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Pilot Study, Using PIT tags to monitor movements of Kuskokwim River Whitefish

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Pilot Study, Using PIT Tags to Monitor Movements of Kuskokwim River Whitefish

Ken C. Harper and Frank Harris

Abstract

Passive Integrated Transponders (PIT) tags were surgically implanted in three broad whitefish *Coregonus nasus*, 84 least cisco *C. sardinella* , and 38 humpback whitefish *C. pidschian* to test their use for monitoring whitefish movements using flat panel antenna systems. Tagged fish were released between two antennas, located 200 m apart, and 78% of the tags were detected passing either upstream into the lake from the release location or downstream. An unexpected 17% of all tagged fish moved downstream and 13% were detected by both antennas. Of the 22% that were not detected, 37% were released the day before or the day of an equipment malfunction. The maximum read distance above the antenna that a fish could be detected was 45 cm. Results indicate this technology is applicable to assess movements of individual whitefish in remote sites.

Introduction

Biological data such as migration timing, seasonal distributions, and location of critical habitat is important in management of whitefish *Coregonus spp*. Whitefish feeding in Whitefish Lake are primarily amphidromous (Harper et al 2006) migrating in the fall to spawning areas in flowing waters similar to other populations (Alt 1979; Bond and Erikson 1985; Reist and Bond 1988; Fleming 1996; Brown et al. 2002, Brown 2006). Fry are washed down to tidally influenced areas in the river delta where they rear in fresh and brackish waters during the first four to six years until mature. After maturity, whitefish move annually from the lower Kuskokwim River and tundra lake areas to up-river tributary spawning areas in the fall (Alt 1979; K. Harper, unpublished data). Whitefish exhibit a fidelity to feeding areas returning multiple years to Whitefish Lake primarily under the ice before May of each year (Harper et al. 2006). Humpback whitefish *Coregonus pidschian* and least cisco *C. sardinella* out-migrate from Whitefish Lake beginning in June and continue into October (Harper et al. 2006). Tagging data in the Chatanika River, a tributary to the Yukon River suggests individual humpback whitefish spawn on sequential years (Hallberg 1988, 1989; Fleming 1996). This life history exposes fish to multiple harvest efforts during intra- and inter-year spawning migrations, and on spawning grounds. Our studies of Whitefish Lake (2001-2003) have indicated that few broad whitefish *C. nasus* are now using the lake (Harper et al. 2006). Broad whitefish leave the lake primarily in September and October when subsistence fishing peaks at the lake. Broad and humpback whitefish are long-lived species and are known to attain ages of 20 and 30 years, respectively, in Whitefish Lake.

Tagging and recognition of individuals within a population is important in fisheries research. Information on individually tagged whitefish can be used to determine migratory behavior, growth, population size, survival rates, fine-scale movements, and long-term fidelity to spawning and feeding areas. These characteristics have rarely been accurately quantified and would be useful in developing management plans for whitefish species. The Kuskokwim River whitefish population is comprised of stock mixtures and management is complicated by harvests that occur

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intensively in small areas and over hundreds of kilometers of river as fish migrate to the spawning grounds. This may create a risk of overexploitation of weak stocks.

Many types of tags and marks have been used to mark fish, but each has its drawback. These studies may be compromised by tag loss, which reduces sample size and introduces bias into population estimates and survival rates (Ricker 1975; Arnason and Mills 1981). Tag loss varies with fish species, tag type, and tagging location. Double tagging experiments are often used to identify tag-shedding patterns and rates (Beverton and Holt 1957; Fabrizio et al. 1999; Wetherall 1982). In populations of long-lived fish, such as whitefish, estimation bias may be especially severe. Annual T-bar tag loss in whitefish tagged in Whitefish Lake was high in 2002, approaching 30% in humpback and least cisco (K. Harper, unpublished data).

Advances in passive integrated transponder (PIT) tag technology, including low cost of PIT tags, offer the opportunity to locate and individually identify large numbers of whitefish without disrupting their natural habitat choice, activity, and behaviors (Prentice et al. 1990). PIT tags have been used to monitor movements of anadromous salmonids, primarily through juvenile bypass systems or adult fish ladders at dams (PSMFC 2000). Past studies using PIT tags have included Columbia River juvenile Chinook salmon *Oncorhynchus tshawytscha* (PSMFC 2000), coho salmon *O. kisutch* and steelhead trout *O. mykiss* movements in small streams (Zydlewski et al 2001), Atlantic salmon *Salmon salar* (Armstrong et al. 1996), and wild trout *O. spp*. (Morhardt et al 2000). In contrast to radio tags, which have a battery that eventually will cease to function, PIT tags contain a small computer chip that transmits its code only when induced by an external energy source (Prentice et al. 1990). Larger 23 x 3.85 mm half duplex PIT tags (134.2 kHz, Texas Instruments®) have allowed a much greater read range than the smaller 12 mm PIT tags commonly used in salmonid studies (PSMFC 2000) and are detectable in an antenna loop of 7.2 m (Zydlewski et al 2002). This has allowed the construction of large antennas that can monitor the width of an entire stream (Zydlewski et al. 2001). Tags have been inserted into the body cavity with nearly 100% tag retention and high fish survival. In wild steelhead trout the retention rate of the larger tags (23 mm) was 98% (Zydlewski et al. 2002). In specially designed facilities at hydroelectric dams, computerized systems automatically detect, decode, and record individual PIT tag codes, thereby providing time, date, and location of detection and eliminating the need to anesthetize, handle, or restrain fish during data retrieval. Since development in the mid-1980s, PIT tags have provided a wealth of information about the distributions, migration timing, migration rates, and survival of juvenile salmonids.

PIT tags are passive, and can remain with the fish for their entire lifetime, which is important when working with long-lived species such as broad and humpback whitefish, and least cisco. Tagged fish can be located within rearing habitats or detected as they emigrate down or upstream to spawning or wintering areas without trapping or handling the fish. With these tags and antenna-systems, researchers have developed a method for passively monitoring movements of species in their natural environment with only one initial handling.

This study was initiated to test the feasibility of using PIT tags and antennas in a remote setting to monitor movements of whitefish. Our objectives were to design and deploy an antenna system capable of spanning the outlet stream of Whitefish Lake, and to determine the feasibility of a remote monitoring system. This information may then be used to develop a tagging program for whitefish in a large drainage with the subsequent collection of information on timing, recruitment, and fidelity to spawning areas and feeding areas where concentrations of fish may occur.

Study Area

The Kuskokwim River is the second largest drainage in Alaska (Figure 1). The glacially turbid main-stem originates in the Kuskokwim Mountains and the Alaska Range, on the northwest side of Mt McKinley and courses for approximately 1,498 kilometers (km). The river flows in a southwest direction and drains into the Bering Sea. Population centers are located at Bethel, Aniak, and McGrath, while an additional 19 small villages are scattered along its length. Travel in this remote portion of Alaska is by aircraft to one of the three hubs, then by boat or small plane to villages.

Whitefish Lake is a shallow 8,064-hectare lake averaging <1.5 m in depth, located within the Yukon Delta National Wildlife Refuge in western Alaska. It is approximately 20 km southeast of Lower Kalskag and 30 km southwest of Aniak (N61^{o} 24' W 160^{o} 01') in the Lower Kuskokwim River drainage. The lake drains into the Kuskokwim River via a 15-km river channel. The Whitefish Lake drainage encompasses 44,340 hectares and includes several small inlet streams that drain into the lake at an elevation of about 19.5 m. Pondweed *Potamogetan spp.*, the primary rooted aquatic vegetation that occurs throughout the lake, is very dense around the lake's perimeter. Frequent winds blowing across the lake stir up the bottom and cause turbidity. Flow contribution from Ophir Creek, the largest inlet stream, was only 2.63 m^3/s. when measured on September 6, 2000.

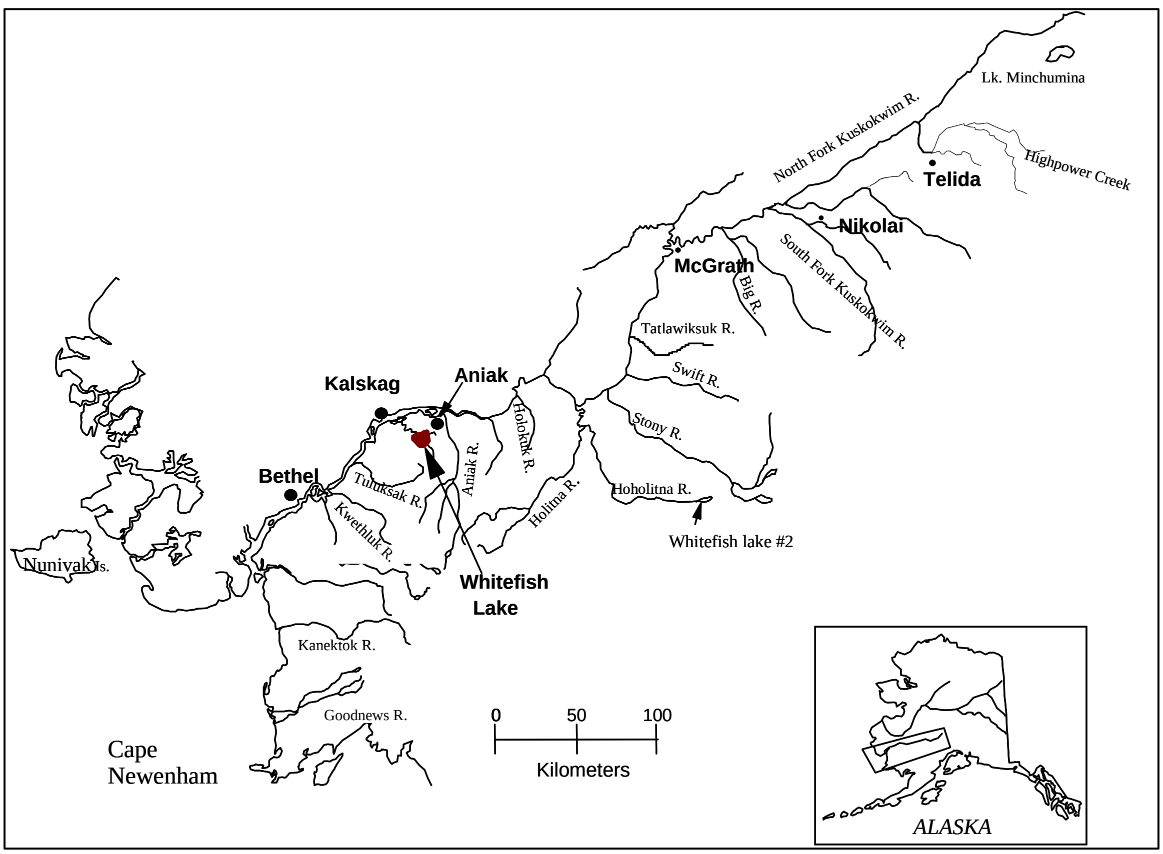

FIGURE 1. —Location of Whitefish Lake.

Methods

Adult broad and humpback whitefish and least cisco were double tagged with PIT tags (23 mm 134.2 kHz read only; Texas Instruments) and a T-bar anchor tag (FD-94; Floy Tag Manufacturing Inc., Seattle Washington). Each Floy tag was inserted within 1 mm of the dorsal fin, approximately 1/3 distance from the posterior edge. An 800 telephone number to the Kenai Fish and Wildlife Field Office and text "Study fish do not eat" was printed on each tag. Fish were captured at a weir as they entered Whitefish Lake (Harper et al. 2006) or in hoop nets set in the lake as part of a concurrent radio telemetry study on movements of whitefish in the Kuskokwim River (FIS 04-304). Tagged fish were anesthetized with a solution of 40 mg/l Aqui-s ®, weighed, and measured to the nearest 10 mm fork length. Sedated fish were placed ventral side up in a neoprene-lined cradle, and their gills were irrigated using a combination of anesthesia and oxygenated water during the procedure. Selected fish also received a radio transmitter (Grant Engineering 11mm X 45mm 148 kHz radio tags) and a 2-3 cm incision large enough to accommodate the transmitter was made anterior to the pelvic girdle approximately 1 cm from the mid ventral axis. PIT tags were co-inserted in fish with radio transmitters. The ventral incision was closed with three or four individual stitches of absorbable suture and Vetbond® adhesive. PIT tags were also inserted into the dorsal cavity of several fish, approximately 5-10 mm to the right side and even with the posterior end of the dorsal fin using a hypodermic needle. Surgical instruments and transmitters were soaked in a cold sterilant (chlorhexidine gluconate) and rinsed in saline solution before use. Surgeries ranged from 4-10 min. Recovery time for fish varied between 3 and 10 min before they were able to maintain an upright condition. Additional time was allowed before release near the capture site.

Tag Detection equipment.

Antennas were constructed using 2-gauge multi-strand electrical wire fashioned into a long loop with parallel wires maintained at a distance of approximately 76 cm. This spacing resulted in the maximum detection distance in air of approximately 46 cm. Parallel spacing was held constant by using PVC pipe and fastening it between each leg of the antenna in a fashion that resembles a rope ladder (Figure 2). Interrogator units consisted of an antenna tuner and Radio Frequency Identification (RFID) reader, both supplied by OREGON RFID®. RFID readers interrogate the water above the antennas approximately 8 to 12 times per second and can detect more than one fish at a time. A palm pilot was connected to the reader to log detected tags. Data were stored on 32 MB multi media cards in an ASCII text file.

Two antennas were fabricated and tested with the RFID reader before being shipped to and installed in Whitefish Lake. One antenna was installed at the mouth of the lake outlet, and the other was approximately 200 meters downstream. All fish were released in between the two antennas, forcing the fish to pass over an antenna to leave the release area. Each antenna was checked daily for maximum read distance and tuned as needed.

Movements of whitefish tagged with both PIT and radio tags was also monitored using seven fixed radio receiver stations located between Bethel and Medfra on the Kuskokwim River. These receiver stations were installed for the concurrent radio telemetry study on movements of whitefish in the Kuskokwim area. Boat and aerial surveys were also conducted, encompassing over 1000 river kilometers.

Data Analysis

Data were downloaded from the palm pilots daily and converted from ASCII text to MS excel files (Appendix 1). Fish passage was verified through cross-referencing of unique numbers on the PIT tag reader.

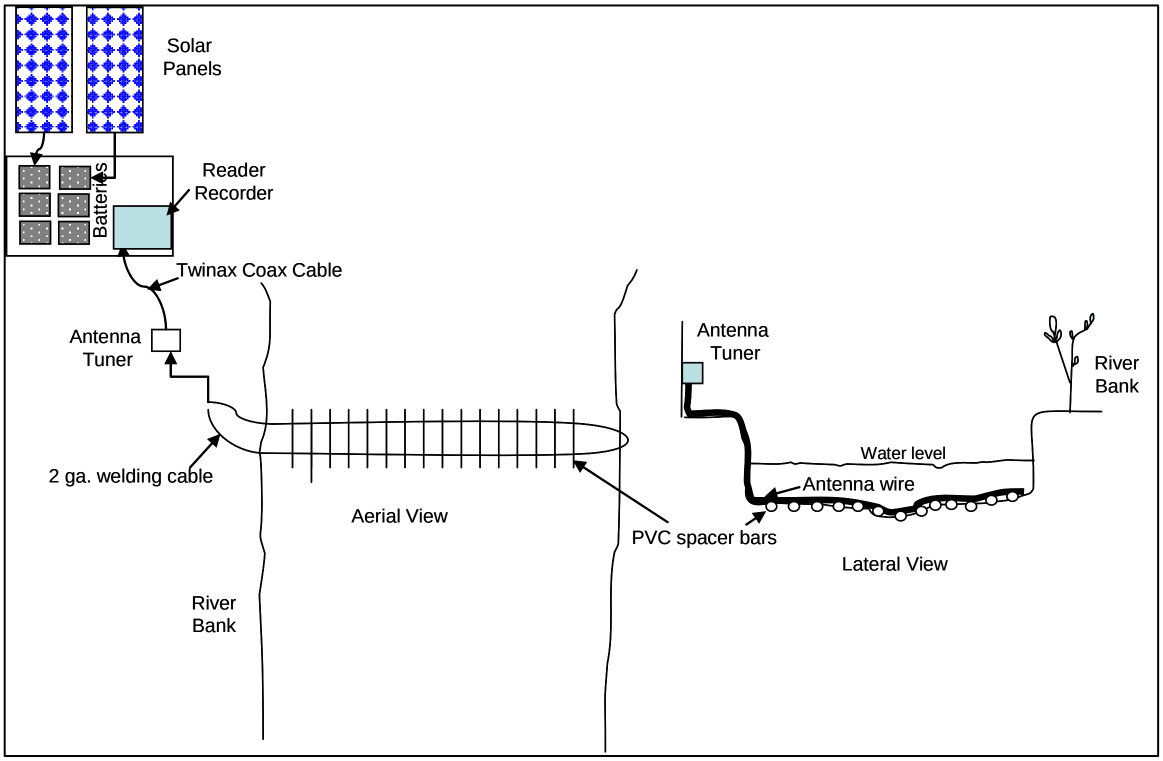

FIGURE 2. —Antenna design and system wiring of a PIT tag monitoring site, Whitefish Lake, Alaska.

Results and Discussion

Fish Collection and Operation

Weir installation was delayed due to a late lake breakup, after which capture of fish was difficult due to low numbers entering the lake. The weir was operational from May 21 until June 13, 2005 capturing 128 least cisco (93%), 7 humpback whitefish (5%), and 2 unidentified whitefish (2%).

Hoop nets were fished at various locations in the lake from May 22 until June 25 and captured 151 whitefish. Of the captured whitefish, least cisco were the most prevalent (72%, N= 108) followed by humpback (27%, N=41) and broad whitefish (1%, N=2).

Tagging

PIT tags were implanted in 125 whitefish captured both at the weir and in hoop nets in Whitefish Lake between May 13 and June 24, 2005. This included 3 broad whitefish, 38 humpback whitefish, 83 least cisco and one suspected hybrid (Appendix 2). All PIT tagged fish were released between the two antennas. PIT tags were also inserted in an additional 34 broad whitefish captured at fish wheels operated near Kalskag in early September (Appendix 3). PIT tags implanted in September are not included in the detection results since the tagging location and time of year made it highly unlikely that these fish would return to Whitefish Lake while the antenna was in operation.

A total of 97 fish were detected on the upstream and downstream antennas, while sixteen fish were detected on both antennas. The direction and timing of the fish varied after tagging, and not all of the fish moved into the lake and remained there. For example, one humpback whitefish crossed the lower antenna and remained in the river for 6 days before it returned, passed both antennas, and entered the lake. Two days later, this fish left the lake and passed both antennas heading downstream. Eight fish moved down across the lower antenna and returned to enter the lake. At least one humpback whitefish left the lake immediately after being tagged and traveled 15 km downstream past the radio receiver station located on the Kuskokwim River, and returned to the lake over two months later.

The overall detection rate was 78% (Table 1). Twenty-eight fish were not detected on either antenna. Humpback whitefish and least cisco had similar detection rates of 78% and 80%, respectively. No broad whitefish were detected and there may be a several reasons for this failure. First, only three broad whitefish were PIT tagged in the spring, with one released before any antennas were set up. The other two broad whitefish were released on June 8. On June 9, it was discovered that the palm pilot on the upstream antenna had lost power for an unknown period between scheduled downloads. Considering that three out of the seven fish released on the June 8 were not detected, it is very possible that these two broad whitefish swam over the antenna while the system was not recording.

TABLE 1. —Total number of whitefish PIT tagged, and detected at the outlet of Whitefish Lake, Alaska, 2005.

Species	Tagged	Detected	Percent Detected	Average number of days from release to detection
Broad Whitefish	2*	0	0%	N/A
Humpback Whitefish	38	30	79%	1.5
Least Cisco	84	67	80%	0.1
Total	124	97	78%	0.6

* 3 total, one tagged prior to installation of antennas

Four hundred whitefish were expected to be PIT tagged at the outlet of Whitefish Lake. Unfortunately, only a small sample size of whitefish were tagged due to low numbers of fish entering the lake when the weir was operational and increasing water temperatures. Most of the whitefish entered the lake under the ice and during break up of the lake, making capture extremely difficult. Once the ice comes off the lake, there is a short period before the water temperature rises above 15°C, the maximum temperature for surgeries. As afternoon water temperatures rose above 15°C, the surgery times were shifted to early mornings. This allowed tagging to continue into June.

The location for PIT tag implantation varied on whether or not the fish received a radio transmitter. Insertion of a PIT tag in the abdomen when it is open for the insertion of a radio tag, required little extra time. Location may affect retention rates, and long term holding to determine retention was not conducted. Additional work to determine the most efficient implantation method for the 23 mm PIT tags is warranted. Since PIT tags are much smaller than radio transmitters, they can be implanted faster using the hypodermic needle method used in juvenile salmonids described by the Columbia Basin Fish and Wildlife Authority, PIT tag steering committee. This reduces stress and improves survival rates.

Tag Detection Equipment/Problems

Antenna length varied according to channel width, and it was determined that the maximum tunable length was a loop of approximately 23 meters on a side. At this length, the antenna would tune but required constant tuning to maintain a maximum read distance. The upstream antenna was used in this configuration for 19 days until a beaver damaged the rubber exterior coating causing the read distance to decrease. Although the read distance was diminished, fish were still detected. The upstream antenna was then moved to a narrower section of the creek and shortened to span a stream channel width of approximately 14 meters. This smaller loop was similar in size to the downstream antenna, and required less maintenance. The read distances on both antennas were approximately 46 cm.

During the initial weeks of monitoring PIT tags, several technical difficulties occurred that might have affected the detection rate. First, the resistor board in the multi-antenna reader (multi-plexor) developed a short causing it to stop functioning. This left the project operating with only the upstream antenna for five days. During this time, fish were released in a shallow water U-shaped holding pen about five feet downstream of the antenna. The fish had to swim upstream towards the antenna to enter the lake but could move downstream and exit to the Kuskokwim River without being detected. However, the detection rate during those five days was 95%, substantially higher than when fish were released between the two antennas. The shallow water and close proximity of the release pen to the operational antenna may have given the fish little room to avoid swimming over the antenna undetected. Without two antennas, it is unknown if the fish moved up to the antenna, were detected and then proceeded to move downstream. Second, although the antennas were checked daily, there were times when the power supply to a palm pilot was disrupted. When this occurred, it would operate for several hours before the internal battery failed and total hours the logger was inoperative is unknown. This happened five times during the spring, most likely lowering the detection rate. During those five days that the palm pilots were off, nine fish were tagged and only four were detected by an antenna. Nineteen percent of all fish not detected were released on a day when the palm pilot had stopped logging data. Ten (37%) of the fish not detected were released the day before, or the day of a palm pilot losing power. The reason for the loss of power was discovered to be in the data/power connection to the palm pilot. The manufacturer remedied the problem by exchanging the palm pilots for newer versions with upgraded software. This newer software version allowed the power connection to be monitored at the time of set up. Third, post-season it was discovered that PIT tags inserted into the body cavity in close proximity to radio tags were not detectable by the reader and would not transmit a signal. This was probably a source of failure for several of the PIT tags inserted in close proximity with the radio tags, or migration of PIT tags in the body cavity after surgery.

Benefits of PIT tag use for Whitefish Research

PIT tag technology has many benefits for monitoring long-lived species like whitefish. Tag loss concerns are minimized in long term tagging studies using an internal tag. Fish tagged as juveniles can be monitored through different life stages at different locations. Multiple collections of data over a fish's lifetime have great potential to reveal behavioral and habitat use characteristics. These are not possible with radio tags, which generally have a short life span compared to whitefish, and are limited by battery size and life. Monitoring antennas for PIT tags can be designed to be left in place over winter, capturing early spring under-ice movements. PIT tags are relatively inexpensive, when compared to radio tags, which dramatically reduces tagging costs. Equipment for monitoring PIT tags is also less expensive than radio telemetry equipment.

The challenges experienced during this pilot study have been solved, paving the way for additional studies using this technology.

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APPENDIX 1. —Example of ASCII file with individual PIT tag codes converted to Microsoft Excel. ®.

			Antenna		Secondary
Date	Time	PIT tag number	Location	Qualifier	Description
6/2/2005	10:51:00	LR 0000 0000000113727597	Whitefish 1	Deep	Upper
6/2/2005	10:51:05	LR 0000 0000000113727597	Whitefish 1	Deep	Upper
6/2/2005	21:53:53	LR 0000 0000000113727645	Whitefish 1	Deep	Upper
6/2/2005	21:53:55	LR 0000 0000000113727645	Whitefish 1	Deep	Upper
6/3/2005	10:33:23	LR 0000 0000000113727531	Whitefish 1	Deep	Upper
6/3/2005	10:33:27	LR 0000 0000000113727531	Whitefish 1	Deep	Upper
6/3/2005	15:09:40	LR 0000 0000000113727563	Whitefish 1	Deep	Upper
6/3/2005	15:31:13	LR 0000 0000000113727644	Whitefish 1	Deep	Upper
6/3/2005	15:31:16	LR 0000 0000000113727644	Whitefish 1	Deep	Upper
6/4/2005	9:50:03	LR 0000 0000000113727533	Whitefish 1	Deep	Upper
6/4/2005	9:50:07	LR 0000 0000000113727533	Whitefish 1	Deep	Upper
6/4/2005	2:12:29	LR 0000 0000000113727593	Whitefish 1	Deep	Upper
6/4/2005	2:12:33	LR 0000 0000000113727593	Whitefish 1	Deep	Upper
6/4/2005	10:40:11	LR 0000 0000000113727611	Whitefish 1	Deep	Upper
6/4/2005	10:40:14	LR 0000 0000000113727611	Whitefish 1	Deep	Upper
6/4/2005	15:07:30	LR 0000 0000000113727630	Whitefish 1	Deep	Upper
6/4/2005	15:07:33	LR 0000 0000000113727630	Whitefish 1	Deep	Upper
6/4/2005	15:20:56	LR 0000 0000000113727643	Whitefish 1	Deep	Upper
6/4/2005	15:20:58	LR 0000 0000000113727643	Whitefish 1	Deep	Upper
6/4/2005	12:05:45	LR 0000 0000000113727647	Whitefish 1	Deep	Upper

APPENDIX 2. —Species composition of whitefish PIT tagged at Whitefish Lake, 2006.

					Radio Tag			
Date	Species	Length	Weight	Floy Tag #	Code	Frequency	PIT Tag #	Pit Tag Detected
5/13/2005	BW	500	1.47	20102	9	148.580	15979620	
5/22/2005	LC	370	0.4	20103	148	148.320	13728106	x
5/22/2005	LC	350	0.41	20104	150	148.320	13727674	x
5/22/2005	LC	320	0.34	20106	152	148.320	13727671	x
5/23/2005	LC	315	0.3	20109	174	148.580	13727689	x
5/23/2005	LC	330	0.35	20114	155	148.600	13727641	x
5/23/2005	LC	330	0.38	20112	173	148.580	13727606	x
5/23/2005	LC	330	0.45	20108	167	148.620	13727607	x
5/23/2005	LC	320	0.33	20110	171	148.580	13728107	x
5/23/2005	LC	360	0.47	20113	161	148.600	13728111	x
5/24/2005	LC	530	0.48	20115	156	148.320	13728109	x
5/24/2005	LC	345	0.46	20116	166	148.620	13728110	x
5/25/2005	LC	355	0.4	20119	170	148.620	13727677	
5/26/2005	HW	445	1.08	20123	120	148.580	13727640	x
5/26/2005	HW	440	1.07	20120	119	148.320	13728105	x
5/27/2005	HW	450	1.34	20126	124	148.320	13727662	x
5/27/2005	LC	340	0.37	20128	146	148.580	13727625	x
5/27/2005	HW	430	1.03	20127	126	148.320	13727679	x
5/27/2005	HW	430	1.05	20124	122	148.320	13727645	x
5/27/2005	HW	490	1.44	20125	123	148.320	13727680	x
5/28/2005	HW	440	0.93	20129	127	148.600	13727609	x
5/28/2005	LC	340	0.38	20131			15979637	
5/28/2005	LC	285	0.19	20134			15987289	
5/29/2005	Hybrid	365	0.54	20136	143	148.580	13727660	x
5/29/2005	HW	450	1.21	20137	128	148.600	13727628	x
5/29/2005	HW	460	1.12	20138	129	148.600	13727661	x
5/29/2005	LC	295	0.3	20139			13727627	
5/29/2005	LC	315	0.3	20140			13727663	
5/31/2005	LC	280	0.2	20146			13727598	x
5/31/2005	LC	320	0.34	20144	142	148.580	13727629	x
5/31/2005	HW	450	1.4	20141	132	148.600	13727596	x
5/31/2005	LC	305	0.26	20143			13727576	
5/31/2005	LC	295	0.19	20145			13727632	
5/31/2005	LC	370	0.48	20142			13727594	x
6/2/2005	HW	445	0.99	20147	133	148.600	13727530	
6/2/2005	LC	295	0.28	20150			13727597	x
6/2/2005	HW	430	0.88	20152	135	148.620	13727659	
6/2/2005	LC	370	0.5	20153			13727561	x
6/2/2005	HW	470	1.11	20148	134	148.620	13727529	
6/2/2005	LC	370	0.47	20149	111	148.620	13727533	x
6/3/2005	HW	410	0.8	20151	139	148.620	13727612	x
6/3/2005	HW	390	0.67	20158	140	148.580	13727643	x
6/3/2005	LC	355	0.45	20159	112	148.620	13727563	x
6/3/2005	LC	310	0.28	20160			13727531	x
6/3/2005	HW	450	1.02	20162	93	148.320	13727564	x
6/3/2005	LC	380	0.55	20165	109	148.620	13727644	x
6/3/2005	HW	470	1.08	20163	99	148.600	13727593	x
6/3/2005	HW	440	1.35	20161	92	148.320	13727562	x
6/3/2005	HW	440	1.04	20164	101	148.600	13727610	x
6/4/2005	LC	365	0.45	20166	108	148.620	13727611	x

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					Radio Tag			
Date	Species	Length	Weight	Floy Tag #	Code	Frequency	PIT Tag #	Pit Tag Detected
6/4/2005	LC	325	0.39	20167			13727647	x
6/4/2005	LC	315	0.32	20168			13727630	x
6/5/2005	LC	315	0.31	20169			13727613	x
6/5/2005	LC	315	0.3	20170			13727614	x
6/6/2005	LC	320	0.36	20171			13727626	x
6/6/2005	LC	320	0.33	20172			13727578	x
6/8/2005	BW	425	0.91	20604	8	148.580	13727546	
6/8/2005	BW	455	1.6	20602	24	148.620	13727547	
6/8/2005	LC	285	0.23	20610			13727581	x
6/8/2005	HW	410	0.84	20175	97	148.320	13727545	
6/8/2005	HW	430	0.92	20603	117	148.580	13727584	x
6/8/2005	HW	385	0.69	20605	98	148.320	13727577	x
6/8/2005	LC	320	0.29	20600			13727513	x
6/9/2005	LC	330	0.33	20610			13727548	x
6/9/2005	LC	315	0.25	20609			13727527	x
6/9/2005	HW	450	1.23	20606	94	148.320	13727516	
6/9/2005	LC	345	0.34	20608			13729504	
6/10/2005	LC	295	0.28	20611			13729493	x
6/10/2005	LC	345	0.47	20616			13727512	x
6/10/2005	LC	320	0.39	20613			13729497	x
6/10/2005	LC	195	0.06	20614			13729498	x
6/10/2005	LC	355	0.34	20615			13729500	x
6/10/2005	LC	140	0.03				13729494	
6/11/2005	HW	415	0.97	20621	96	148.320	13727559	x
6/11/2005	LC	450	1.12	20617	114	148.580	13729499	x
6/11/2005	HW	430	1.16	20618	105	148.600	13729491	
6/11/2005	LC	350	0.74	20622	110	148.620	13729501	x
6/11/2005	HW	430	1.31	20620	103	148.600	13729490	x
6/11/2005	LC	290	0.28	20619			13729496	x
6/11/2005	LC	290	0.31	20624			13729503	x
6/13/2005	LC	345	0.54	20627	165	148.620	13729481	x
6/13/2005	LC	315	0.34	20628			13729488	
6/13/2005	LC	325	0.36	20629			13729489	x
6/13/2005	LC	385	0.59	20630	153	148.320	13729484	x
6/13/2005	HW	435	1.15	20626	141	148.580	13729492	x
6/14/2005	HW	400	0.85	20632	138	148.620	13729483	x
6/15/2005	LC	320	0.33	20636			13729502	x
6/15/2005	LC	300	0.29	20640			13727542	
6/15/2005	LC	280	0.21	20639			13729477	
6/15/2005	LC	290	0.22	20638			13729478	x
6/15/2005	LC	280	0.27	20637			13729480	x
6/15/2005	HW	400	0.78	20632	145	148.580	13729482	x
6/15/2005	LC	340	0.47	20633	160	148.600	13729485	x
6/15/2005	LC	345	0.37	20634			13729479	x
6/15/2005	LC	290	0.29	20635			13729476	x
6/15/2005	LC	280	0.23	20641			13729486	
6/16/2005	LC	310	0.3	20643			13729469	
6/16/2005	LC	305	0.28	20647			13729470	x
6/16/2005	LC	280	0.25	20646			15979753	
6/16/2005	LC	310	0.31	20644			13729472	x

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Date	Species	Length	Weight	Floy Tag #	Radio Tag Code	Radio Tag Frequency	PIT Tag #	Pit Tag Detected
6/16/2005	LC	350	0.49	20642	175	148.320	13729475	x
6/16/2005	LC	280	0.24	20645			13729473	x
6/18/2005	LC	360	0.48	20731			13729471	x
6/18/2005	HW	470	1.4	20737			13729466	x
6/18/2005	HW	420	0.96	20725			13729457	x
6/18/2005	LC	350	0.43	20726			13729468	x
6/18/2005	LC	300	0.22	20727			13729461	x
6/18/2005	LC	305	0.29	20728			13729462	x
6/18/2005	LC	280	0.15	20729			13729456	x
6/18/2005	HW	470	1.48	20730			13729474	x
6/18/2005	LC	310	0.32	20732			13729465	x
6/18/2005	LC	310	0.2	20733			13729463	x
6/18/2005	HW	500	1.49	20736			13729458	x
6/18/2005	HW	410	0.83	20738			13729467	x
6/18/2005	LC	310	0.23	20734			13729464	x
6/21/2005	HW	470	1.15	20739			13729455	
6/21/2005	LC	310	0.33	20740			13729452	x
6/21/2005	LC	320	0.36	20741			13729449	
6/21/2005	LC	300	0.27	20742			13729460	x
6/21/2005	LC	300	0.24	20745			13729459	
6/24/2005	LC	300		20749			13729446	x
6/24/2005	HW	460		20746			13729451	x
6/24/2005	HW	420		20747			13729450	
6/24/2005	LC	340		20748			13729448	x
6/24/2005	LC	350		20325			13729447	x

BW = broad whitefish
HW = humpback whitefish
LC = least cisco

APPENDIX 3. —PIT tag numbers from broad whitefish radio tagged at the ADF&G fish wheels in the main channel of the Kuskokwim River.

					Radio Tag		
Date	Species	Length	Weight	Floy Tag #	Code	Frequency	PIT Tag #
9/3/2005	BW	440	1.52	20330	102	148.600	13729443
9/3/2005	BW	435	1.56	20329	176	148.580	13729444
9/3/2005	BW	455	1.37	20328	29	148.620	13729445
9/4/2005	BW	465	1.42	20332	106	149.580	13729440
9/4/2005	BW	435	1.44	20331	157	148.620	13729441
9/5/2005	BW	430	1.2	20338	169	148.620	13729435
9/5/2005	BW	450	1.52	20341	149	148.320	13729432
9/5/2005	BW	430	1.27	20337	100	148.600	13729436
9/5/2005	BW	510	2.08	20339	131	148.600	13729434
9/5/2005	BW	430	1.12	20333	125	148.320	13729439
9/5/2005	BW	515	2.03	20335	151	148.320	13729438
9/5/2005	BW	490	1.85	20336	104	148.600	13729437
9/5/2005	BW	445	1.42	20340	163	148.620	13729433
9/6/2005	BW	455	1.4	20345	179	148.580	13729428
9/6/2005	BW	455	1.46	20346	182	148.580	13729427
9/6/2005	BW	505	1.04	20343	116	148.580	13729429
9/6/2005	BW	430	1.38	20347	178	148.580	13729425
9/6/2005	BW	475	1.27	20348	181	148.580	13729426
9/6/2005	BW	485	1.79	20349	185	148.620	13729424
9/6/2005	BW	425	1.33	20342	177	148.620	13729431
9/6/2005	BW	460	1.49	20344	168	148.620	13729430
9/7/2005	BW	540	2.37	20185	10	148.580	13729415
9/7/2005	BW	450	1.55	20189	0	0.000	15979890
9/7/2005	BW	450	1.55	20189	0	0.000	0
9/7/2005	BW	450	1.55	20189	0	0.000	15979890
9/7/2005	BW	590	1.72	20188	47	148.600	13729416
9/7/2005	BW	445	1.49	20177	183	148.620	13729423
9/7/2005	BW	430	1.19	20186	54	148.620	13729414
9/7/2005	BW	430	1.39	20184	31	148.580	13729417
9/7/2005	BW	460	1.54	20183	25	148.620	13729420
9/7/2005	BW	485	1.55	20182	190	148.580	13729418
9/7/2005	BW	495	1.9	20181	188	148.580	13729421
9/7/2005	BW	435	1.09	20180	186	148.580	13729419
9/7/2005	BW	480	1.67	20179	191	148.580	13729422
9/7/2005	BW	455	1.47	20178	184	148.620	0
9/7/2005	BW	460	1.46	20187	22	148.620	13729413

BW = Broad whitefish