

Alaska Fisheries Data Series Number 2002-1  
January 2002

**Movement Patterns of Radio-Tagged Adult Humpback Whitefish  
in the Upper Tanana River Drainage**

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## **Abstract**

Radio telemetry technology was employed to track the movements and locate critical habitats of adult humpback whitefish in the upper Tanana River drainage. Ninety-five transmitters were surgically implanted in humpback whitefish in three locations in the spring and summer of 2000 and 2001. Their movements were monitored for several months using boat and aerial tracking techniques. Relocations suggest that adults frequent lake habitats in the spring and early summer, and move from lake to river habitats by mid to late summer. By late fall, most tagged fish were concentrated in two discrete upstream regions of the drainage; one in the Nabesna River, 15 to 30 km upstream from its mouth, and the other in the Chisana River, 80 to 100 km upstream from its mouth. These regions are thought to be spawning areas. By winter all tagged fish had dropped back downstream into regions of the Tanana River or in the Tetlin Lake system, where they appeared to be overwintering. A selection of feeding, spawning and overwintering areas, all critical habitats for humpback whitefish, have been located. Rearing areas for juvenile fish have not been located.

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## Introduction

Concerns have recently been voiced about possible declines in humpback whitefish *Coregonus pidschian* populations in the upper Tanana River drainage. Local subsistence fishers have spoken to Tetlin National Wildlife Refuge personnel directly (B. Schulz, U.S. Fish and Wildlife Service, Kanuti National Wildlife Refuge, personal communication) and have voiced concerns at the Eastern Interior Federal Subsistence Advisory Council meetings as well. The main issue seemed to involve a perception that humpback whitefish, the primary species targeted in local subsistence fisheries, were less abundant now than they were in the past.

Addressing local residents' perceptions of reduced abundance of humpback whitefish directly, without baseline information about previous stock status for comparison, is not possible. Data regarding stock or population numbers are not available. Neither spawning nor wintering areas have been identified. Juvenile rearing areas are unknown. Movement patterns within the upper Tanana River drainage, as well as possible migrations far outside the region, have not been confirmed or refuted. Knowledge of important habitats for humpback whitefish in the area, as well as some understanding of their seasonal and annual movement patterns, is required before any real problems can even be identified with confidence. Management action intended to remedy identified problems would have to follow. Interpreting movement patterns and recognizing the importance of seasonal locations requires a basic understanding of humpback whitefish biology and life history. A brief synopsis follows.

Humpback whitefish and their close relatives, referred to by McPhail and Lindsey (1970) as the "*Coregonus clupeaformis*" complex, are widely distributed across northern North America and Asia (Figure 1). Fleming (1996) presents age distribution data from a spawning population sampled on the Chatanika River in interior Alaska, suggesting that median ages are in the neighborhood of 9 or 10 years. Reist and Bond (1988) suggest that maximum ages may be as high as 20 years or more on the Mackenzie River in northern Canada. And Power (1978) presents a convincing image of a sectioned otolith from a fish captured in Quebec, which he estimated to be 57 years old. It is clear that the species is capable of growing very old.

Spawning maturity is reached by 4 to 8 years of age, is variable depending on sex and location, and individuals can spawn multiple times (Alt and Kogl 1973; Alt 1979; Reist and Bond 1988; Fleming 1996). Large females may produce 50,000 or more eggs for each spawning event (Townsend and Kepler 1974). Like all whitefish species, they spawn in freshwater in the fall. However, several different life history scenarios are possible for the species. They inhabit and spawn in large lake systems, they are found in brackish water near the mouths of the rivers they inhabit, and they migrate along river corridors and spawn in flowing water (Bidgood 1974; Alt 1979; Reist and Bond 1988; Lambert and Dodson 1990; Fleming 1996).

FIGURE 1.—Humpback whitefish *Coregonus pidschian* are medium sized whitefish in the Family: Salmonidae, Subfamily: Coregoninae. The scale bar is in cm.



Humpback whitefish living in large river systems are thought to follow a generalized life history pattern that Reist and Bond (1988) describe and illustrate very well. The following leans heavily on their work, with other supporting literature cited as appropriate. Spawning takes place in the late fall in flowing water over a gravel substrate (Alt 1979). Humpback whitefish are broadcast spawners. Eggs are cast into the water column where they drift downstream and sink to the bottom, becoming lodged in the interstitial spaces in the gravel (Scott and Crossman 1973;

Morrow 1980). They develop through the winter, hatch in the spring, and emerge into the water column as the high flows of spring and early summer fill the waterways (Naesje et al. 1986; Shestakov 1991; Bogdanov et al. 1992). The tiny juveniles are carried downstream by the rapidly flowing water to a wide array of chance destinations that include backwaters along the river, off-channel lakes, and estuary regions at river mouths (Shestakov 1992). Juveniles that find themselves in habitats that support their needs survive, while others perish.

After several years of growth, young humpback whitefish become mature and prepare to spawn. Beginning in early to mid-summer, they migrate to upstream spawning sites. Like many other coregonid fish, they feed little or not at all for several weeks leading up to spawning (Alt 1969; Dodson et al. 1985). Major spawning areas appear to be used each year, so fidelity to natal spawning areas is thought to be relatively high (Hallberg 1989). Following spawning, adults retreat downstream to overwintering locations (Alt 1979), and eventually to feeding areas by the following spring. Based on tag recapture data, Fleming (1996) suggests that some individuals may spawn on sequential years in the Chatanika River in interior Alaska. However, Lambert and Dodson (1990) calculated the energy demands associated with spawning and contend that it would be nearly impossible to accomplish annually. They propose instead that the species may actually be spawning every other year or even less frequently. Reist and Bond (1988) concur, and contend that for any given fall there are three main components of a population: immature fish far downstream of the spawning areas; mature non-spawners also somewhere downstream of the spawning areas but not necessarily in the same places as immature fish; and mature spawners at or near upstream spawning areas. Based on these concepts, we might infer that spawning areas are the extreme upstream limit of a population's range, and the rearing areas for immature fish are the extreme downstream limit.

As this project began, some unpublished data were available regarding capture locations for mature humpback whitefish in the upper Tanana River, but movement patterns and critical habitats were virtually unknown. Brown et al. (2001) demonstrated that radio telemetry technology could be used with humpback whitefish, and that a year or more of movement data could be collected from individual tagged fish. Combining seasonal locations from radio tagged

fish with the basic understanding of humpback whitefish life history promised to provide insight into movement patterns and critical habitat areas of the upper Tanana River drainage. This paper describes two years of radio telemetry work with humpback whitefish tagged in three distinct regions of the upper Tanana River drainage.

### **Study Area**

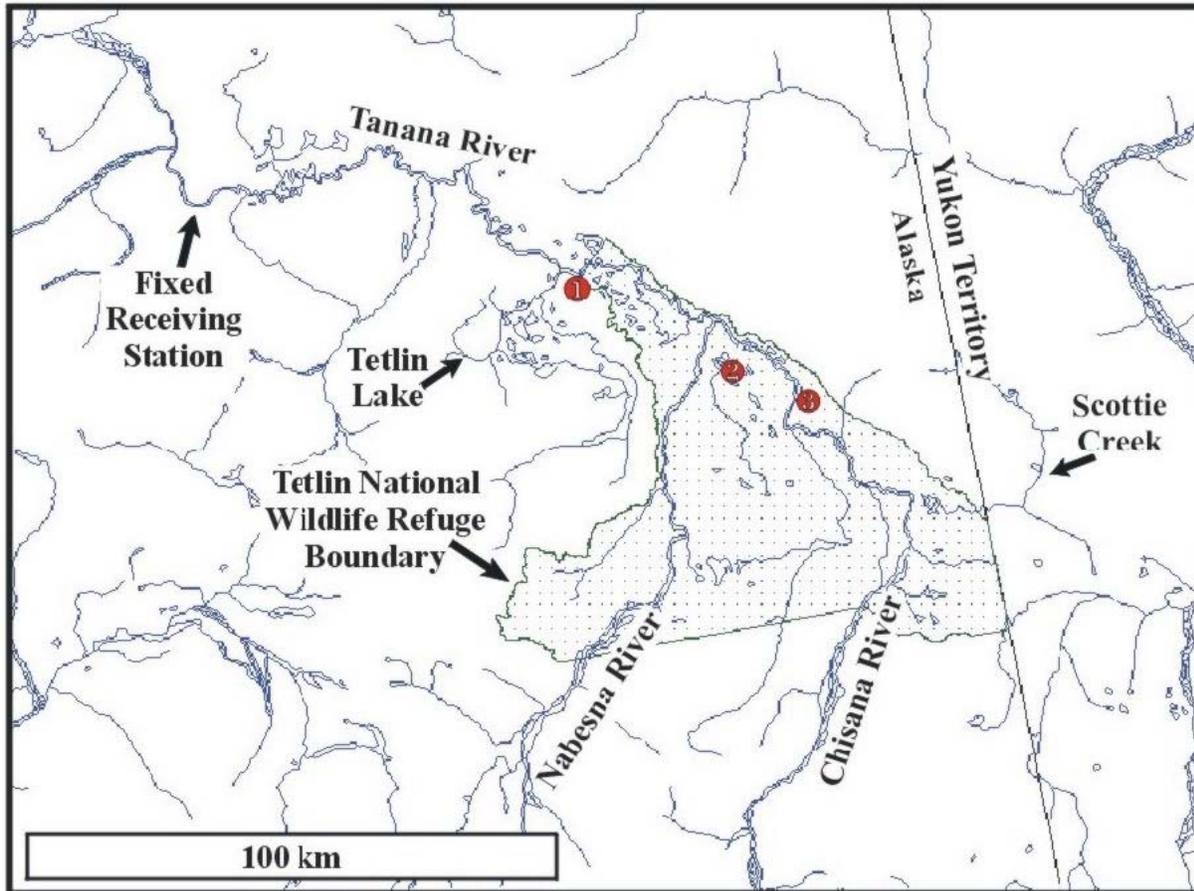
The upper Tanana River drainage, in eastern interior Alaska, is a complex region of interconnected lake systems, sloughs and rivers (Figure 2). Wetland areas lie at relatively high elevations, from 500 m to 600 m above sea level. The region experiences a continental climate, with cold winters and warm summers (Brabets et al. 2000). Rivers and lakes generally freeze by mid-October and remain frozen until late April or May. Annual precipitation in the region may total 25 cm or more (U.S. Fish and Wildlife Service 1990).

The Nabesna and Chisana Rivers flow north from heavily glaciated valleys of the Wrangell Mountains to the south. Flow from these rivers is highly turbid during the summer months and clear during the winter. The Tanana River originates at the confluence of the Nabesna and Chisana Rivers, and shares their annual cycles of turbidity and clarity. These three major rivers, along with an assortment of lakes, sloughs and smaller streams in the region, are the water bodies of interest in this study.

### **Methods**

Radio transmitters used in this study were designed to operate on four frequencies within 149 MHz. Approximately 24 digitally coded transmitters were active on each frequency. Radio tags weighed about 9 g, and were approximately 5 cm long and 1 cm in diameter. They were each equipped with a whip antenna about 42 cm long. They 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.

FIGURE 2.—The study area lies in the upper Tanana River drainage in the eastern interior of Alaska. The tagging sites are indicated by the numbered circles. Number one indicates the Kalutna River site, number two indicates the Fish Lake site, and number three indicates the Tenmile Lake site.



Humpback whitefish were captured for tagging at three different locations in the upper Tanana River drainage: the mouth of the Kalutna River; in Fish Lake; and in Tenmile Lake (Figure 2). Transmitters were surgically implanted into a total of 95 fish from the three sites. Thirty-two transmitters were deployed from the Kalutna River in July, 2000, 31 transmitters from Fish Lake in late May, 2001, and 32 transmitters from Tenmile lake in early June, 2001. Morris et al. (2000) suggested that water temperatures greater than 16°C could reduce survival in coregonid fish following surgery. Hence, implantations were conducted only when fish could be released

into water colder than this. Monofilament gillnets with 5 cm or 10 cm stretch mesh webbing were utilized for fish capture. Approximately 5 m of netting was set and constantly monitored until a fish struck the net, at which time the fish was disentangled, placed into a tub of water, and evaluated for tagging. Adult fish appearing to be unharmed by capture were considered to be suitable candidates for tagging.

Candidate fish were anesthetized and prepared for surgery immediately following capture. They were placed directly into a clove oil anesthetic solution prepared as described by Anderson et al. (1997). The clove oil was diluted in solution to a concentration of 20 mg/L, somewhat less concentrated than Anderson et al. (1997) reported using. Fish were considered to be fully anesthetized when they lost equilibrium and rolled upside down. Weight and fork length were recorded from sedated fish, and they were then ready for surgery.

Radio transmitters were surgically implanted in candidate fish. Anesthetized fish were placed ventral side up in a padded, V-shaped tagging cradle and provided with a constant stream of water over their gills. Anesthesia solution bathed the gills until the first suture was tied. Fresh water was then used until the surgery was complete. All surgical tools, as well as the radio transmitters themselves, were soaked in an antibacterial wash and then rinsed in distilled water prior to use. Scales were removed from the incision area, anterior to the pelvic fins and just to the fish's left of center (Winter 1996). An incision, approximately 2 cm long, was then made through the belly wall parallel to the long axis of the fish. A grooved director, a narrow metal device about 10 cm long, was inserted into the fish's body cavity towards the rear. A 25 cm long, flexible, hypodermic needle was then inserted through the belly wall posterior to the pelvic fin, its tip meeting the grooved director inside. The needle was then pushed along the grooved director, which protected internal organs from the sharp needle tip, until the needle emerged from the incision. The transmitter antenna was then threaded into and through the needle, and the needle and grooved director were removed so the antenna remained through the body cavity and the posterior needle hole. The transmitter was then inserted into the body cavity through the incision. Simple interrupted stitches with monofilament sutures were used to close the incision (Wagner et al. 2000). Most fish required three stitches for adequate closure. A tissue adhesive

compound was applied to the wound line and the suture knots as a final step. Upon completion of surgery, fish were placed into a tub of water to recover. Once upright position was steady, fish were released.

Relocation of radio-tagged humpback whitefish was accomplished by boat surveys and aerial telemetry flights at approximately 3 to 4 week intervals. Additionally, a fixed receiving station was established about 150 km downstream from the confluence of the Nabesna and Chisana Rivers (Figure 2) to document long-distance emigration from the study area if it occurred. Relocations were linked to GPS coordinates and plotted on topographic maps. Movements relative to previous locations and to the tagging site were calculated following each survey, and critical habitat areas were identified.

## **Results**

All radio-tagged fish appeared to be mature adults. The overall median length of tagged fish was 44 cm, and ranged from 39 cm to 51 cm (Table 1). The overall median weight was 1.13 kg, and ranged from 0.84 kg to 1.79 kg (Table 1). Sex could not be confidently determined by outward appearance. However, 10 radio-tagged fish were known to be female, because eggs were observed in the body cavity or were dislodged by the grooved director or needle during surgery. The sexes of the other 85 fish were undetermined.

Radio-tagged humpback whitefish were located by a regular series of boat and aerial telemetry surveys. Rarely were all fish located on any one survey. However, when the results of multiple surveys were considered together, the seasonal movement patterns of nearly all tagged fish became clear.

TABLE 1.—Length and weight distributions of humpback whitefish from the upper Tanana River, and length distribution data from humpback whitefish sampled on the Chatanika River spawning grounds (Fleming 1996)

	Sample (N)	<u>Length (cm)</u>		<u>Weight (kg)</u>	
		Median	Range	Median	Range
Kalutna River	32	43	39 to 51	1.10	0.85 to 1.66
Fish Lake	31	44	40 to 49	1.08	0.84 to 1.47
Tenmile Lake	32	46	39 to 51	1.34	0.87 to 1.79
Total	95	44	39 to 51	1.13	0.84 to 1.79
Chatanika River	1,513	44	36 to 56	—	—

Generalized movements by season, habitat, and upstream or downstream trends occurred for all three groups of fish, and were similar among groups. No fish were recorded moving downstream past the remote receiving station, showing that mature humpback whitefish tagged in this study restricted their migrations to the upper part of the Tanana River drainage. The Kalutna River fish were tagged at the confluence of the Kalutna and Tanana Rivers in July, so their locations in the spring were unknown. However, during the following spring, 28 of the original 32 fish were located in Tetlin Lake. Both Fish Lake and Tenmile Lake fish were captured in lakes in late May or early June. Following is a synopsis of seasonal movement patterns and locations of critical habitat areas as determined from relocations of radio-tagged humpback whitefish in this study.

Annual patterns of movement were similar for all three groups of tagged fish. Adult humpback whitefish inhabit lake systems in the upper Tanana River valley each spring and early summer. A few radio-tagged fish moved between lake and river habitats during this early season, but most fish remained in the lakes, which are thought to be utilized for feeding (Figure 3a). During mid to late summer, radio-tagged fish made a distinct move from lake to river habitat. They distributed themselves widely along the river system with concentration areas in the vicinities of their respective lake outlets, and also near the confluence of the Nabesna and Chisana Rivers (Figure 3b). By early fall, most fish had moved into the lower reaches of the Nabesna and Chisana Rivers, which was: 1) a distinct upstream movement for Kalutna River fish; 2) no real

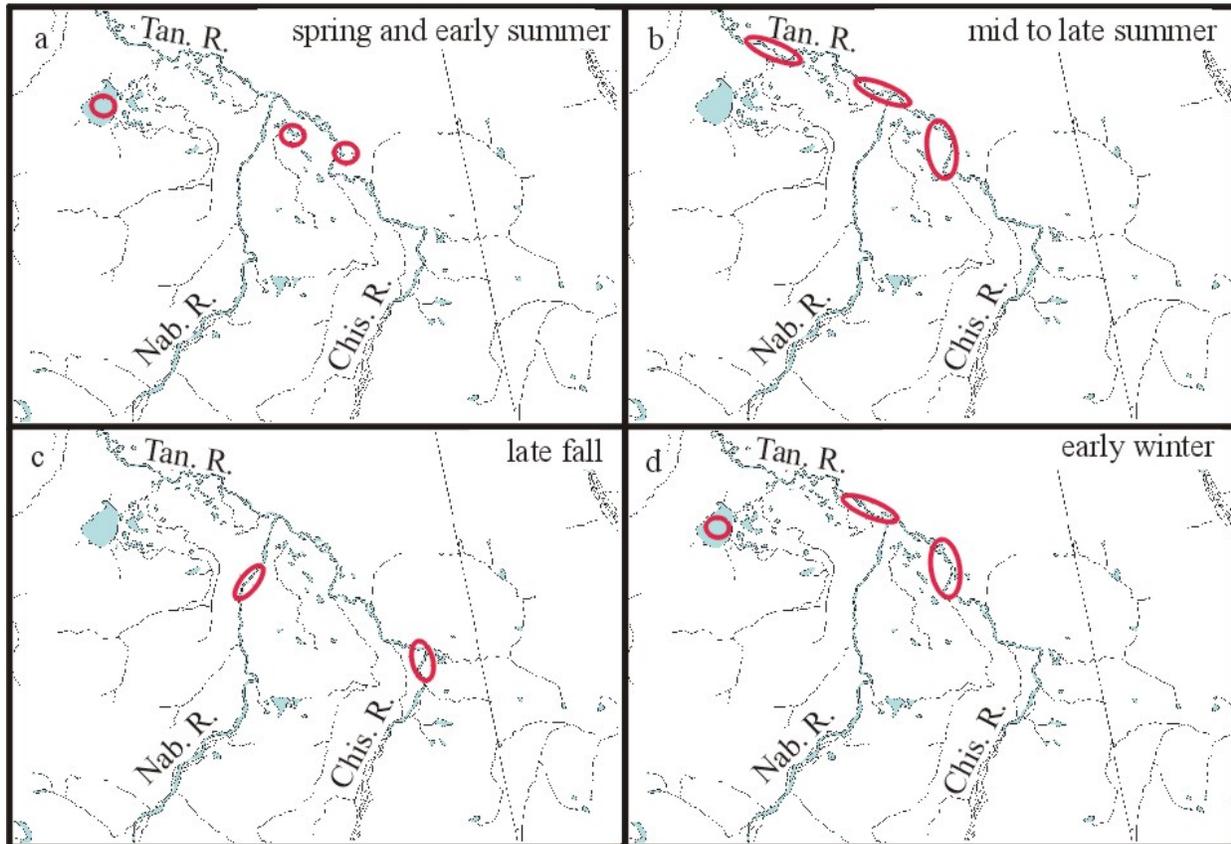
trend for Fish Lake fish; and 3) a downstream movement for some Tenmile Lake fish. During late fall, the expected spawning time for humpback whitefish (Alt 1979; Reist and Bond 1988), concentrations of radio-tagged fish were located in the Nabesna and Chisana Rivers (Figure 3c). All told, 46 fish were located during the spawning season in a relatively discrete region of the Nabesna River, from 15 to 30 km upstream of the Nabesna River mouth, and 34 fish were located in a similarly discrete region of the Chisana River, from 80 to 100 km upstream from the Chisana River mouth. Fish from all three tagging locations were found in both regions, which are suspected as being major spawning areas. Six fish were located elsewhere than the spawning areas, and another nine fish were unaccounted for during the spawning season. In early winter, radio-tagged fish were primarily located in river habitat downstream from the suspected spawning areas (Figure 3d). Concentration areas seemed to be in the vicinities of their respective lake outlets and near the confluence of the Nabesna and Chisana Rivers. The fish tagged at the mouth of the Kalutna River provided an exception to this generalization. About half of these fish were in the Tanana River near the confluence of the Nabesna and Chisana Rivers, and the other half had ascended the Tetlin River and were located in Tetlin Lake during the early winter.

Late winter and spring locations of Kalutna River fish showed that many of them moved from river habitat to Tetlin Lake during the winter. By spring of the year following tagging, 28 of the original 32 tagged fish were in Tetlin Lake. Of the remaining four fish, one was harvested in the Nabesna River, over 55 km upstream of the tagging location, one disappeared about 3 weeks following tagging, one moved about 50 km downstream after tagging and remained in the Tanana River near the mouth of a small stream through the winter, and one disappeared after being located in the Nabesna River during the spawning period.

Fish from the three tagging sites shared river habitat in the summer, fall, and winter, but appeared to segregate among lake habitats. Fish tagged at the Kalutna River mouth migrated into Tetlin Lake, where they presumably were feeding. Only one fish from that group was ever located in another lake system. Only one fish from Fish Lake group was located in another lake system. It had ventured into the Scottie Creek wetland area in the late fall. And two fish from

Tenmile Lake were located in the late summer in Fish Lake. All other fish were located either in the river system or in their “home” lake only. These results suggest that there may be a high degree of fidelity to feeding habitats among humpback whitefish.

FIGURE 3.—Seasonal movement patterns of radio-tagged humpback whitefish in the upper Tanana River drainage. Abbreviations are as follows: Tan. R. (Tanana River); Nab. R. (Nabesna



River); Chis. R. (Chisana River).

## Discussion

### Current investigation

At the time of tagging, it was unclear what component of the humpback whitefish population were being sampled; mature spawners, mature non-spawners, immature fish, or a mix of two or more of these groups. There was a striking similarity in the lengths of fish radio-tagged in this

study with those reported by Fleming (1996) for humpback whitefish in the Chatanika River spawning area (Table 1), suggesting that mature fish were radio-tagged in the upper Tanana River. Nine small humpback whitefish, less than 30 cm FL, were captured during the project, but they were thought to be too small to accept a radio transmitter and were not tagged. Their presence suggests that at least some immature fish are present in the upper Tanana River drainage.

Rarely are all radio-tagged fish located on any single survey. Survey efforts are not usually comprehensive of all possible geographic areas where a fish might travel. Instead, a judgement is made regarding positions thought to be likely and flights are directed in those places. If few fish are found, survey efforts are expanded. However, at some point, usually when nearly all fish are located, a survey will be terminated. The reasons for detection failure of a tagged fish may be that it was not encountered during the survey, or that conditions did not allow decoding of tags that were heard. Conditions that might complicate decoding of a transmitter include a fish at great depth, since signal strength is attenuated with depth (Winter 1996), or signal collisions when two or more transmitters on the same frequency are in the same geographic location. In both cases, the signals may be heard by the surveyor, but may be difficult for the receiver to decode and identify. These detection failures are not considered to be serious problems because fish missed on one survey are usually located on the next, allowing their seasonal movement patterns to be deduced anyway.

Movement patterns exhibited by tagged humpback whitefish have been particularly revealing when compared with our understanding of the basic life history of the species. Of primary interest are the critical habitats identified based on fish presence at specific times of the year. Critical habitats for fish include spawning, rearing, feeding, and overwintering. Describing migration routes and the timing of these migrations is of interest as well. Disrupting these critical habitats or interfering with fish activities in these habitats can put fish populations at risk. Knowledge of critical habitat areas will enable informed management of development and exploitation activities to prevent impact to the habitats or the fish stocks, as well as providing opportunities for scientific study of the fish populations.

Critical habitats identified during this project include spawning areas, feeding areas, and overwintering areas. The two suspected spawning areas are perhaps the most important discovery to date. They are both relatively small, each extending along 15 to 20 km of river. Both areas were used by fish from all three tagging locations. It is clear that a large proportion of the mature humpback whitefish population of the upper Tanana River are confined to these two areas during the late fall, leaving them extremely vulnerable to exploitation or habitat disturbance at that time.

Lakes that have some connection to the river system in the upper Tanana River drainage appear to be utilized by humpback whitefish for feeding. Fish from the Kalutna River mouth migrated to Tetlin Lake, presumably to feed. Fish tagged in Fish Lake and Tenmile Lake were captured in lakes they were feeding in. There was very little movement among lake systems by radio-tagged fish, suggesting that there is a high degree of fidelity to feeding habitats. Humpback whitefish may feed in the turbid flowing water of the upper Tanana River drainage. However, most humpback whitefish that are sampled from large turbid rivers such as those in the upper Tanana River drainage have little or no food in their stomachs (John Burr, Alaska Department of Fish and Game, personal communication; unpublished data). It is assumed that the majority of feeding occurs in the various lake systems and that little or no feeding occurs in river habitats.

River habitat appears to be the primary overwintering area for humpback whitefish. Fish from all three groups of tagged fish shared habitat in the lower reaches of the Nabesna and Chisana Rivers, as well as just downstream in the Tanana River, in early winter. Only fish tagged at the Kalutna River mouth have been tracked through the entire winter, and they did not stay in one location throughout the winter. Many of them moved from the Tanana River into Tetlin Lake during the winter, a migration of over 50 km, 20 km of which were upstream in the Tetlin River. We will have to wait to see what movements are made by tagged fish from Fish and Tenmile Lakes, as their radio transmitters are active through July 2002.

### **Future investigation**

The Scottie Creek wetland system in the upper Chisana River is an extensive region of interconnected lake and stream habitat (Figure 2). Humpback whitefish are known to be present in the area, yet only 1 of 95 radio-tagged fish from elsewhere has been located in the system. The Chisana River spawning area is in the vicinity of the mouth of Scottie Creek, so many of the radio-tagged fish were near there and had the opportunity to enter (Figure 3c). Scottie Creek may represent another major feeding area in the upper Tanana River drainage, and humpback whitefish from the system presumably migrate to one or both of the identified spawning areas in the fall. Thirty-two radio tags will be deployed on humpback whitefish from the Scottie Creek wetlands in the spring of 2002, and their seasonal movements will be recorded.

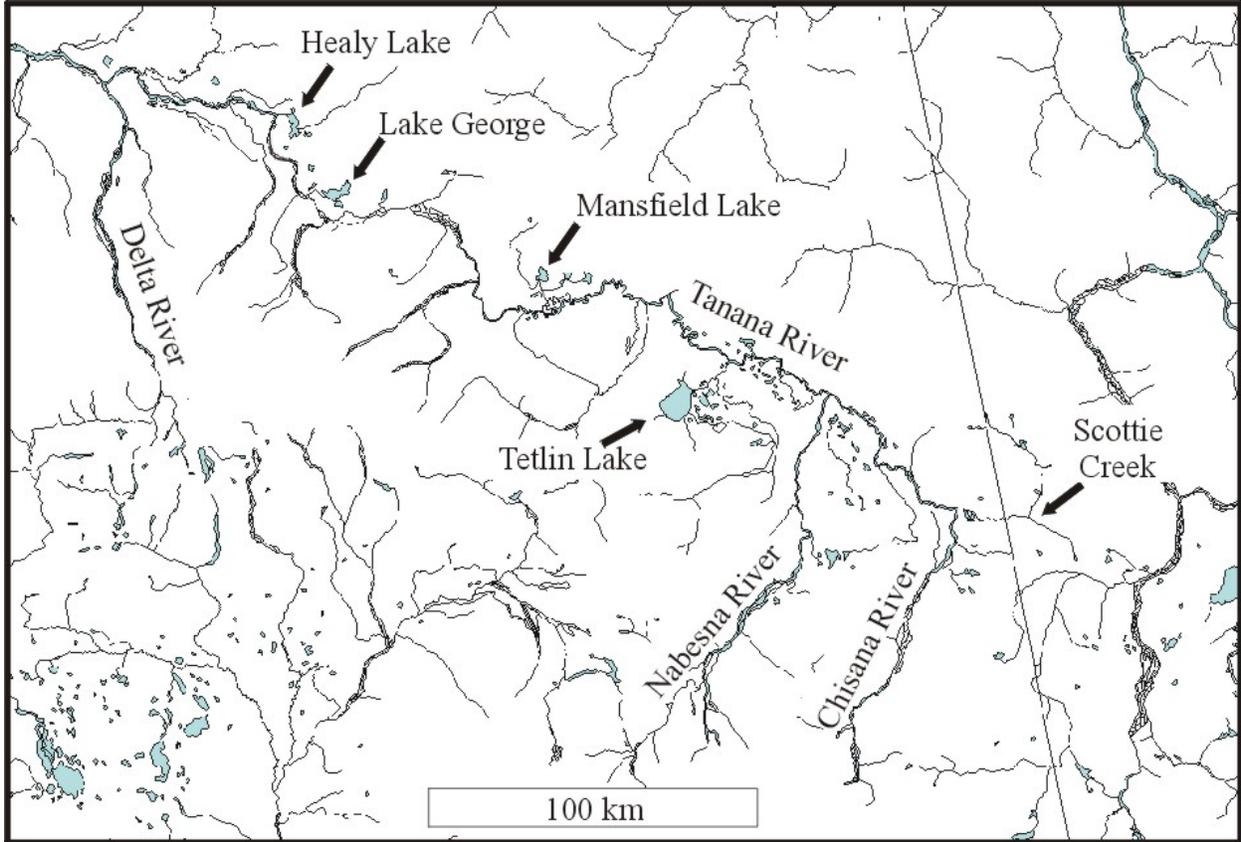
Another group of 32 transmitters programmed to operate through three spawning seasons will be deployed on humpback whitefish from Tenmile Lake to address a persistent biological question; whether or not sequential year spawning occurs. Tenmile Lake fish were chosen for this purpose because the age distribution of fish from the site includes a greater proportion of older fish than that from other areas of the upper Tanana River drainage (unpublished data), suggesting a higher survival rate, a quality important for multi-year studies. It is absolutely clear that some mature fish within a population do not spawn every year. Direct evidence for this is the documented presence of mature fish that are not in spawning condition during spawning season (Bond and Erickson 1985; Lambert and Dodson 1990). However, there may be a component of the population that spawns every year. Hallberg (1988; 1989) presents anchor tag recapture data from a substantial number of humpback whitefish that were found in the Chatanika River spawning area two years in a row, implying that at least some fish were spawning on sequential years. The weaknesses to this deduction are twofold: 1) capture and tagging may dissuade some fish from completing spawning; and 2) spawners and non-spawners may be present in spawning areas. The transmitters deployed to address the incidence of sequential year spawning will be programmed to transmit during two week periods, at three times during the year, for about 2.5 years. Transmit periods will be in late September, late January, and late May, respectively corresponding with spawning, wintering, and spring feeding periods. This will provide information on individual fish through three spawning seasons. In addition to addressing the sequential year spawning issue, the project should provide solid data regarding fidelity of

humpback whitefish to critical habitat areas. A companion sampling survey of the spawning areas is planned to verify spawning and to determine if non-spawners are present.

The rearing areas of juvenile humpback whitefish are unknown. Age distribution data from a sampling project conducted in 1998 (unpublished data), as well as the results of sampling for this project, reveal that immature fish, while present in low numbers, are under-represented in the catch from the upper Tanana River drainage. For fish species with high fecundity, such as any of the coregonid fish, there must be great numbers of juvenile fish that experience very low survival rates in any spawning population (Hilborn and Walters 1992). Their near absence in catches from the upper drainage, despite the fact that age 1 and older fish would be of a size vulnerable to the nets that were used, implies that they reside somewhere else in the river system. This, combined with the extensive data presented by Naesje et al. (1986), Shestakov (1991), and Bogdanov et al. (1992), on downstream migrations of juvenile coregonid fish in Asian and Scandinavian rivers each spring, would suggest that a majority of juvenile humpback whitefish from the upper Tanana River migrate to rearing areas far downstream. If this is true, we might speculate that adult humpback whitefish found in the upper Tanana River drainage colonize lake habitats for feeding following their first spawning event. Presumably they would recognize the smell of good feeding habitat as they pass outlet streams and subsequently take up residence in the lakes.

Three major lake systems downstream of the current study area have been identified as candidate locations for further investigation of humpback whitefish in the Tanana River drainage (Figure 4). All three are on the north side of the Tanana River. Mansfield Lake and its companion wetland system is approximately 132 km downstream from the confluence of the Nabesna and Chisana Rivers. Lake George is about 70 km farther downstream and Healy Lake is another 24 km farther still. Humpback whitefish are known to be present in all three wetlands.

FIGURE 4.—An expanded view of the upper Tanana River drainage with major wetland feeding habitats and other pertinent geographic features labeled



## **Acknowledgments**

This project was funded through a grant from the U.S. Fish and Wildlife Service, Office of Subsistence Management. Fieldwork, data analyses, and writing were conducted by personnel from the Tetlin National Wildlife Refuge and the Fairbanks Fishery Resource Office. In addition, aerial surveys were possible only because of the dedicated efforts of USF&WS pilots Bill Smoke (Tetlin National Wildlife Refuge), Mike Vivian (Yukon Flats National Wildlife Refuge), Don Carlson (Arctic National Wildlife Refuge), and Dave Sowards (Arctic National Wildlife Refuge). Pilot Jay Worley from Wright's Air Service contributed to the effort as well. Advice on surgical procedures and techniques were provided by fishery biologist Doug Palmer from the Kenai Fishery Resource Office, and Dr. Val Stuve and Susan Samson from the Aurora Animal Clinic in Fairbanks, Alaska.

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