occur during the brief summer months for whitefish species (Schmidt et al. 1989), and feeding habitats are widely distributed across the landscape (Reist and Bond 1988). Feeding habitats are not known to be limiting, except perhaps in closed lake systems (Healey 1975; Power 1978). Mature fish are probably more dispersed during the spring and summer feeding period than at any other time of the year. Overwintering habitat can be a limiting factor for whitefish populations, particularly in extreme environments such as Alaska's Beaufort Sea coast where freshwater refugia are required for survival, but are few in number (Craig 1989; Schmidt et al. 1989). Overwintering habitat may not be limiting for whitefish populations in less extreme environments. Understanding where these important habitats are located allows us to plot migrations, assess distribution, direct sampling efforts effectively, and evaluate risks faced by whitefish populations.

Our knowledge of spawning, rearing, feeding, and overwintering habitats of humpback whitefish, broad whitefish, and least cisco in the Selawik River area is extremely limited. Johnson (1986a) attempted to locate spawning and overwintering habitats of humpback and broad whitefish in the Selawik River using radio telemetry. However, only 9 of 25 tagged fish were relocated after tagging. Two of the nine relocated fish had traveled upstream to suspected spawning areas, but no site-visits were conducted to verify the activity. Two other tagged fish were relocated in Selawik Lake, leading Johnson (1986a) to speculate that they overwintered there. Humpback whitefish, broad whitefish, and least cisco are all known to be highly migratory in the Mackenzie River drainage (Reist and Bond 1988), and we expect similar life history characteristics to prevail in the Selawik River.

Radio telemetry has been a very effective tool for tracking fish migrations and locating important habitats used by fish. Eiler et al. (1992) identified many previously known and new sockeye salmon *Oncorhynchus nerka* spawning areas in the turbid waters of the Taku River in southeast Alaska and British Columbia by tracking radio-tagged fish to their destinations. Chang-Kue and Jessop (1983), Howland (1997), Brown (2000), and Underwood (2000) all identified the timing of spawning migrations and located spawning habitats used by coregonid fish species using radio transmitters that lasted only a few months. More recently, Brown (2006) used long-duration transmitters to identify spawning, overwintering, and feeding habitats of humpback whitefish in the upper Tanana River, Alaska, and provided information on habitat fidelity and spawning frequency as well. The primary goal of this study was to identify: 1) spawning; 2) overwintering; and 3) feeding habitats used by mature humpback whitefish, broad whitefish, and least cisco radio-tagged in the Selawik River delta. Secondary goals were to explore annual

habitat fidelity and spawning frequency. This document details the findings from the first two years of a three year study.

Methods

Humpback whitefish, broad whitefish, and least cisco were captured for tagging in the Selawik River delta (Figure 2) in areas used by Selawik residents for fishing (Johnson 1986b; Georgette and Shiedt 2005). The delta was arbitrarily categorized into north and south regions to help characterize migration patterns. The regions were defined as being north or south of an east-west line separating the large Inland and Tuklomarak lake systems in the south from the smaller interconnected lake systems in the north. Monofilament gill nets with 5 cm stretch mesh webbing were utilized for fish capture. The gill nets were set and constantly monitored until fish became entangled, at which time they were removed, placed into a tub of water, and evaluated for tagging.

Mature fish were sought for tagging, as one of the primary objectives was to identify spawning areas. Brown (2004) evaluated maturity of female fish in the Selawik River delta using a gonadosomatic index and determined that minimum fork length at maturity for humpback whitefish, broad whitefish, and least cisco were 380 mm, 445 mm, and 275 mm respectively. Fleming (1996) reported that the smallest mature humpback whitefish and least cisco in the Chatanika River were 334 mm and 264 mm respectively. Tallman et al. (2002) reported that the smallest mature broad whitefish in a Mackenzie River population was about 390 mm. Alt (1976) reported that size at maturity was somewhat variable, depending on location. In most of his sampled populations in Alaska, broad whitefish were mature when they were 450 to 500 mm. In this study an effort was made to tag fish of lengths similar to or greater than those reported to be mature by Brown (2004) for humpback whitefish (380 mm), broad whitefish (445 mm), and least cisco (275 mm) in the Selawik River delta.

Radio transmitters used in this study operated on four frequencies in the 162 MHz range. Individual transmitters were digitally coded for unique identification. The radio tags for humpback whitefish, broad whitefish, and least cisco weighed 8.9 g, 10 g, and 7.7 g respectively. They were 11 mm in diameter and 49 mm, 59 mm, and 43 mm long respectively. They each had a whip antenna about 42 cm long. The 2004 transmitters (n = 96) were programmed to turn on at the time of surgery and transmit every 3 s for 24 weeks, go dormant for 16 weeks during the winter, and then begin transmitting again until the battery expired. They were expected to last for approximately 13 months, providing a yearlong record of fish locations. The 2005 transmitters (n = 64) were programmed to transmit for two months during each of three important life history periods: 1) spawning (September and October); 2) overwintering (January and February); and 3) feeding (May and June). They were expected to last for two years, providing information on seasonal habitat use, habitat fidelity, and spawning frequency of tagged fish.

In June 2004, radio transmitters were surgically implanted into 96 fish, 32 each in humpback whitefish, broad whitefish, and least cisco using methods detailed by Brown (2006). These fish were relocated during aerial telemetry flights at approximately 3 to 4-week intervals. Additionally, a fixed receiving station was established on the Selawik River upstream from all tagging activities (Figure 2) to document upstream migrations. In 2005, transmitters were implanted in 64 fish, 32 each in humpback whitefish and broad whitefish. These fish were

relocated with aerial telemetry flights during three seasons of the year only. Relocations were linked to GPS coordinates and plotted on topographic maps. Movements relative to previous locations and to the tagging site were determined following each survey, and general patterns of movement were described. Preliminary identification of spawning areas were based on late fall aggregations of fish in upstream, gravel-substrate, flowing water habitats, as characterized by McPhail and Lindsey (1970) and Morrow (1980). Overwintering habitats were based on locations obtained between November and March, and primary feeding habitats were based on May and June locations.

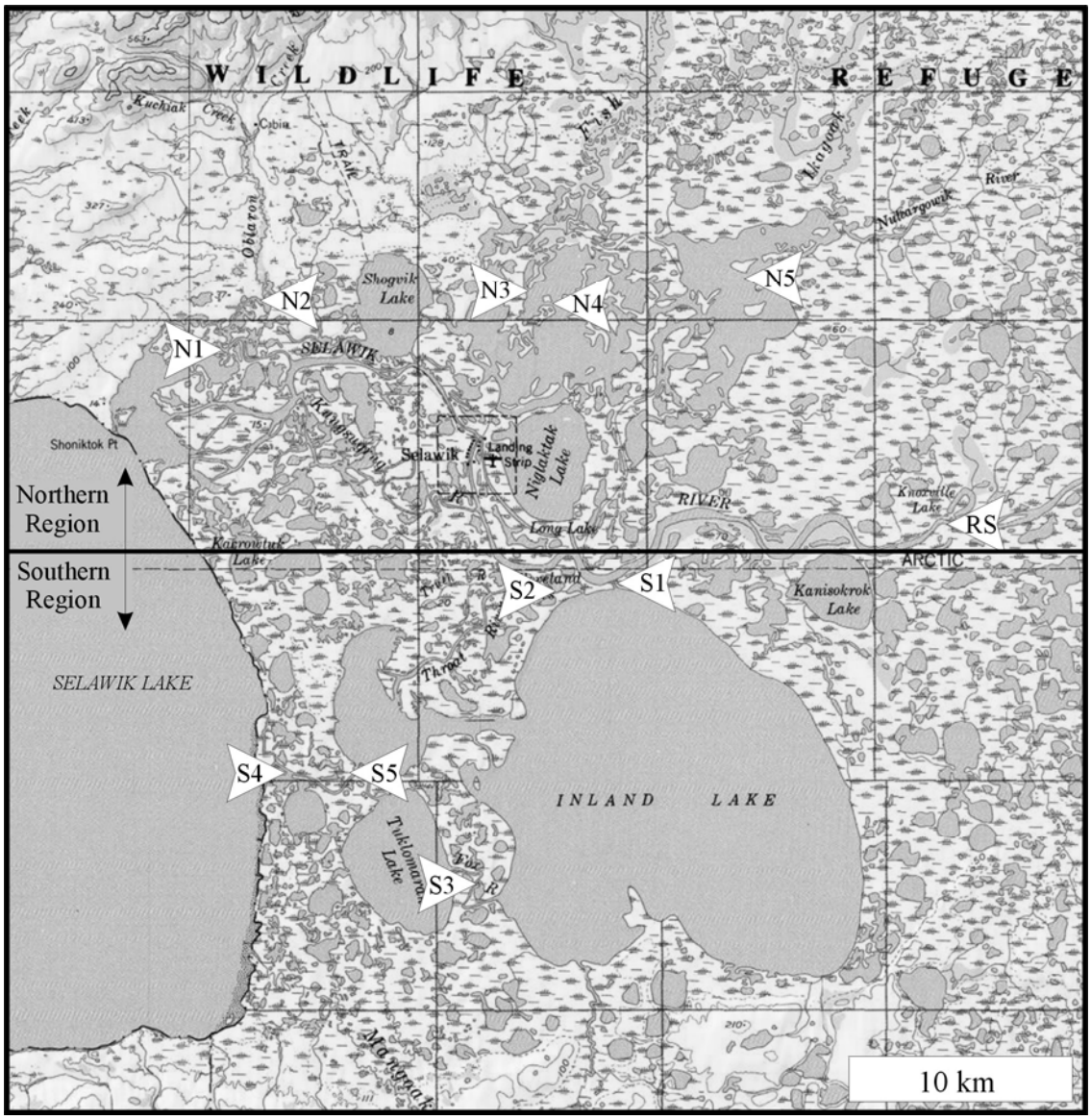

Figure 2. Tagging sites in the north (N#) and south (S#) Selawik River delta during 2004 and 2005. The location of the remote radio receiving station is indicated by the "RS".

Location analyses were done with each fish to determine if sufficient movement had occurred between locations to know with certainty that fish were alive from one season to the next. Brown (2006) and Fleming (1996) evaluated the positional error that occurs during aerial surveys by repeat locations of stationary transmitters. They generally agreed on the relative

precision of aerial telemetry locations and determined that a positional difference of 2 km between surveys was a sufficient distance to ensure that fish movement had occurred. In this study, survival was accepted if a fish position from one survey was at least 2 km from a previous position.

Results

Humpback whitefish, broad whitefish, and least cisco were tagged at five sites in the northern region of the Selawik River delta and five sites in the southern region (Figure 2). Brown (2004) considered the Selawik River delta to be feeding habitat for all three species based on a high percentage of fish found with food in their stomachs in the early summer. In general, when fish were located in the Selawik River delta, they were located in their tagging region. Few fish tagged in the north were relocated in the south, and few fish tagged in the south were relocated in the north (Table 1). Some fish of all three species were relocated in Selawik Lake, indicating that it was used as a migration route or for other life history activities. Some fish were never relocated following tagging.

Table 1. Tagging and relocation history of radio-tagged humpback whitefish (HBWF), broad whitefish (BWF), and least cisco (LC) by major regions of the Selawik River delta. Note that an individual fish may be located in more than one region.

Tagging region	Species	Number tagged	relocated in north region	relocated in south region	relocated in Selawik Lake	not relocated
North	HBWF	40	21	1	9	14
South	HBWF	24	2	12	10	5
North	BWF	36	21	4	7	9
South	BWF	28	2	21	6	4
North	LC	16	12	5	4	3
South	LC	16	4	11	1	4

During the spawning season 33 humpback whitefish, 42 broad whitefish, and 21 least cisco were relocated. Twenty humpback whitefish and seven broad whitefish were relocated in flowing water, gravel-substrate habitats that could be characterized as spawning habitat. All the rest remained in flat-water, soft-substrate habitats of the Selawik River delta or in Selawik Lake, habitats that would not generally be characterized as spawning habitats for whitefish species. Humpback whitefish considered to be spawning were located as much as 35 km up the Fish River (n = 13), a small tributary of the Selawik River that flows into the northern part of the delta, about 230 km up the Selawik River (n = 5) in the same region that Underwood (2000) identified as an inconnu spawning area, and about 20 km up the Singauruk River (n = 2), a small stream draining into the northeastern part of Selawik Lake (Figure 3). The seven broad whitefish that were considered to be spawning were located as far as 280 km up the Kobuk River, upstream from the Ambler River.

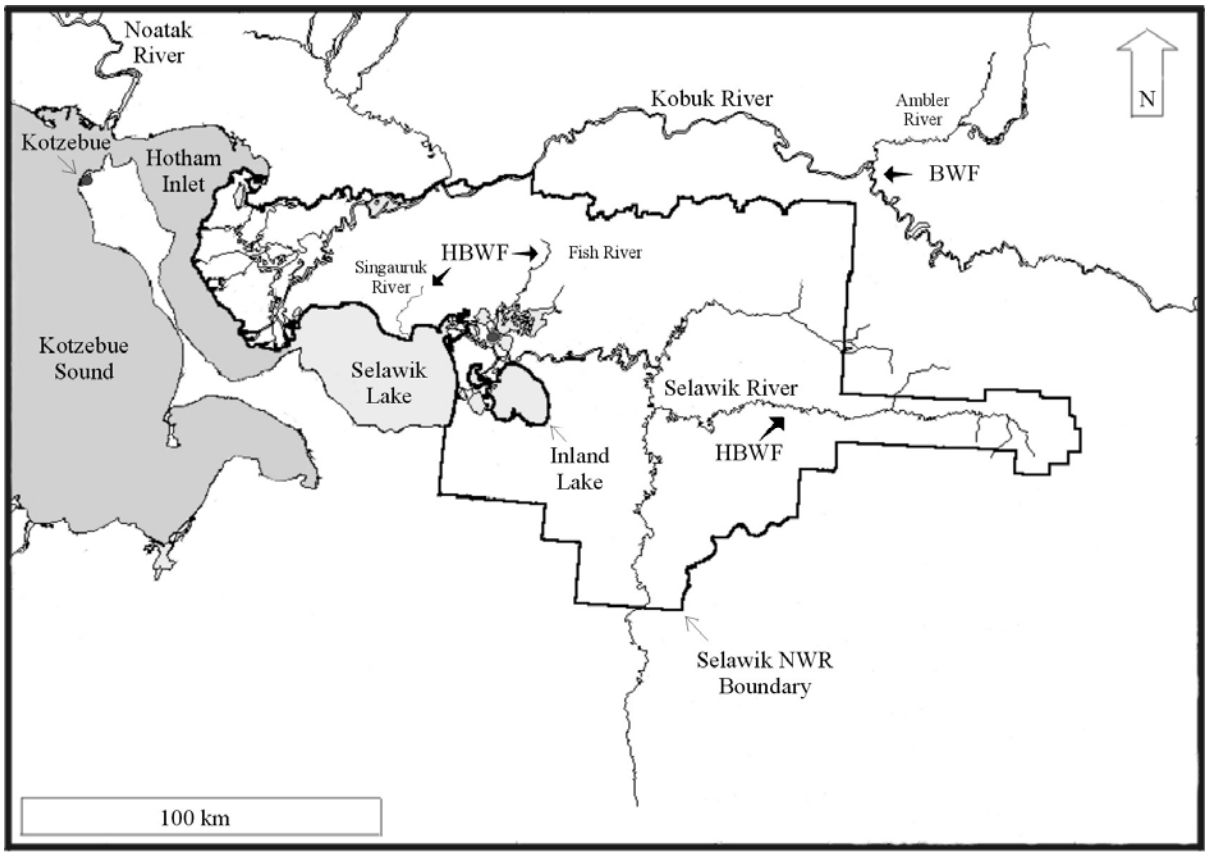

Figure 3. Spawning regions of humpback whitefish (HBWF) in the Selawik River drainage and broad whitefish (BWF) in the Kobuk River based on spawning season aggregations in gravel-substrate, flowing water habitats.

Twelve of 64 humpback whitefish (19%), 11 of 64 broad whitefish (17%), and 16 of 32 least cisco (50%) were relocated in the Selawik River delta and in Selawik Lake during the winter. The relative scarcity of tagged humpback and broad whitefish in the winter suggests that many of them disperse into Selawik Lake or Hotham Inlet at that season. Selawik Lake is a freshwater system (U.S. Fish and Wildlife Service, unpublished data) but is too large to effectively survey for tagged fish, and Hotham Inlet is brackish, which attenuates radio transmission making relocation impossible there. Brown (2004) conducted otolith chemistry investigations with fish captured in the summer and fall in the Selawik River delta and found that most humpback and broad whitefish migrated to brackish or saltwater every year. Hotham Inlet is therefore, a likely location for humpback and broad whitefish that were not relocated in the winter aerial surveys. By contrast, the otolith chemistry data for least cisco indicated that very few individuals migrated to brackish water during their lives, and they were relocated in the Selawik River delta region during the winter at a greater rate than the other species. Selawik Lake is thought to be the most likely location for least cisco not relocated during the winter.

Residents of the village of Selawik pursued their subsistence fishing traditions in the Selawik River delta during 2004 and 2005, as evidenced by the many nets in the water and large numbers of fish drying on racks. Most of the fishing appeared to be in the northern part of the delta. Nets and fish racks were observed in both the spring and the fall. Despite the obviously successful fishing effort by local residents and the many radio-tagged fish present in the area, there were no

reported harvests of tagged fish, and no radio-tags were identified as being in the village or out of the water (transmitters out of the water produce a much stronger signal than when they are in the water).

As of this writing we have made significant progress towards identifying spawning habitats, which appear to be clear for humpback whitefish, suggestive but not conclusive for broad whitefish, and unclear for least cisco. It is expected that before the project is complete there will be greater clarity to the spawning behavior and spawning areas for broad whitefish and least cisco. Data regarding overwintering habitats and the second year's feeding habitats are incomplete and analyses are pending. A full analysis of project results will be completed by December 2011.

Discussion

Relocations of tagged whitefish in the Selawik River delta and Selawik Lake suggest that there is some geographic segregation of stocks in the region and that they are not simply a randomly moving aggregation of fish in the region. The finding that few fish migrated from the northern region of the Selawik River delta to the southern region, or from the southern region to the northern region, indicates that most individuals remain in a localized area while in the delta. Further, the localized area selected by humpback whitefish specifically, appears to be related to their spawning areas. For example, of the 13 humpback whitefish that migrated into the Fish River during spawning season, 12 were tagged in the northern region and only one was tagged in the southern region, and all five of the humpback whitefish that migrated up the Selawik River during spawning season were tagged in the southern region. Additionally, most fish of all species located in northeast Selawik Lake were tagged in the northern region and most of those located in southeast Selawik Lake were tagged in the southern region, suggesting that fish found in the northern region are accessing the delta primarily through the northern mouth of the Selawik River and those found in the southern region are accessing the delta primarily through the southern mouth. Presumably, populations in the northern region could vary in abundance independently from those in the southern region. These data could be used to direct fishing effort to different groups of fish if needed.

Thirty-nine of 160 tagged fish (24%) were never relocated following tagging, while others were relocated on nearly every survey. It is possible to miss fish on aerial surveys, but the odds of missing a fish repeatedly when a transmitter is operating properly is extremely unlikely. Transmitter malfunctions are rare, and all transmitters were tested prior to being deployed. While we can't know where a fish is without relocating it, the repeated absence of signals from these fish suggests that they were not present in the Selawik River delta following tagging, and had probably migrated out of the area.

The Kotzebue region of northwest Alaska contains some habitats that cannot be surveyed with traditional radio telemetry techniques. Fish radio transmissions are attenuated by saltwater of even brackish concentrations (5 to 15 ppt). Brown (2004) found that most humpback whitefish and broad whitefish, and some least cisco, captured in the Selawik River delta traveled to saltwater, as evidenced by high strontium (Sr) levels in their otoliths. Salinity testing in Selawik Lake, in both summer and winter, revealed that it is a freshwater lake (U.S. Fish and Wildlife Service, unpublished data). By contrast, Hotham Inlet was found to be a brackish water

environment under ice-cover during the winter, with the northern part of the inlet being mixed with salinities ranging from 7 to about 23 ppt, and in the southern part of the inlet being stratified with a relatively thick freshwater layer lying above a relatively thin saline layer of about 25 ppt. The salinity of Hotham Inlet was not examined in ice-free conditions. It is clear from these data that fish from the Selawik River delta with high levels of Sr in their otoliths had migrated at least into Hotham Inlet.

Salinity is not the only factor that could prevent a comprehensive accounting of all radio-tagged fish. Selawik Lake is a large water-body with approximate dimensions of 30 by 42 km. A systematic grid survey of the entire lake with 1 km intervals would require approximately 1,300 km of flying taking about 8 hr to complete. This approach was considered but never done. Instead, it was reasoned that flying around the lake at approximately 1 km from shore, and flying random, mid-lake transects when weather allowed would document the presence of at least some fish in the lake. This strategy resulted in the relocations of 38 fish in Selawik Lake, consisting of 19 humpback whitefish, 13 broad whitefish, and 6 least cisco. Similar flights were conducted without success in Hotham Inlet, and it is suspected that salinity levels in the inlet may have been too high for successful radio transmission.

Georgette and Shiedt (2005) documented the presence of whitefish of several species in both the Kobuk and Noatak rivers based on the harvests and accounts of residents of those rivers. It was initially thought that some humpback whitefish, broad whitefish, and least cisco might be migrating to spawn in these other rivers and just using the Selawik River delta for feeding, similar to Kobuk River inconnu (Alt 1977; Miller et al. 1998; Underwood 2000). Aerial surveys of these rivers during the spawning seasons of 2004 and 2005 located broad whitefish in the Kobuk River and no fish in the Noatak River. Seven broad whitefish were ultimately relocated in the Kobuk River, most in the vicinity of the Ambler River mouth, about 280 km up the Kobuk River. The Kobuk River was the only place where broad whitefish were located in gravel-substrate, flowing water habitat, and it is considered to be evidence of a spawning location.

Known whitefish spawning areas have always been characterized as having a rock, gravel, or sand substrate, and never as a mud or other soft material substrate (McPhail and Lindsey 1970; Scott and Crossman 1973; Morrow 1980). Spawning areas for humpback whitefish (and the closely related lake whitefish *C. clupeaformis*) have been documented in flowing water (Alt 1979) and in lakes (Anras et al. 1999). Distinct migrations from summer feeding areas to fall spawning areas are recognized in places (Lambert and Dodson 1990; Fleming 1996), and are assumed to occur for most riverine populations. The migrations of radio tagged humpback whitefish into the Fish River, Singauruk River, and to the upper Selawik River in late September and early October are interpreted as being spawning migrations, and the sites are assumed to support spawning populations. Humpback whitefish present in recognizable spawning habitats represented only 31% of radio-tagged fish. An additional 13 humpback whitefish were located during the spawning season, but not in gravel-substrate, flowing water habitats, so they were not thought to be spawning. Fall aerial survey flights into the Kobuk River found no humpback whitefish, suggesting that those feeding in the Selawik River delta during spring (when fish were tagged) were not part of the Kobuk River spawning population.

Spawning areas for broad whitefish are much less clearly defined than for other whitefish species, primarily because they spawn later than the others, during or shortly after the process of freeze-up (Reist and Bond 1988). Cheng-Kue and Jessop (1983) identified broad whitefish

spawning areas in the mainstem Mackenzie River using radio telemetry, based on radio-tagged fish behavior. They located spawning areas at approximately 240 km and 630 km upstream from the river delta. The substrate over which spawning occurred was not known, but the upstream site was at the foot of a major rocky rapid and it is assumed that the substrate was composed of rocky material of some sort. Morris (2003) similarly used radio telemetry to identify broad whitefish spawning areas in gravel substrate regions of the Colville and Ublutuoch River deltas in northern Alaska. Those fish did not migrate to upstream spawning areas, but remained in the delta region. Kobuk River harvest data collected by Georgette and Shiedt (2005) indicated that broad whitefish made spawning migrations up that river, but no similar data exist for the Selawik River. The migrations of radio-tagged broad whitefish into the Kobuk River in October and early November were interpreted as being spawning migrations and indicate that at least some of the broad whitefish that feed in the Selawik River delta are Kobuk River stocks. Brown (2004) found that approximately half of mature broad whitefish present in the delta during September were preparing to spawn, which led to the expectation that about half of the radio-tagged fish would migrate to spawning areas in the fall, yet only 11% were present in recognizable spawning habitats.

Spawning areas for least cisco have been documented in flowing water (Fleming 1996) and their presence in isolated lakes indicates their capacity to spawn in lake habitats as well (Doxey 1991). Distinct migrations from summer feeding areas to fall spawning areas are recognized in places (Berg 1962; Fleming 1996), and are assumed to occur for most riverine populations. However, Berg (1962) contended that while some least cisco found in the deltas of large Asian rivers migrated to upstream spawning areas, others simply spawned in the delta environment. Kobuk River harvest data collected by Georgette and Shiedt (2005) suggested that least cisco make spawning migrations up that river, but no similar data exist for the Selawik River. Brown (2004) found that all mature least cisco in the delta during September were preparing to spawn, which led to the expectation that all radio-tagged fish would be spawning during the fall. Only 21 of the 32 radio-tagged least cisco were located during spawning season (late September to mid-October). All were located in the delta or in Selawik Lake, and none in gravel-substrate habitats in upstream regions of the Selawik River or other drainages in the region. Fall aerial survey flights into the Kobuk River found no least cisco, suggesting that those feeding in the Selawik River delta during spring (when fish were tagged) were not part of the Kobuk River spawning population.

Future Plans

Transmitters deployed in 2004 expired in summer 2005. Those deployed in 2005 will remain active through fall 2006 allowing locations to be obtained during a second spawning season. Particular attention will be given to searching the Kobuk River drainage for broad whitefish. The incidence of repeat spawning of humpback whitefish will be investigated in the three identified spawning areas. It is expected that many fish that were not present on spawning areas in 2005 will be present in 2006. Fall surveys in 2006 will conclude the field component of the project, and a final report of the entire project is expected to be complete by May 2007.

Acknowledgements

The USFWS, Office of Subsistence Management, provided $222,500 in funding support for this project through the Fisheries Resource Monitoring Program, under agreement number 04-102. This project was conducted by the U. S. Fish and Wildlife Service, Fairbanks Fish and Wildlife

Field Office and the Selawik National Wildlife Refuge. In addition, a number of individuals provided substantial logistical and field assistance that greatly enhanced the project operations. They include Ralph Ramoth Sr., Susan Georgette, Clyde Ramoth, Joe McCoy, and Kevin Kaiser. Many others from the village of Selawik offered assistance and encouragement. This project would not have been possible without such broad community support, and it is appreciated.

Key Words

humpback whitefish, *Coregonus pidschian*, broad whitefish, *Coregonus nasus*, least cisco, *Coregonus sardinella*, whitefish, coregoninae, spawning, overwintering, radio telemetry, aerial survey, transmitter, surgical implant, Alaska, Selawik River, Selawik Lake, Selawik National Wildlife Refuge, Stock Status and Trends

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