Spawning Location, Run Timing, and Spawning Frequency of Kobuk River Sheefish

Annual Report for Study 08-103

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May 2009

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ABSTRACT

Radiotelemetry methods are currently being used to document spawning locations, describe the timing of upstream and downstream spawning migrations, and estimate the spawning frequency of sheefish in the Kobuk River. In 2008, 150 mature sheefish were captured and radiotagged from 17 July to 30 August. Five aerial tracking surveys were conducted from 3 September to 27 September to locate sheefish in their spawning area. Radio-tagged sheefish were located in the mainstem Kobuk River between the Mauneluk River and Beaver Creek. A pair of stationary tracking stations located just upstream of Kobuk Village and one in the village were used to record downstream migration after spawning. The mean date of downstream passage in 2008 was 22 September. Aerial surveys, boat surveys, and stationary tracking stations will be used to track sheefish radiotagged in 2008, and an additional 150 sheefish to be radiotagged in 2009, through the fall of 2011. This will provide the required information to estimate the timing of the spawning migrations and spawning frequency of sheefish in the Kobuk River.

INTRODUCTION

Sheefish or inconnu *Stenodus leucichthys* are an extremely important resource in the northwest Alaska. Their importance stems from their extensive use as a subsistence food, their value as a commercial resource, and their reputation as a trophy sport fish (Georgette and Loon 1990). The Kobuk River sheefish population supports inriver subsistence and sport fisheries along with winter subsistence and commercial fisheries that occur in Hotham Inlet and Selawik Lake (Figure 1). Kobuk River sheefish are also harvested by subsistence users living in the Selawik NWR (villages of Selawik, Noorvik, and Kiana). Sheefish harvested in Hotham Inlet and Selawik Lake are a mixed-stock comprised of the only two known spawning populations in the region, the Selawik and Kobuk River populations (Alt 1987). The exploitation of these stocks is poorly understood due to incomplete estimates of total annual harvest, unknown stock composition in the mixed-stock winter fisheries, and unknown total exploitable stock abundance. An understanding of these basic elements is necessary to describe the population dynamics of each stock and identify sustainable harvest levels. However, before conducting additional spawning population assessments, a better understanding of spawning locations, run timing, and spawning frequency is required. Estimates of spawning frequency are critical in determining whole population sizes based on spawning population estimates, while spawning locations and estimates of run timing will provide the basis for improving and/or assessing the design of population assessment techniques like mark-recapture experiments or sonar.

OBJECTIVES

The objectives for this multiple year study are to use radiotelemetry techniques to:

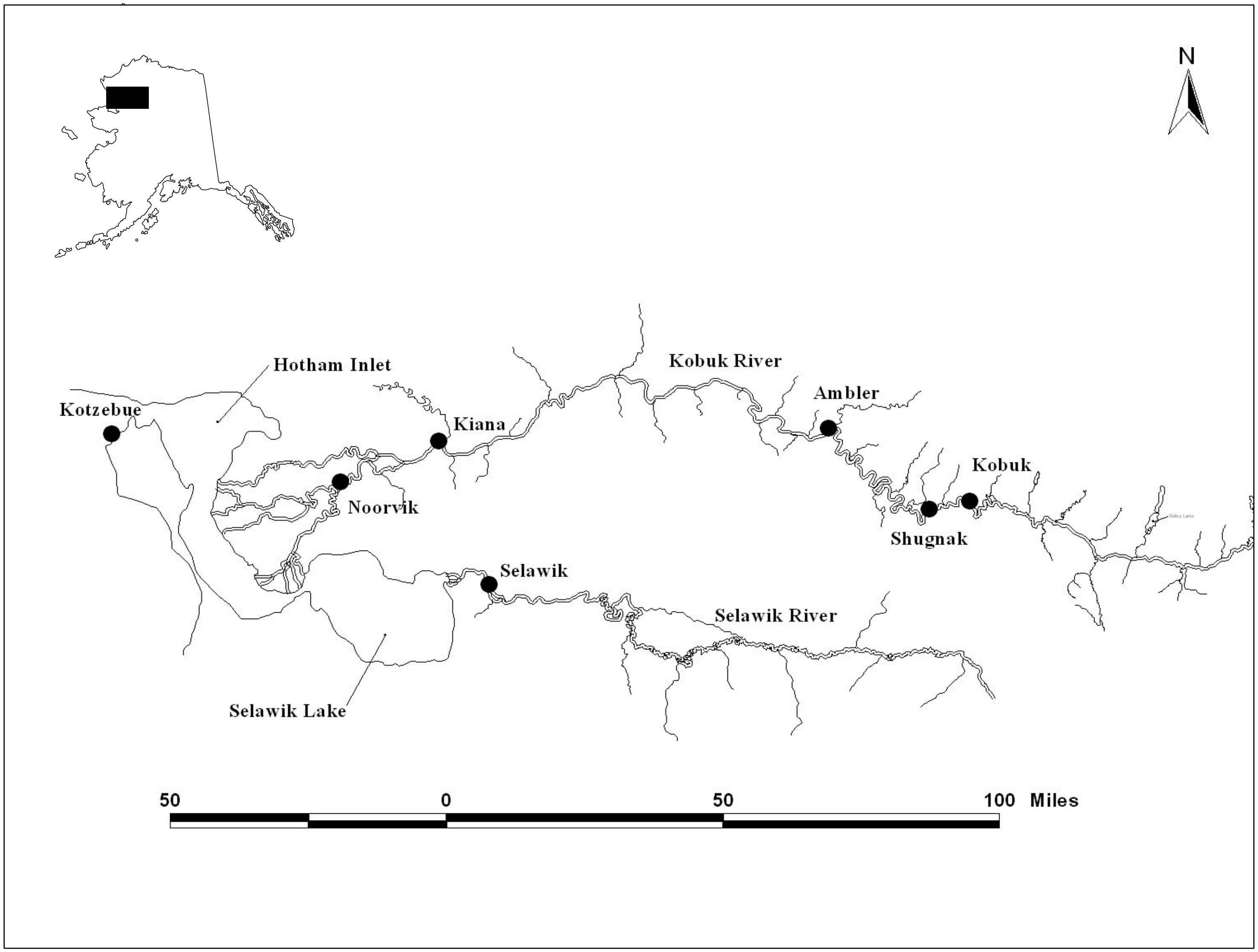

Figure 1.–A map of the Kobuk and Selawik River drainages including Hotham Inlet, Selawik Lake, and surrounding communities.

1. document spawning locations of sheefish within the Kobuk River upstream of the village of Kobuk;
2. describe the timing of spawning migrations (upstream and downstream) for mature sheefish within the Kobuk River drainage;
3. estimate the proportion of the sheefish spawning population in 2008 and 2009 that returns annually to spawning areas upstream of the village of Kobuk from 2009 to 2011 such that each annual proportion is within 10 percentage points 90% of the time; and,

An additional task will be to:

4. identify and characterize different spawning frequency strategies used by adult sheefish in the Kobuk River, estimate the proportion of adults using each strategy, and estimate the potential variation in the proportion of adult sheefish spawning in any given year.

METHODS

Radiotelemetry techniques are currently being used to estimate spawning frequency, document spawning areas, and estimate run timing (upriver and downriver migrations) of mature sheefish in the Kobuk River. Migrating sheefish were captured and radiotagged upstream of the village of Kobuk (Figure 2) to ensure that all fish sampled were mature and bound for upriver spawning areas. The duration of the migratory period past the capture site is known to last ~ 6 weeks from mid-July to late August, with the majority of the run passing during the first three weeks of August. Efforts were made to distribute radio transmitters over the entire duration of the run and in proportion to run strength to guard against potential differences in run-timing related to spawning areas (e.g. upper vs. lower reaches of spawning area) or spawning frequency. Sex-related differences in spawning behavior are more likely because of the higher energetic demands of producing eggs; therefore, attempts were made to distribute radio transmitters equally among males and females. Data related to movements, run-timing, and spawning locations were collected using a combination of aerial tracking surveys and stationary tracking stations.

A three-person crew was used to capture (hook-and-line), sample, and radiotag 150 sheefish. The same methods will be used to radiotag an additional 150 sheefish in 2009. Radio transmitters were surgically implanted following the surgical methods detailed by Brown (2006) and Morris (2003). Radio transmitters were deployed over the course of the upstream spawning migration, and 2 hours of fishing effort was expended at the capture site during each sampling day. For each sheefish radiotagged, data collected included:

1) measurement of length to the nearest 5 mm FL;
2) sex;
3) location (river-kilometer and GPS coordinate); and,
4) date.

The deployment schedule (Table 1) was based on an approximation of the upstream migration past Kobuk village, which is just downstream of the capture site. The first day of the run corresponds to the first day a sheefish was captured.

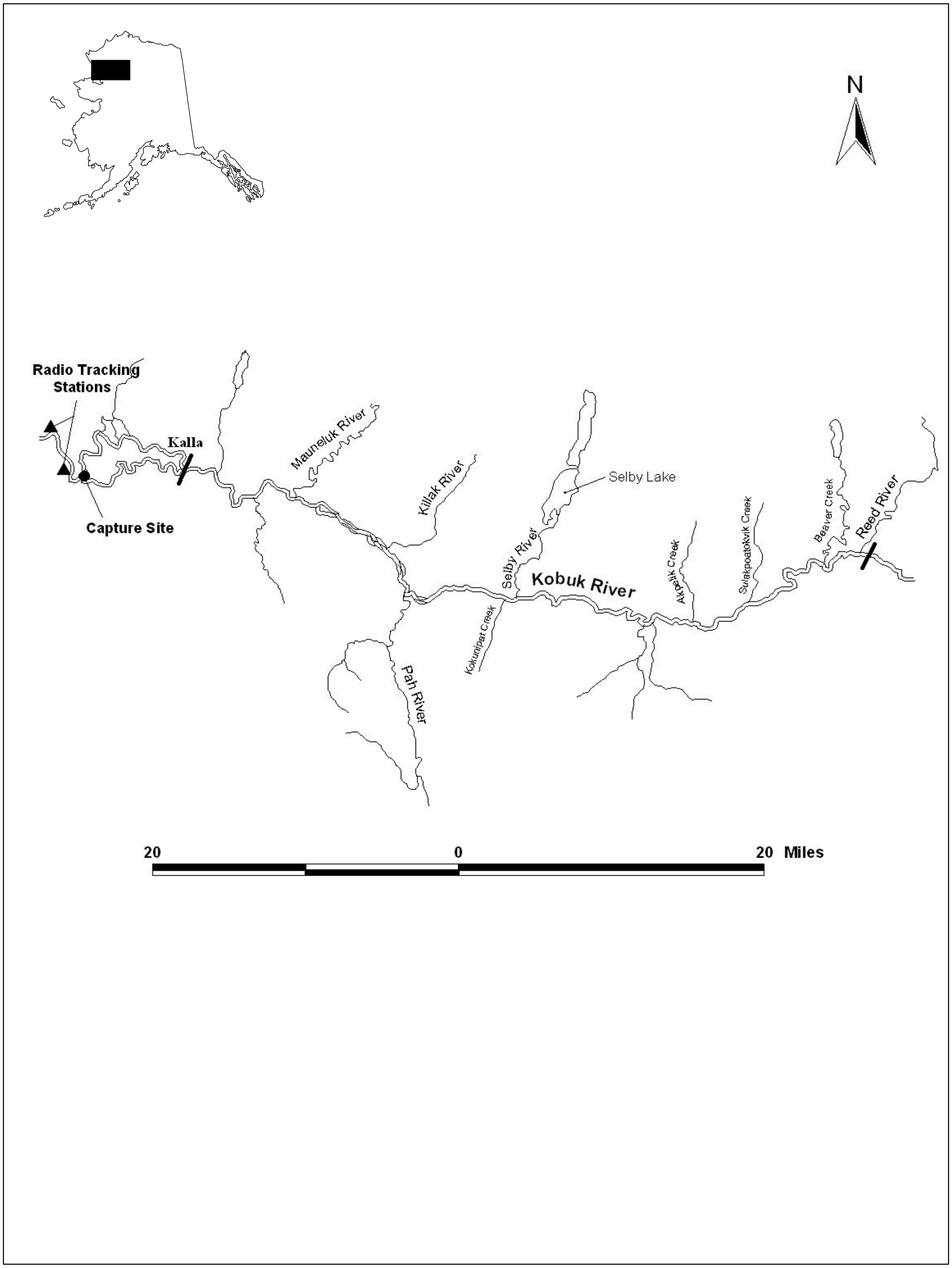

Figure 2.–Map of the Upper Kobuk River demarcating the capture area and tracking station locations.

Table 1.–Number of radio transmitters deployed and scheduled by day of run in 2008 and the scheduled deployment for 2009.

	2008		2009	
Day of Run[a]	Transmitters Deployed	Actual Cumulative	Scheduled Deployment	Scheduled Cumulative
1	1	1	1	1
2	2	3	2	3
3	1	4	2	5
4	3	7	2	7
5	2	9	2	9
6	2	11	2	11
7	2	13	2	13
8	2	15	2	15
9	2	17	2	17
10	2	19	2	19
11	2	21	2	21
12	3	24	3	24
13	3	27	3	27
14	3	30	3	30
15	3	33	3	33
16	3	36	3	36
17	3	39	3	39
18	3	42	3	42
19	3	45	3	45
20	4	49	4	49
21	4	53	4	53
22	4	57	4	57
23	3	60	4	61
24	5	65	4	65
25	4	69	4	69
26	5	74	5	74
27	5	79	5	79
28	5	84	5	84
29	5	89	5	89
30	5	94	5	94
31	5	99	5	99
32	5	104	5	104
33	5	109	4	108
34	4	113	4	112
35	4	117	4	116
36	4	121	4	120
37	4	125	4	124
38	4	129	4	128
39	4	133	4	132
40	4	137	4	136
41	4	141	3	139
42	3	144	3	142
43	6	150	3	145
44			2	147
45			2	149
46			1	150

[a] Day 1 corresponds to the first day the crew catches a sheefish.

Radio transmitters were allocated equally by sex and among three size categories within a sex. Sex was assigned by inspecting external characteristics (i.e. gravidness and presence of swollen vent for females) and/or by inspection of gonads. In cases where sex could not be determined, no radio transmitter was inserted. The length categories were for males: ≤799 mm FL, 800-849 mm FL, and ≥850 mm FL; and for females: ≤899 mm FL, 900-9974 mm FL, ≥975 mm FL.

Implanted radio transmitters operate on one frequency with individual transmitters digitally coded for identification. The transmitters are operational over a four-year period and are programmed to operate for 18 weeks per year (July through mid-November) transmitting 24 hours per day.

Radio-tagged sheefish were located using a combination of stationary tracking stations, aerial surveys, and boat surveys. A total of three tracking stations were erected to ensure that all fish migrating to and from spawning areas were identified. The first station is located in Kobuk (Figure 2) and local students are monitoring and downloading the information as part of their class work. The remaining two stations are located upstream of Kobuk (Figure 2). Each station includes a deep-cycle battery, a solar array, an antenna switch box, a steel housing box, two Yagi antennas, and a Lotek™ SRX 600 data logger. The tracking stations were operational between mid-July and November. The receivers monitored the frequencies continuously and received from both antennas simultaneously. When a signal of sufficient strength was encountered, the receiver would pause for 8 s on each antenna, and then transmitter frequency, transmitter code, signal strength, date, time, and antenna number was recorded on the data logger. Recorded data were downloaded every 7-21 days.

A series of five aerial tracking surveys over the spawning area, currently believed to extend from Kalla to the Reed River (Figure 2), were conducted from a small fixed-wing aircraft throughout the known spawning period (September to early October). Surveys were done in cooperation with the U.S. Fish and Wildlife Service. In addition, a dedicated boat survey of the spawning area was conducted in 2008 as well as opportunistic tracking while navigating the river.

Water temperatures (ºC) during the spawning period until freeze-up were recorded throughout the spawning area with six electronic temperature data loggers. Water temperatures were recorded hourly using optic data loggers with a ten-year battery life. Data loggers were anchored in flowing water in protected areas and exact locations were identified on maps and in latitude and longitude coordinates (decimal degrees, Alaska NAD27 Datum). Data loggers will be retrieved and downloaded during the open water period of 2009.

Data Analysis

Spawning Locations

Multiple aerial and boat surveys were conducted throughout the spawning area to pinpoint spawning locations. Typically, the farthest upstream location of a radio-tagged sheefish was assigned as the spawning location. The entire river reach used for spawning was partitioned into 10 km reaches and each reach was weighted by the proportion of transmitters present to identify patterns in fish densities. The spawning densities among partitions will be examined each year to identify any variation in areas selected for spawning.

Run Timing

An upstream and downstream run-timing profile was constructed for all fish migrating past the tracking stations. Profiles are presented annually and for all years pooled. Contingency table analyses using chi-square tests were performed to explore for independence of migratory timing and sex. For example, the ratio of males to females from the beginning of the downstream migration until the mean date of passage was compared to the ratio from the mean date of passage to the end of the downstream migration. If significant differences existed, run-timing profiles for each sex were constructed. At the completion of the study, a generalized description of migratory patterns along the length of their migration from Hotham Inlet to their spawning area and back (i.e. from mid-June through mid-November) will be developed using data from all aerial surveys and tracking stations.

Run timing profiles were described as time-density functions, where the relative abundance of sheefish located upstream and downstream of the tracking stations during time interval *t* were described by (Mundy 1979):

$$f(t) = \frac{R_t}{\sum_{t=1}^{T} R_t} \quad (1)$$

where:

$f(t)$ = the empirical temporal probability distribution over the total span of the spawning migration (upstream and downstream) for sheefish spawning in the Kobuk River; and,

R_t = the subset of radio-tagged sheefish that migrated past the tracking stations during day *t*.

The mean date of passage ($\bar{t}$) past the tracking stations (upstream and downstream) were estimated as:

$$\bar{t} = \sum_t t\, f(t), \quad (2)$$

the variance of the mean date of passage will be estimated as:

$$Var\left(\bar{t}\right) = \frac{\sum_{t=1}^{T} \left(t - \bar{t}\right)^2 f(t)}{\sum_{t=1}^{T} R_t}. \quad (3)$$

Spawning Frequency

All sheefish radiotagged in 2008 were destined to spawn later that same fall. The first analysis of spawning frequency (fish that spawn in 2008 and 2009 and fish that spawned in 2008, but not in 2009) will not take place until after the 2009 spawning season and a similar analysis will be conducted after the 2010 spawning season.

To facilitate data analysis, all radio-tagged sheefish will be assigned a "fate" (Table 2) every time they are located. The known fates of all radio-tagged sheefish are required to attain unbiased estimates of spawning frequency. Fates are determined from a combination of information collected from tracking stations, aerial and boat tracking surveys, tag returns from harvested fish and from "ground-truthing"

Table 2.–List of possible fates of radio-tagged sheefish in the Kobuk River used to assess spawning frequency.

Fate	Description
Unknown (U)	A fish that was never located because of radio transmitter failure or could never be located after tagging. Fish with this fate will be culled from the data set.
Tagging Mortality (TM)	A fish that dies in response to transmitter implantation prior to the first aerial survey. Fish with this fate will be culled from the data set.
Fishing Mortality (FM)	In a given year, a fish reported harvested in one of the fisheries prior to passing the tracking station near the village of Kobuk. Fish with this fate will not be used for calculating proportions for current and subsequent years it was known to be dead.
Indefinite (I)	A sheefish that was alive the prior year but was never located during a subsequent year. During the years subsequent to its last confirmed location, this fish will be culled from the data set.
Spawner (S)	In a given year, a fish that migrated past the tracking station near Kobuk and either died immediately thereafter due to fishing or natural mortality or completed its upstream and downstream spawning migration. Based on several observations (e.g. four surveys during the summer), a fish that displayed an obvious migration pattern towards the spawning area, but failed to pass the tracking station at Kobuk will also be included.
Non-Spawner (NS)	In a given year, a fish that was located at least once during the summer in the lower portions of the Kobuk or Selawik rivers but did not pass the tracking station at Kobuk, a fish that did not display a obvious migration pattern towards the spawning area, or a fish that was located and judged to be alive (e.g. returned to spawn) in subsequent years.

of radio transmitters with suspect fates (e.g., fish that are harvested and not reported).

Mortality can be easily inferred from lack of movement between trackings because sheefish are highly migratory. In other words, if a sheefish is located twice and fails to move a significant distance (e.g., 10 km) over a period of one month or greater, then it's likely to have died or lost its transmitter. In contrast, assigning a fate of "non-spawner" may be problematic because radio transmitters cannot transmit through the brackish waters of Hotham Inlet where sheefish may seasonally reside for foraging during years where they do not spawn. However, a number of non-spawning sheefish enter the lower portions of the Kobuk River and Selawik Lake during the open-water period to forage (Alt 1987), which will make it possible to locate them from the air. Because natural mortality is thought to be minimal during summer, fish that are located at least once during the summer can be inferred to have survived to the fall, and therefore, would be considered to have been alive at the time of spawning for that year. Non-reporting of harvest by sport fishers would be considered negligible because the chance that a radio-tagged fish is harvested and not reported is very small. Non-reporting of a radio-tagged sheefish in the subsistence fishery is likely to occur and can be easily deduced during aerial surveys. Radio transmitters removed from the water have a sharp increase in their signal strength and range, and a non-reported harvest would be inferred if such a transmitter is located within a village, established fish camp or cabin, either from the air or during boat surveys.

To further aid in accounting for all fates, radio transmitters have return information printed on them and a monetary reward for their return is offered. Local residents have voiced their support for this project and good cooperation and reporting is expected. Informational flyers and posters describing the project and encouraging transmitter returns were posted in all villages where harvests may occur and announcements were made at appropriate stakeholder meetings and over the radio.

Despite all attempts to account for all fates, some ambiguity will inevitably remain for a small number of fish for a given year and at the conclusion of the study. To quantify their added uncertainty in parameter estimates sensitivity analyses will be conducted.

Attaining unbiased estimates of spawning frequency assumes that radiotagging does not affect spawning behavior. However, there is no explicit test for this assumption because we cannot observe the behavior of unhandled fish. Sheefish surviving until the following open water period will be used as evidence that the stress of bearing radio transmitters has been eliminated and spawning-related behavior (run-timing, selection of spawning area, and spawning frequency) was representative of the population.

The proportion of sheefish spawning in a given year and its variance will be calculated (Cochran 1977) as:

$$\hat{p}_t = \frac{x_t}{n_t} \quad (4)$$

$$\hat{V}(\hat{p}_t) = \frac{\hat{p}_t(1 - \hat{p}_t)}{n_t - 1} \quad (5)$$

where:

$\hat{p}_t$ = the proportion of sheefish spawning in year t;

x_t = the number of sheefish with fate (S) in year t; and,

n_t = includes all sheefish with fate (S) and (NS) in year t.

90% confidence intervals around $\hat{p}_t$ will be calculated using exact binomial confidence limits (Cochran 1977).

Spawning Frequency Strategies

If the proportion of sheefish spawning varies significantly from year to year, a more complete characterization of the spawning strategies used will be necessary to model the probability that an adult spawns in a given year. If different distinct patterns are observed (i.e., some fish consistently skip one year between spawning events while others appear to spawn more regularly skipping every 3rd or 4th year) then the individual patterns would be described. The proportions of adults exhibiting each pattern as well as the proportion of sheefish spawning in any given year will be estimated using a Bayesian approach (Gelman et al. 1995). Variance and 90% credibility interval for the proportion of adult sheefish spawning in any given year will be obtained from the resulting posterior distribution.

RESULTS

A total of 150 mature sheefish were captured and surgically implanted with a radio transmitter from 17 July to 30 August 2008. Efforts were made to deploy radio transmitters in proportion to their upstream migration, sex, and length (Figure 3). The ratio of males to females was similar before and after the mean date of passage, which implies both sexes were tagged proportionally to their downstream migration (χ^2=1.17, d.f.=1, p=0.28).

A total of five aerial surveys from 3 September to 30 September located 81 radio-tagged sheefish from Beaver Creek downstream to just below Kalla (Figure 4).

Downstream migration began as early as 10 September and concluded on 15 October (Figure 5). The mean date of passage for the fall downstream migration was 22 September.

DISCUSSION

Previous studies and local knowledge have established that sheefish in the Kobuk River tend to reach spawning areas upstream of Kobuk village by late August (Alt 1987, Taube and Wuttig 1998). Capturing and radio-tagging 150 sheefish just upstream of Kobuk village for approximately six weeks before the end of August ensured that a representative proportion of the spawning population was sampled (Figure 3).

Taube and Wuttig (1998) and Underwood (2000) verified that post-spawning sheefish migrate quickly back to overwintering areas in the lower rivers or estuaries. Estimates of downstream migration after spawning support this finding with a rapid increase in number and compressed timing toward the end of September (Figure 5).

Final estimates of spawning frequency and migration timing can not be completed at this time. Continued radiotagging in 2009 coupled with tracking station and survey data collected through 2011 will be used to determine the fates of all radio-tagged sheefish and their upstream and downstream spawning migration timing. Once the annual fates are determined the final estimates will be calculated.

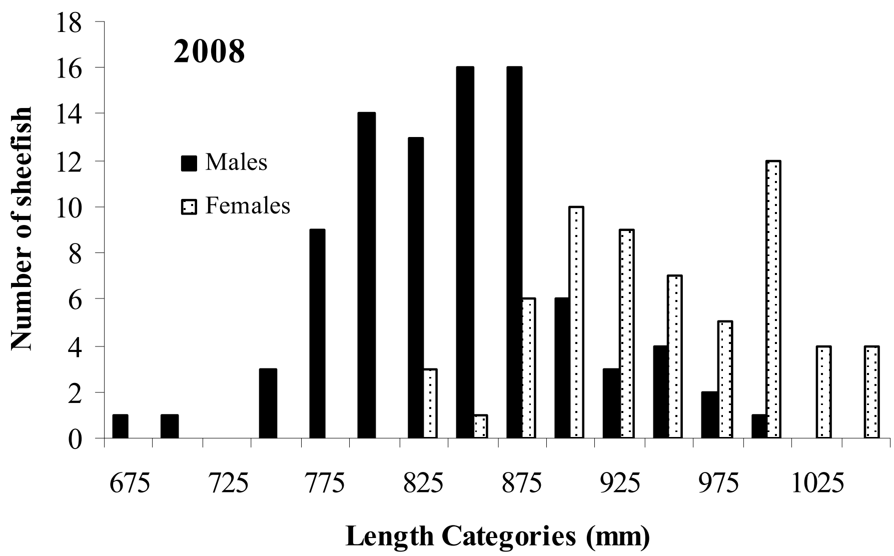

Figure 3.–Number of male and female sheefish radio-tagged by length, 2008.

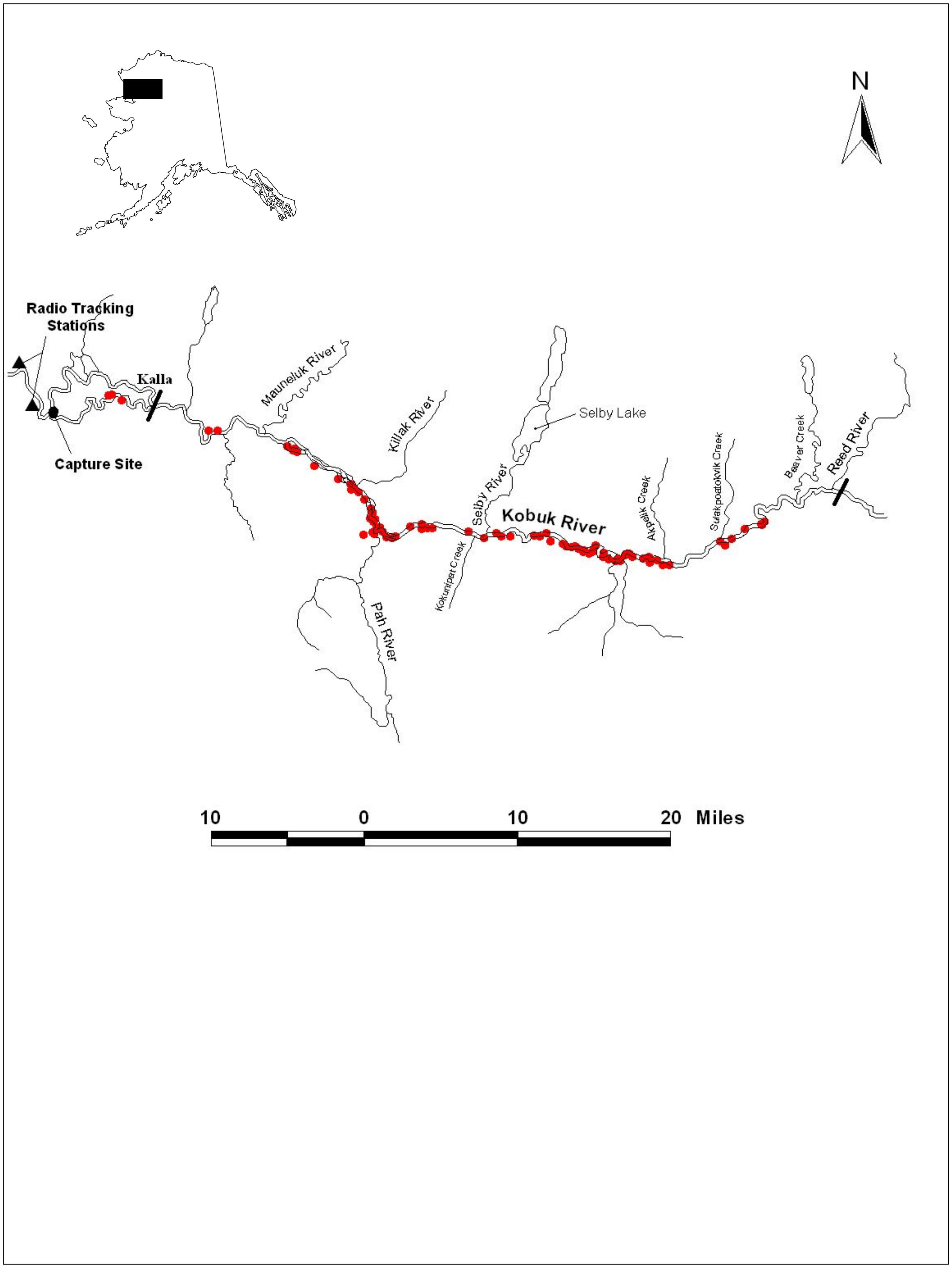

Figure 4.–Map of the spawning area in the Upper Kobuk River demarcating the spawning locations of radio-tagged sheefish, 2008.

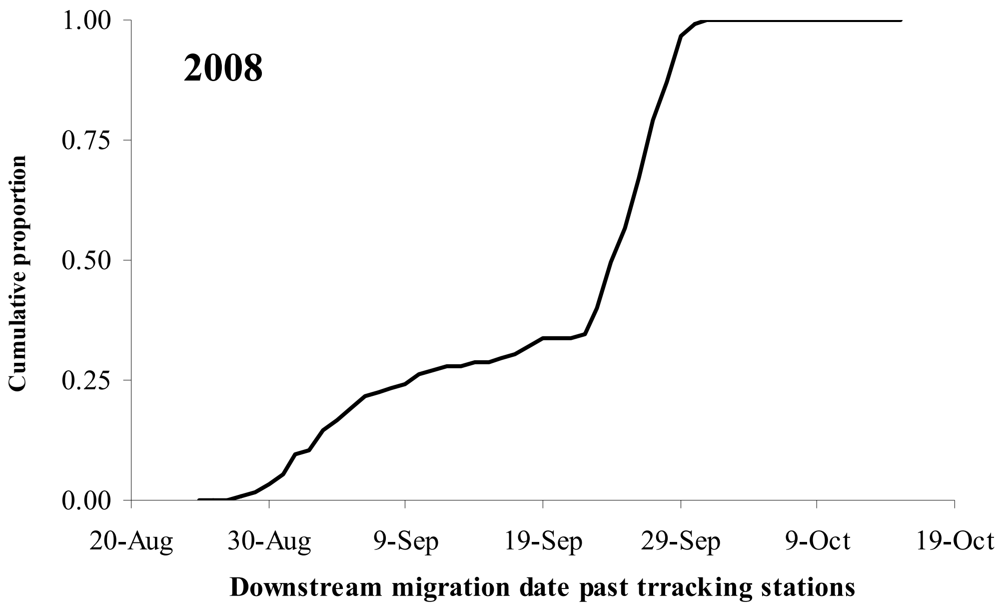

Figure 5.–Downstream migratory run-timing of radio-tagged sheefish past tracking stations located near Kobuk Village, 2008.

ACKNOWLEDGEMENTS

This study is a cooperative project between the Alaska Department of Fish and Game, U.S. Fish and Wildlife Service, and the National Park Service. The U.S. Fish and Wildlife Service, Office of Subsistence Management provided $74,371 in funding under agreement number 701818J685. Additional funding was provided by the US Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-24, Job No. S-3-1(b). The author would like to thank the sampling crew: Heather Scannell, Loren St. Amand, Randy Brown, Bill Carter, David Lorring, and Jason Moyer; whose efforts and dedication led to a successful field season. The author would also like to thank the following people for their logistic support and advice: the Kobuk Traditional Council, Rosie and Elmer Ward, Kenny Barr, Agnes Bernhardt, Shungnak Village Store, Shungnak Village Public Safety Officer, Kiana Village Office, and a countless number of local river residents.

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