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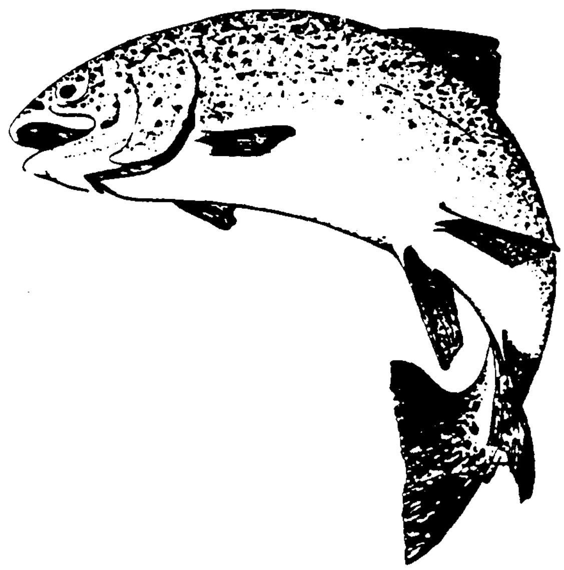
REVIEW OF SHEEFISH *(Stenodus leucichthys)* STUDIES IN ALASKA



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REVIEW OF SHEEFISH *(Stenodus leucichthys)* STUDIES IN ALASKA[1]

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This paper summarizes knowledge obtained through 22 years of study of Alaska sheefish. Nine stocks of sheefish (inconnu) (*Stenodus leucichthys* Guldenstadt) have been described in Alaska from the Kuskokwim River system north to the Kobuk-Selawik River. The Kuskokwim, Lower Yukon, Koyuk, and Kobuk-Selawik River sheefish are estuarine anadromous while resident nonanadromous stocks occur in the Yukon River tributaries of the Nowitna, Minto Flats (Tanana River), Porcupine, Salmon Fork of the Black, and upper Yukon Rivers.

Anadromous sheefish of the Kobuk-Selawik, Lower Yukon, and Kuskokwim Rivers are more abundant and individual fish reach larger maximum sizes than fish of nonanadromous stocks. Minto Flats and Kuskokwim River sheefish grow faster than fish from other areas, reaching 6.4 kilograms and 810 millimeters by age 10. Kobuk-Selawik River fish live considerably longer than fish from other stocks reaching maximum ages of 21 years and maximum weights of 25.5 kilograms. Age at first maturity of Alaska sheefish ranges from a low of age 4 to 8 for males and 7 to 9 for females of the Kuskokwim River stock up to age 7 to 9 for males and 9 to 12 for females of the Kobuk-Selawik stock.

Sheefish generally overwinter in lower reaches of rivers and estuarine waters, migrate upstream in summer to feeding grounds, and migrate further upstream to spawning grounds in the late summer and fall. Migrations of over 1,600 kilometers have been documented. Sheefish spawn in late September and early October at water temperatures of 0-5 degrees Celsius. They are broadcast spawners and spawn only in late afternoon and evening. Numbers of spawners range from 100 in the Chatanika River to 3,700 in the Kobuk River. Spawning grounds have been identified for all major sheefish stocks. Availability of spawning habitat with desired current (2 meters per second), water depth (2 meters), and bottom substrate of differentially sized gravels may be the most critical factor limiting sheefish distribution and abundance.

Adult sheefish are mainly piscivorous and whitefish (*Coregonus* sp.), Arctic lampreys (*Lampetra japonica* Martens), and longnose suckers (*Catostomus catostomus* Forster) are important food items. Feeding sheefish in the upper Yukon and Holitna Rivers seasonally prey heavily on fingerlings of chum salmon (*Oncorhynchus keta* Walbaum), coho salmon (*O. kisutch* Walbaum), and chinook salmon (*O. tshawytscha* Walbaum).

Sheefish are harvested by subsistence, commercial, and recreational users with subsistence harvests exceeding all others. The major commercial fishery (Kotzebue Sound) has a harvest quota of 1,136 kilograms or approximately 3,300 fish yearly. Statewide recreational harvest has ranged from 1,250 to 3,950 fish from 1977-1985.

Sheefish have been experimentally stocked in landlocked lakes and ponds along the road system in the Tanana River drainage. In general, survival of stocked sheefish has been poor. Hatchery rearing techniques for sheefish fingerlings have improved in recent years, however a consistent source of viable eggs and poor growth and survival of stocked fish continue to be the major limitations to a successful large scale enhancement program.

KEY WORDS: sheefish, *Stenodus leucichthys*, stock structure, fisheries, food habits, life history, spawning, migrations.

INTRODUCTION AND BACKGROUND

The sheefish (*Stenodus leucichthys* Guldenstadt) is a long slender silver colored fish. The head is about 25% of standard length and the lower jaw is strong and projecting. The lighter coloration, slender profile and strong extended lower jaw are characteristics used in distinguishing sheefish from the common whitefish species (*Coregonus* sp., *Prosopium* sp.). The sheefish has numerous tiny teeth disposed in velvet-like bands, the maxillary is toothless but the vomer, palatines and tongue each have a band of villiform teeth. The nostrils are double-flapped. The dorsal body surface is somewhat dark, the dorsal and caudal fins are dusky at the margins while the other fins are immaculate. Sheefish in Alaska seldom exceed 10 kg although fish over 26.5 kg have been captured in the Kobuk River. Larger size fish have been reported from Siberia (Wynne-Edwards 1952).

The sheefish is a member of the whitefish subfamily Coregoninae in the family Salmonidae. The species *leucichthys* is now considered the only worldwide member of the genus *Stenodus* (Berg 1932) although Alaskan and Canadian sheefish were originally given species status and named *Stenodus mackenzii* by Evermann and Goldsborough (1907). Later research in Siberia and North America classified the species into three subspecies: *Stenodus leucichthys leucichthys* in the Caspian Sea drainage, *Stenodus leucichthys nelma* in Siberian waters, and *Stenodus leucichthys mackenzii* in Alaska and Canada (Dymond 1943). The Alaskan and Canadian populations were shown to be taxonomically synonymous with the Siberian form and are now classified as *Stenodus leucichthys nelma* (Pallas) (Alt 1969a).

The main meristic characteristics used to separate subspecies have been gill raker and lateral line scale counts (Dymond 1943; Krasikova 1960; Berg 1948). Mean total gill raker counts for Alaskan populations ranged from 19.7 in upper Yukon River fish to 21.0 in Kobuk River fish and lateral line scales ranged from 100-108 (Alt 1967).

The worldwide distribution of sheefish is holarctic, from the White Sea in the U.S.S.R. at 40°E Long. across Siberia, Alaska and Northwestern Canada, 128°W Long., to the Anderson River drainage (Alt 1969a). The species is widely distributed in Siberia but comparatively local in North America. The sheefish is generally confined to river drainages and associated brackish water environments. But, at the east and west extremities of its range, large lake associated populations are found. These lake populations occur in the Great Slave Lake system in Canada and the Caspian Sea in eastern U.S.S.R. In the U.S.S.R., sheefish are present in the great northern rivers from the White Sea eastward and including the drainages of the Ponoy, Onega, Dvina, Mezen, Pechora, Ob, Irtysh, Yenisei, Lena, Vilyui, Indigirka, Kolyma, and Anadyr rivers as well as the Caspian Sea-Volga River drainage. Smith (1957) hypothesized that *Stenodus* originated in the rivers of Siberia, then spread to Alaska during the Bering Sea Land Bridge era and became distributed via brackish water transfer associated with the melting of the Wisconsin stage of glaciation.

In Canada, sheefish occur in the upper Yukon River system to the Teslin Lake system and the Mackenzie River upstream to at least the Muskwa River (Laird River) (Carl et al. 1959; Hatfield et al. 1972). In the Mackenzie system, a landlocked local population is found in the drainage of Great Slave Lake (Fuller 1955). Sheefish are also found in the lower Babbage and Firth rivers and west of the Mackenzie River near Demarcation Point (Kendel et al. 1974), in the Canadian portion of the Porcupine River (Bryan 1973), and a small population is present in the Anderson River (Slastenenko 1958).

In Alaska, sheefish have a limited distribution from the Kuskokwim River system at 60°N Lat. to the Kobuk-Selawik drainage at 67°N Lat. (Figure 1). They are widely distributed in the Yukon River system and a small stock is found in the Koyuk River in Norton Sound. Sheefish are not found in drainages of the North Slope of Alaska. In general, sheefish occupy larger slower moving river systems. The major portion of their life, except for spawning, is spent in this environment. Generally sheefish are not found in lakes in Alaska. They do, however, overwinter in large freshwater inlets and lakes such as Hotham Inlet and Selawik Lake near Kotzebue and occupy stream connected lake systems for summer feeding in the lower Yukon and Kuskokwim Rivers.

Most sheefish in Alaska, as in Siberia and western Canada, are estuarine anadromous, while much smaller numbers belong to local nonanadromous stocks. Sheefish undertake movements or migrations related to feeding, spawning, and overwintering, with estuarine anadromous sheefish undertaking the longest migrations. Kobuk River sheefish migrate 320 km from overwintering to spawning grounds while fish of the lower Yukon stock travel up to 1,600 km. Sheefish in the great Siberian rivers, such as the Ob and Lena, migrate up to 2,400 km to reach spawning grounds (Vork 1948a; Kirilov 1962). At breakup of Alaska's large rivers in May, sheefish migrate upstream from wintering grounds (generally located downstream or in estuarine waters) to feeding areas. For most fish, these migrations are relatively short. However, in tributary streams such as the Holitna, Takotna, and Tatlawiksuk in the Kuskokwim system and the Iditarod, Innoko, and Yuki Rivers and Birch and Beaver Creeks, these migrations exceed several hundred kilometers. Sheefish that will spawn in the fall undertake similar feeding migrations but during summer they continue upstream to spawning grounds. The spawning migration is quite protracted with fish reaching spawning grounds in August and September. Feeding fish migrate back to overwintering areas during August and September while post-spawning sheefish reach overwintering grounds in October through December. After hatching, young of the year sheefish move to lower reaches of rivers and associated estuarine areas for rearing.

Sheefish spawn during the last week of September and the first 2 weeks of October, depending on the location. Spawning grounds for all major Alaskan sheefish stocks have been located. Spawning sites occur in the middle and upper reaches of rivers and all stocks of sheefish spawn in

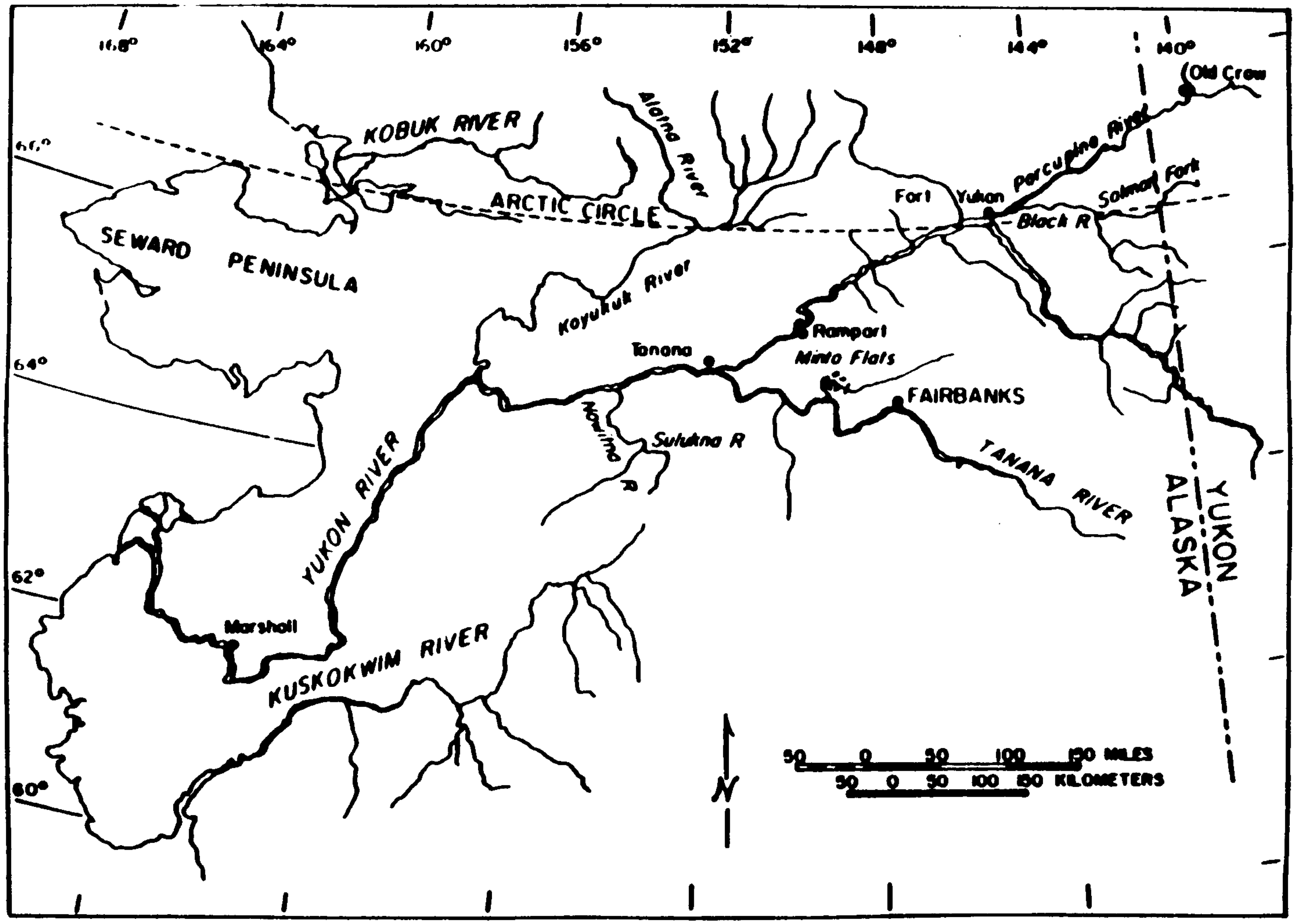

Figure 1. Range of sheefish in Alaska.

very restricted areas. Major spawning locations include the upper Kobuk and upper Selawik Rivers, Koyukuk River near Hughes, Alatna River, main Yukon River near Beaver, Porcupine River near the Coleen River, Upper Chatanika River, and Big River and lower Highpower Creek in the Kuskokwim system.

Sheefish spawn in the evening. Eggs are released near the water surface and sink to the bottom where they lodge between differentially sized gravels. Depending on the stock, sheefish males first mature between age 4 and 9 and females mature between age 7 and 12. At spawning, eggs are 2.5 mm in diameter and comprise 20 to 25% of body weight. A 9.2 kg female from the Kobuk River contained 148,000 eggs while a 20.5 kg female contained 455,000 eggs (Geiger 1969).

Alaska Department of Fish and Game (ADF&G) spawning observations conducted on the Kobuk, Koyukuk, and Kuskokwim Rivers indicate that prespawning sheefish congregate in deep water holding areas in the vicinity of spawning grounds and as spawning time approaches move upstream or downstream to spawning areas. Fish move in small schools at this time and pair up at the onset of spawning. Females release eggs near the surface of the water. Males follow closely behind and underneath the female and immediately fertilize the eggs. Males normally do not come to the surface of the water, although occasionally in the clear Kobuk River males have been observed breaking the water surface behind a female (Alt 1969a). The female first comes to the surface at the upper part of the spawning bar and after the first spawning spurt (each spurt lasts 1-3 seconds) is carried downstream where she returns to the surface to extrude eggs again. Females come to the surface with a loud splash, the tail appears first above the water surface, then the dorsal fin and often a portion of the dorsal surface of the body emerges. With a vigorous writhing of the body, the female skitters across the water, expelling eggs. This movement usually is perpendicular to the direction of current. In most instances the dorsal-ventral body axis is in a vertical plane (dorsal fin straight up), but in some instances the body axis is rotated as much as 120° (in an almost horizontal plane) with the current pressing almost directly on the abdomen. It is not known how many spawning spurts are required to extrude all eggs, but one female was observed coming to the surface six times in one spawning pass. Some fish continue downstream after the first spawning pass, while others swim back upstream close to shore after completing a pass over the spawning bar. Some Russian scientists (e.g. Kirilov 1962) indicate that occasionally two males accompany a female on the spawning run. This behavior was not observed with Alaska sheefish.

Berg (1948) suggested that nonconsecutive spawning is the rule in Siberian rivers and Nikol'skii (1954) indicated that some sheefish spawn at intervals of 3-4 years. Approximately 30% of the Kobuk-Selawik River female sheefish over 700 mm examined during early summer of 1965 contained small eggs (less than 1 mm diameter) and retained eggs from the previous year's spawning. This indicates that many of these sheefish are nonconsecutive spawners. However, tagged sheefish have been recovered on the upper Kobuk River spawning grounds the year after being tagged in the same location, indicating that some sheefish, especially small males, are capable of consecutive spawning.

No information on time of hatching is available for Alaskan sheefish. In the Ob River, U.S.S.R., sheefish eggs had an average incubation period of 182 days and hatched between 15 and 25 April (Vork 1948b). Smolyanov (1960) stated that Kubena River, U.S.S.R. sheefish hatch between 14 and 22 April.

Sheefish grow at a fairly rapid rate with fish of the faster growing Minto Flats and Kuskokwim River stocks reaching 6.4 kg by age 10. The largest sheefish in Alaska (up to 23 kg) are found in the Kobuk River. Fish of nonanadromous stocks seldom reach 10 kg.

Sheefish are piscivorous and feed mainly on lampreys, whitefish, northern pike, longnose suckers, and young salmon. A few instances of cannibalism have been noted. Rearing sheefish feed mainly on insects and plankton but young of the year sheefish have been observed feeding on small fish in the upper Yukon River. Although Kirilov (1962) stated that some sheefish feed during the spawning migration and on the spawning ground, Nikol'skii (1954) reported a cessation of feeding during the spawning period. Vork (1948b) reported that feeding stops completely at the upper reaches of the Ob River near the spawning grounds.

Sheefish taken during the summer in Selawik Lake and lower Selawik River are heavily parasitized by the tapeworm *Proteocephalus exiquus*. Other parasites of Alaska sheefish include: the tapeworms *Sapthebothrudea* sp. and *Cyanthocephalus truncatus*; a nematode, *Cucullanus* sp.; an acanthocephalan, *Neoechinorhyncus rutile*; and external parasites such as the leech, *Pisciola* sp. and the copepod *Salmincola inermis* (Alt 1969a and 1970). Hoffman (1967) lists 21 parasites of sheefish in Siberian waters.

Sheefish have been used for subsistence by Alaska's rural residents for many years. Little commercial utilization occurred prior to the late 1940's when a small scale fishery began at Kotzebue (Wigutoff and Carlson 1950). Recreational fishermen in Alaska and the rest of the world were unaware of either the existence or the high gamefish quality of the sheefish until popular writers such as Dufresne (1946) and other outdoor writers published articles.

Prior to 1960, most scientific information on Alaskan sheefish consisted of short notes on taxonomy, distribution, and descriptions (Jordan and Evermann 1900, Dall 1870, Wilimovsky 1958, Galerman and Craven 1952, Gilbert 1895, Scofield 1899, Smith 1957). In contrast to the paucity of published Alaskan data, Russian scientists had long conducted detailed life history and population dynamics studies of sheefish (Chumayeviskaya-Svetovidova 1930; Titenkov 1951; Berg 1932; Podlesnyi 1941; Smolyanov 1960; Kirilov 1962; Kuznetsov 1932; Kiselevich 1936; Nikolskii 1954; Vork 1937; Bauer 1945; Koneva 1966; Menshikov 1935; Letichevskii 1958; Mikhilov 1958; and Krasikova 1960). Russian research has been conducted on the subspecies *nelma* which occurs over most of Siberia and the nominate subspecies *leucichthys* which is found within the drainage of the Volga-Caspian system.

It was not until 1960 that a directed research program on the biology of sheefish in Alaska was initiated by the University of Alaska. This research dealt with taxonomy and ecology of sheefish in the upper Yukon, Chatanika, and Kobuk-Selawik River drainages (Alt 1965, 1967, 1969a). Subsequently, the Alaska Department of Fish and Game began a study of the Minto Flats sheefish stock (Alt 1968). Between 1967 and 1971, Department research emphasized tag and recovery studies to determine movements and stock status of all major sheefish stocks in Alaska (Alt 1969a, 1970, 1971a, 1972, 1973a; Geiger 1969). This research was conducted on the Kuskokwim, lower Yukon, Koyukuk, and Kobuk-Selawik River drainages and Minto Flats. Concurrent with tagging studies, data were collected on age and growth (Alt 1973a), spawning, food habits, and human utilization of sheefish. With completion of preliminary studies on the major known sheefish stocks in Alaska, research was directed toward sheefish in the middle Yukon and Porcupine River drainages. This three year study provided the first evidence of existence of local stocks within the range of anadromous sheefish of the lower Yukon River (Alt 1973b, 1974, 1975).

After 1974, Department sheefish research efforts were scaled down and conducted in conjunction with cataloging and inventory studies of various waters in western Alaska. In 1977, spawning grounds of the local stock of sheefish in the Salmon Fork of the Black River were located (Alt 1978). Between 1976 and 1977, a study on the Kobuk River spawning sheefish was conducted to compare age-length-weight data with that collected in 1966-1969 (Alt 1979). During 1978-1980, a similar study was conducted on the Holitna River summer feeding fish (Alt 1981). Surveys were conducted on the lower Kobuk and Selawik Rivers and Kotzebue Sound areas in 1978 and 1979 with the objective of locating rearing sheefish (Alt 1980). One of the objectives of a 2 year study of the Innoko River was to determine the stock status of fish found in the lower 480 km of this Yukon River tributary stream (Alt 1982). A population study of Melozitna River sheefish was performed in 1983 (Alt 1984). In September 1984, the spawning grounds of the local Nowitna River sheefish stock were delineated (Alt 1985). In the fall of 1985, a radio tagging project conducted on the Yukon River above Rampart located spawning grounds of the major segment of the anadromous lower Yukon River stock (Alt 1986).

Sheefish enhancement studies began in Alaska in 1967 and have continued to the present. Results of these studies have been reported in ADF&G progress reports and are summarized in a report by Alt and Parks (1987). A sheefish bibliography was published by Alt (1976).

The goal of this report is to summarize all available data on sheefish in Alaska. Most of this information was obtained during 22 years of University of Alaska and Alaska Department of Fish and Game research conducted by the author. Presently the body of sheefish knowledge is spread among scientific papers, federal aid in fish management reports, Department of Fish and Game reports, and other unpublished reports. Information in this report is presented on major life history parameters for each known Alaskan sheefish stock. For the purposes of this paper, a sheefish stock will be defined, as proposed by Ricker (1972), i.e., "the fish spawning in a particular lake or stream (or portion of it) at a particular season, which fish to a substantial degree do not interbreed with any group spawning in a different place, or in the same place, at a different season." In practical terms this will be any group of sheefish that spawn in a particular area and do not mix during spawning with any other group of sheefish.

The common name sheefish is used throughout this report even though the name inconnu has been suggested by the American Fisheries Society Committee on common and scientific names. The fishing public, as well as state and federal resource agencies in Alaska, use the common name sheefish.

MATERIALS AND METHODS

The methods used for collecting, analyzing and reporting data were similar throughout the 22 years of the study. Fish were collected by beach seine, fishwheel, weir, hook and line, and sinking and floating gill nets 20 to 40 meters long and 2 to 3 meters deep with mesh sizes ranging from 1.2 to 10 cm bar mesh. Traditional native made seines and gill nets were often utilized on the Kobuk River. Transportation to study areas was by commercial and charter aircraft, riverboat, and raft. Fairbanks was the main base of operations with Kotzebue, Kobuk, Selawik, Nome, Bethel, Sleetmute, and Rampart occasionally used as field stations. Approximately 48,000 km of river were travelled in the course of this study.

Fish were weighed to the nearest 50 grams, measured to the nearest millimeter, and sex and maturity determined through gross examination of the gonads (Alt 1969a). Fish were aged using scale samples (Alt 1969a). Scales were mounted between two glass slides and annuli were counted using microscopes or microfiche readers. For age and growth studies conducted prior to 1973, fork length at the end of each year of life was back calculated according to the direct proportion method of Van Osten (Alt 1969a). For movement and migration studies, fish were tagged with Petersen, spaghetti, and Floy anchor tags. A $1-$2 tag reward was paid by the Division of Commercial Fisheries for returned tags.

Selawik area subsistence harvest data were collected by interviewing ice fishermen contacted during the April and May ice-fishery. Harvest data for the Kotzebue area, Yukon River, and Kuskokwim River were obtained from the Division of Commercial Fish harvest surveys and probably represent minimum estimates.

Various portions of this research have been published in Biological Papers of the University of Alaska, Annual Reports of Progress - D.J. Federal Aid in Fish Restoration Studies, Transactions of the American Fisheries Society, Journal of the Fisheries Research Board of Canada, Alaska Department of Fish and Game Research Report Series, and various popular magazines and newspapers. Research funding and support has been provided mainly by Federal Aid in Fish Restoration Funds as well as the National Science Foundation, University of Alaska, the Anadromous Fish Fund, and the U.S. Fish and Wildlife Service.

RESULTS AND DISCUSSION

Kobuk River-Selawik Sheefish

Sheefish in the Kotzebue Sound drainages of the Kobuk and Selawik rivers are the best understood of all Alaskan populations of sheefish because of their large size, the important trophy recreational fishery, as well as the traditional subsistence and commercial fisheries directed toward them. Considerable research was conducted on Kobuk-Selawik sheefish during 1964 to 1983. Most detailed spawning information on the species is from observations made on the Kobuk River. The Kobuk and Selawik systems lend themselves to aerial enumeration of spawning fish and the most precise harvest estimates are available from this area.

Stock Status:

Sheefish in the Kotzebue Sound drainages of the Kobuk and Selawik Rivers are considered a single stock with common overwintering grounds and spawning grounds both in the upper Kobuk and upper Selawik Rivers. During tagging studies in 1968 and 1969, recovery efforts were not conducted on the Selawik River spawning grounds to determine if these fish home to spawn. Therefore, the question of whether Kobuk and Selawik sheefish represent separate spawning stocks remains unanswered.

While no recent aerial spawning counts or population estimates are available, observations made during the past 22 years and discussion with local fisherman during the same period indicate that stocks are healthy and abundance probably fluctuates based on year class survival. Other data which support the conclusion that the Kotzebue Sound sheefish stock is healthy include:

1. Annual harvest has not increased since 1965. Recreational harvest levels have increased slightly from 1965 but subsistence and commercial harvest are similar to or lower than past levels. Exploitation rates of Selawik River sheefish (including mature and immature fish) obtained from tag returns was estimated at 8.5%. Kobuk River sheefish exploitation rate (spawners only) was estimated at 24% to 48% (Alt 1970, 1977a);

2. In 1983, a larger proportion of large females was observed on the Kobuk River spawning grounds than had been observed in prior years (9 of 75 fish weighed over 13.7 kg); and

3. Range extensions of Kobuk-Selawik River sheefish have been reported at various times during the past 21 years, especially after 1982. Local residents reported capturing sheefish by hook and line in the Noatak River 64 km upstream from the mouth and near the Noatak River hatchery. A few fish have been captured upstream as far as Noatak village. Ripe female sheefish (10.9 to 13.6 kg) were captured by ADF&G employees in early October near the Noatak hatchery (Peter Robb, ADF&G Noatak Hatchery Manager, pers. comm. 1987). This may indicate that a spawning stock of sheefish is becoming established for the first time in the Noatak River.

Distribution:

Kotzebue Sound sheefish are distributed throughout the nearshore estuarine areas of Kotzebue Sound (Figure 2). The major area of abundance is Hotham Inlet but a few fish occur in the Sheshalik and Krusenstern areas as well as southern Kotzebue Sound, especially during summer. Test netting at various times during the past 10 years has indicated that nearly all sheefish occupying the estuarine environment during summer are immature. Local fishermen from Kotzebue Sound villages report catching small numbers of sheefish near Buckland and Deering in the estuarine environment. No extensive winter sampling has been conducted, so Kotzebue Sound sheefish winter distribution is unclear. Sheefish are occasionally harvested during the winter subsistence tomcod ice fishery near Kotzebue in early winter. By late winter, sheefish move back into the more freshened environment of Hotham Inlet (locally called Kobuk Lake).

Sheefish occur in the various channels and sloughs of the lower Kobuk River. Prespawning fish sometimes ascend the Kobuk River as far upstream as the mouth of Reed River but in general the area upstream of the Selby River is the upper limit of distribution. Test netting in tributary streams and discussions with area residents indicate that sheefish do not enter tributary streams of the Kobuk.

In the Selawik River system sheefish are found in Selawik Lake, Inland Lake, Middle Lake, Tuklomarak Lake, Tuklomarak River, Fox River, and the main Selawik River upstream of the mouth of Ingruksukruk Creek. The extensive slough system in the area near Selawik is utilized by sheefish, although they are seldom found in other small lakes associated with these sloughs (Alt 1980). Sheefish, as a rule, do not ascend Selawik River tributaries. They have been captured a short distance up the Tagagawik River but sheefish apparently do not spawn in this tributary.

Rearing sheefish have never been found in rivers where sheefish spawn. The only Kobuk-Selawik stock rearing sheefish that have been found were in the estuarine environment of Kotzebue Sound (Figure 2). Sheefish age 3 and older are very abundant in Hotham Inlet, the lower Kobuk River, Selawik Lake and the associated slough environment (Alt 1979, 1980).

Movements:

Kobuk and Selawik River sheefish are considered estuarine anadromous or amphidromous. Tagging studies conducted between 1961-1974 on overwintering, feeding, and spawning fish revealed that Selawik Lake is an important overwintering and feeding area for fish spawning in both the Kobuk and Selawik Rivers. Some movement of sheefish between Selawik Lake and Hotham Inlet has been documented (Alt 1977b). Although no fish were tagged in Hotham Inlet, the recovery there of fish tagged on both the Kobuk and Selawik River spawning grounds suggests that it is also an important overwintering area.

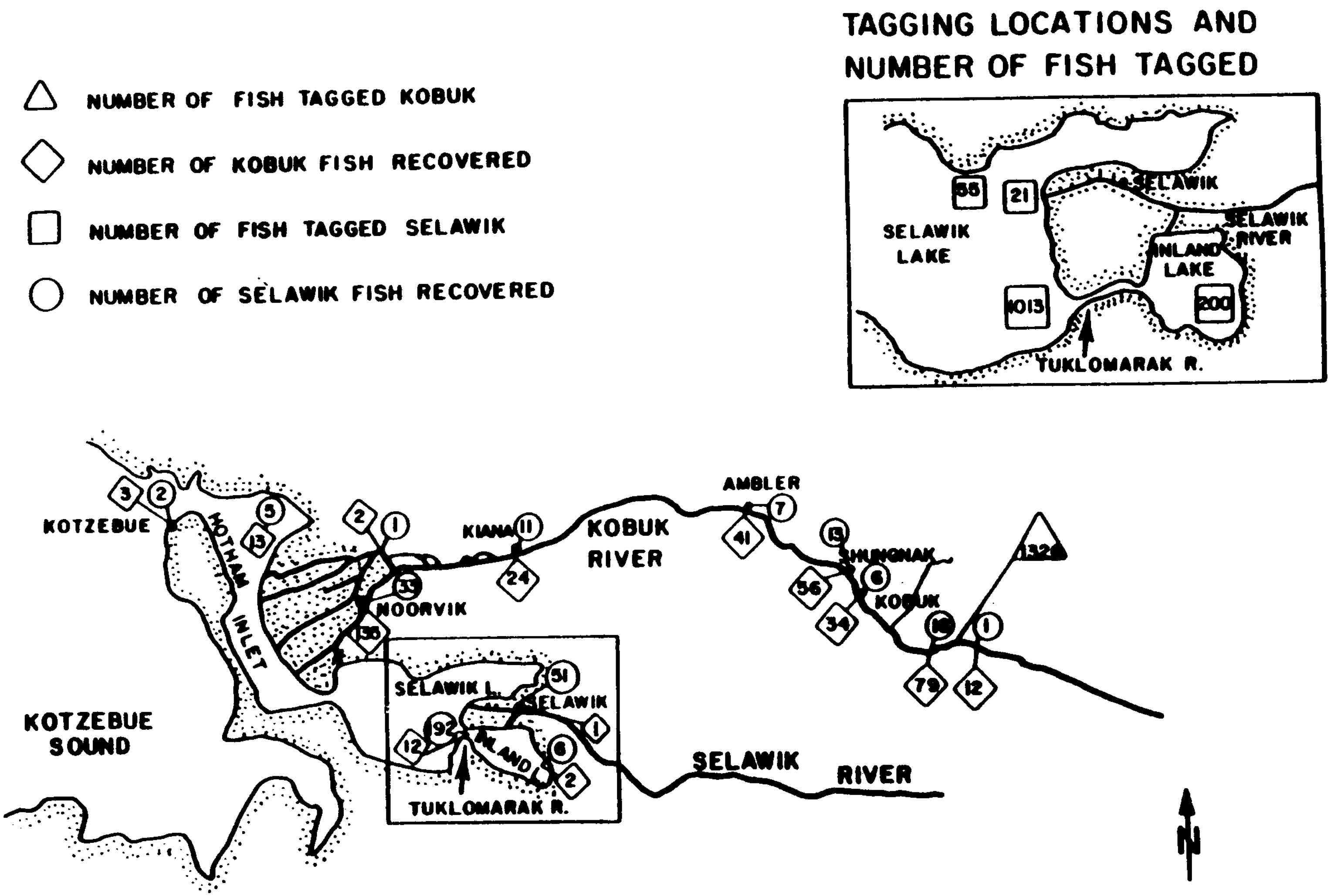

Figure 2. Tag and recovery locations of Kobuk-Selawik River sheefish, 1967-1974.

During the tagging study (1967-1971), 1,326 Kobuk River sheefish were tagged on the spawning grounds above Kalla in September. By 1974, 414 fish (31%) had been recovered, including 281 fish captured during the postspawning downstream migration during October and November of the same year as tagged (Alt 1977a). A high percentage of tags were recovered in the same year as tagged (Table 1). All these fish were tagged as prespawners, and nearly all recoveries were made on the postspawning migration by villagers living downstream of the spawning grounds. In 1969, the estimated exploitation rate during the downstream migration was 42.7%. This high exploitation rate estimate may have been an artifact of tagging stress. Village subsistence fishermen mentioned that tagged fish were swimming erratically, close to shore, and were easily caught in gill nets. Tag returns from the five villages along the Kobuk River indicate that sheefish undertake a fairly fast downstream migration to the villages of Kiana and Noorvik after spawning, then a slower migration to wintering areas farther downstream. Of 134 wintering ground recoveries of fish tagged on the Kobuk River, 103 were recovered on the Kobuk River in subsequent years, 16 were recovered in the Hotham Inlet-Kotzebue Sound area, and 15 were recovered in the Selawik area.

Tag recoveries from the five villages along the Kobuk River and on the spawning grounds provided specific information on the upstream spawning migration (Alt 1973a). After ice breakup in the Kobuk River, prespawning fish enter the lower Kobuk River. Riley, Melville, Lewis Rich, and Mukuksok Channels are the main migration routes into the Kobuk River, with other mouths of the river serving as lesser migration routes. Mukuksok Channel empties into Selawik Lake and sheefish that overwinter in Selawik Lake and spawn in the Kobuk River migrate up this channel. A fairly fast upstream migration to Noorvik and Kiana is indicated. Fish reach Noorvik in early June, Kiana during mid-late June, Ambler in July, and Shungnak and Kobuk in July and August (Figure 2). Fish arrive in the vicinity of the spawning ground in late July, August, and early September. As fish approach Ambler the migration slows and fish disperse. After spawning in late September, there is a rapid downstream migration with fish reaching Kiana and Noorvik by mid-October. During the tagging study, subsistence gill nets set under the ice at Noorvik and Kiana caught large numbers of tagged postspawning sheefish as well as nonspawning sheefish from mid-October to mid-November. Postspawning fish generally reached overwintering areas in Selawik Lake and Hotham Inlet by late December.

Immature and nonconsecutive spawning sheefish move into the estuarine waters of Kotzebue Sound, and into the lower Kobuk River as far upstream as 80 km above Kiana for summer feeding. During the sheefish study, only one nonspawning fish was found in the vicinity of the spawning grounds.

In the Selawik area, 1,289 fish were tagged in June of 1968 and 1969. These were mostly immature and nonconsecutive spawning fish. Fish were tagged mainly in Selawik Lake at the mouth of the Tuklomarak River, but some fish were also tagged in the Inland Lake Selawik River man-made channel, Selawik Lake, and the mouth of Selawik River (Figure 2). By 1974, 346 of the Selawik tagged fish had been recovered, including 249

Table 1. Sheefish tag-recovery summary, Kobuk River, 1966-1969.

Tagged		Recovered			
Year	Number	Year	Number	Percent	Cumulative Percent
1966	40	1966	4	10.0	10.0
		1967	7	17.5	27.5
		1968	4	10.0	37.5
		1969	0	0.0	37.5
1967	116	1967	19	16.4	16.4
		1968	20	17.2	33.6
		1969	7	6.0	39.6
1968	334	1968	95	28.4	28.4
		1969	16	4.8	33.2
1969	279	1969	119	42.7	42.7
Total	769		291	37.8	37.8

(72%) in the Selawik area, 90 (26%) in the Kobuk River, and 7 (2%) in the Kotzebue Hotham Inlet area.

During their upstream migration, Selawik River prespawning fish reach the spawning grounds via the Tuklomarak River-Tuklomarak Lake-Fox River-Inland Lake route; or via Middle Lake to Inland Lake then through the man-made channel to the Selawik River; or by entering the Selawik River directly (Alt 1969a, 1980). Selawik residents capture both prespawning and feeding fish near Selawik village soon after spring breakup. Little information is available on the run timing of spawners up the Selawik River, but test netting results and discussions with local residents indicate prespawners have moved upstream of Selawik and the entrance of the Inland Lake man-made channel into Selawik River by late June. Prespawning sheefish are present at the mouth of the Tagagawik River by late July and August and begin arriving in the vicinity of the spawning grounds, approximately 200 km up the Selawik River, by August and September. After spawning, the fish move down river and begin feeding near Selawik village. Postspawning fish begin to reach Selawik village by late October and, in some years, Selawik residents catch spent fish as late as early January.

Immature and nonconsecutive spawning adult sheefish move into summer feeding areas in nearshore Selawik Lake and the lower Selawik River and the extensive lake and slough systems associated with Selawik and Inland Lakes. A definite fall immigration of these fish was noted beginning in early September 1974. Winter movements of sheefish in Selawik Lake occur in response to movements of prey items (*Coregonus* sp., *Mesidotea entenon*, and *Mysis relicta*). Movements of sheefish fry have not been documented and no fry have been captured during summer in the main rivers. It is suspected that fry are carried by the spring floods to the lower river where they make their way to brackish water as Kirilov (1962) reported for Siberian Rivers. Age 2 and 3 sheefish have been captured during sampling in estuarine waters of Kotzebue Sound, but no young of the year fish have been captured.

Spawning:

The Alaska Department of Fish and Game has conducted counts of spawning sheefish in index areas of the Kobuk and Selawik Rivers (Table 2). The Kobuk River index area extended from Kalla (36 km upstream of Kobuk village) to the mouth of Beaver Creek, and the Selawik River index area extended from the mouth of Ekiek Creek to 10 km upstream of Ingruksukruk Creek. Aerial spawning index counts on the Kobuk River between 1966 and 1979 have ranged from 1,025 fish in 1967 to 8,166 spawning fish in 1971 (Table 2). The 1966 and 1967 counts are thought to be low because aerial observers misidentified a large school of up to 2,000 sheefish as whitefish. Total counts of spawning sheefish on the Selawik River were 1,500 and 1,200 fish in 1968 and 1971, respectively. The greatest spawning concentrations of sheefish in the Kobuk River were located downstream of the Mauneluk River upstream to the Selby River. On the Selawik River, the greatest spawning concentrations were in the vicinity of Ingruksukruk Creek. Because of difficulty in aerially enumerating fish in lower reaches of both index areas, and since some spawners are still migrating upstream to spawning grounds, aerial surveys should be

Table 2. Aerial survey counts of spawning sheefish in the Kobuk and Selawik Rivers 1966-79. Counts were not conducted between 1972 and 1978.

Year	Date	Sheefish Counted	
		Kobuk River	Selawik River
1966	5 Sept	1,200	
1967	22 Sept	1,025	
1968	early Sept	4,973	1,243
1969	early Sept	3,654	
1970	6 Sept	3,220	
1971	30 Aug	8,166	1,105
1979	12 Sept	2,824	

considered minimum abundance estimates. For comparative purposes, a Petersen mark recapture abundance estimate of Kobuk River spawning fish was performed in 1970. Fish were tagged on the spawning grounds and the recovery effort took place before fish reached the mouth of the Kobuk River on the post-spawning migration. Thirty-two of 124 tagged fish (25.8%) were recovered. This provided an estimate of 7,130 fish while the aerial count in the same year provided a count of only 3,220 fish (Alt 1971a).

Kobuk River sheefish spawn the last week of September over gravel bars located from above Kalla to slightly upstream of the Selby River mouth (Alt 1969a). Locations of spawning areas change with time and with physical changes in the river. Prior to 1965, much spawning occurred in the vicinity of Kalla. No spawning has been observed near traditional areas at this site since 1965. Since the late 1970's, spawning counts and observations have not been conducted. However, aerial overflights, reports of recreational and subsistence fishermen, and personal observations indicate that prespawning concentrations of sheefish are shifting upriver to the area below the Mauneluk River and to areas above Selby River possibly as far upstream as Beaver Creek.

Surveys of the Kobuk River spawning grounds were performed in 1965 and 1966. Most spawning ground observations were conducted off Harvey's Bar, 45 km above Kobuk, and a bar 38 km above Kobuk during 1965 and 1966 (Alt 1969a). Sheefish spawned only in late afternoon and evening with spawning in 1965 and 1966 beginning as early as 1545 hours on an overcast day but generally not beginning until after 1700 hours. Peak of spawning activity was around 1800 hours and spawning each day was completed by 2200 hours. Time of spawning in both 1965 and 1966 was similar even though water temperatures in 1966 were 3 to 4°C warmer than in 1965. In 1965, water temperature during spawning ranged from 1.4 to 4.4°C while in 1966 it ranged from 4.4 to 4.6°C (Alt 1969b). In 1965, the peak of spawning occurred at water temperatures between 2.6 and 3.2°C.

Spawning occurred in the relatively swift main current, both where it moved along the cut bank and also in the center of the channel. No spawning was observed over gravel bars on the inside curve of the river in slower current. Water depth at spawning sites was between 1.8 and 2.7 m in 1965 and between 1.2 and 2.4 m in 1966. Major spawning activity took place in water from 1.5 to 1.8 m deep. Optimum spawning substrate was composed of differentially sized coarse gravel (25 to 100 mm) with no silt and some sand present. Some spawning occurred over uniformly sized gravel and twice fish were observed spawning over a 50% sand bottom. In spawning areas the moderately swift current keeps the bottom silt free, and it appears that the differentially sized gravel is a prerequisite to insure lodging of the eggs.

No on-site spawning surveys were conducted on the Selawik River, but based on the number of river miles containing suitable spawning gravel (40 km), and the much smaller size of the Selawik River, it appears that considerably more spawning habitat is available on the Kobuk River. The proper combination of water depth, velocity, and bottom composition is found over approximately 100 km of the Kobuk River.

Lower Yukon River Anadromous Sheefish

The most abundant stocks of sheefish in Alaska occur in the lower Yukon River, Koyukuk River, and in the mainstem middle Yukon River (Alt 1975, 1977b). These fish also undertake the longest migrations of any sheefish in Alaska to reach spawning areas in the Koyukuk River and middle Yukon River near Beaver. ADF&G studies of lower Yukon River anadromous sheefish have occurred since 1967.

Stock Status:

Yukon River tagging studies conducted during 1967-69 and 1972-74 provided evidence that two stocks of lower Yukon River anadromous sheefish exist. Ninety-six fish were tagged on Koyukuk and Alatna River spawning grounds in 1967 and 1968. Tag recoveries were made along the Koyukuk River and in the Yukon River (Alt 1977a). None of these tags were ever recovered in the Yukon River upstream of the mouth of the Koyukuk River. Thus it is believed that the Koyukuk River spawning segment homes to spawn and therefore represents a separate stock. Likewise, none of the fish tagged on middle Yukon River spawning migration routes in the Rampart area were ever recaptured in the Koyukuk-Alatna system. Fish tagged in the lower Yukon River have been recovered in both the Koyukuk and the middle Yukon River (55 of 439 tagged fish were recovered) (Alt 1977a). Few of the 459 prespawning fish tagged at Rampart or at 19 Mile Research site above Rampart have ever been recovered and it is believed that many of these fish perished from tagging stress (Alt 1975). In 1973, electrophoretic analysis of sheefish tissue was conducted on fish from Koyukuk River and middle Yukon River spawning grounds as well as fish from the upper Yukon River stock. Results indicated little evidence either for or against stock differences (Alt 1974).

The stock status of sheefish found at the mouth of Hess Creek, the Ray, Dall, and Hodzana Rivers, and at various areas of the middle Yukon River during summer and fall is still unclear. No spawning grounds for these fish have been located despite surveys of the Tozitna, Ray, Dall, Hodzana, and Chandalar Rivers, and Beaver and Hess Creeks. Alt (1975) tagged fish at the mouths of these streams (1972-1974) and concluded that they could belong to the lower Yukon River anadromous stock or represent separate spawning stocks. Evidence supporting the former conclusion is:

1. Growth rates are similar to anadromous fish (Alt 1973a, 1974);
2. Taxonomic characteristics are similar to anadromous fish ; and,
3. Sheefish tagged at tributary stream are absent in fall samples in these areas. A possible explanation for this is that prespawning adults may have already joined the migration to spawning grounds in the main Yukon River.

Evidence supporting the conclusion that these fish represent a separate stock or stocks includes:

1. Sheefish tagged at the mouths of tributary streams have never been recaptured in the lower Yukon River; and

2. Large numbers of sheefish are present near the mouths of tributary streams immediately after breakup, indicating that they overwintered in the middle rather than the lower Yukon.

Sheefish captured at river mouths farther downstream in the Yukon appear to be lower Yukon anadromous fish. For example, sheefish tagged near Shageluk Eddy on the lower Innoko River were recovered in the main middle Yukon River in July and August of the same year as tagged (Figure 3). This indicates that prespawning Innoko River sheefish are part of the anadromous lower Yukon River population (Alt 1983).

Distribution:

Sheefish of the anadromous lower Yukon River stocks are distributed from the estuarine environment of the Bering Sea throughout the extensive lake and slough system of the lower Yukon River, the lower reaches of tributary rivers such as the Innoko, Anvik, Bonasila, Yuki, Rodo, Melozitna, Tozitna, Koyukuk, Alatna, and the main Yukon River to Ft. Yukon. They do not enter the Tanana River. Sheefish found at the mouths of tributary streams such as Dall, Ray, and Hodzana Rivers and Hess, Beaver, and Birch Creeks during summer are probably lower Yukon River anadromous fish. Lower Yukon sheefish are also found in the Koyukuk River upstream as far as Allakaket and up the Alatna River as far as 5 km above the mouth of Siruk Creek (Alt 1969a and 1977a). Allakaket residents report occasional sheefish catches in the lower section of the South Fork Koyukuk River and in the main Koyukuk River a few miles above Allakaket (Alt 1986).

Movements:

Feeding and nonspawning sheefish reach overwintering grounds in the lower Yukon River by late October (Crawford 1979). Some of these fish move to the estuarine environment during winter and others remain in the lower Yukon River. Postspawning sheefish reach the lower Yukon River by November. Most tag returns of postspawning fish in December are received from subsistence fishermen in the lower 500 km of the Yukon River. The pattern of catches and tag returns indicates that overwintering grounds are located in the lower 350 km of the Yukon River and in estuarine areas off the Yukon River mouth. Postspawning fish generally do not reach the ocean until January or February. It was previously thought that spent fish did not migrate to the Yukon River mouth. However, recovery of a postspawning radio tagged fish (tagged on the spawning grounds 32 km downstream from Ft. Yukon on 15 October 1986) below Emmonak in the main Yukon River on 15 March 1986 demonstrated that at least some postspawning sheefish reach brackish water (Alt 1986). Even though suitable overwintering areas exist in the main Yukon River above Tanana, there have been no reports of sheefish captured there during winter, nor have spent sheefish been captured during summer test netting in the middle Yukon River. However, immature fish and individuals that would spawn the following fall have been captured at mouths of Yukon tributaries such as the Dall, Ray, Koyukuk Rivers and Hess Creek immediately after breakup which indicates that they had overwintered in the middle Yukon River.

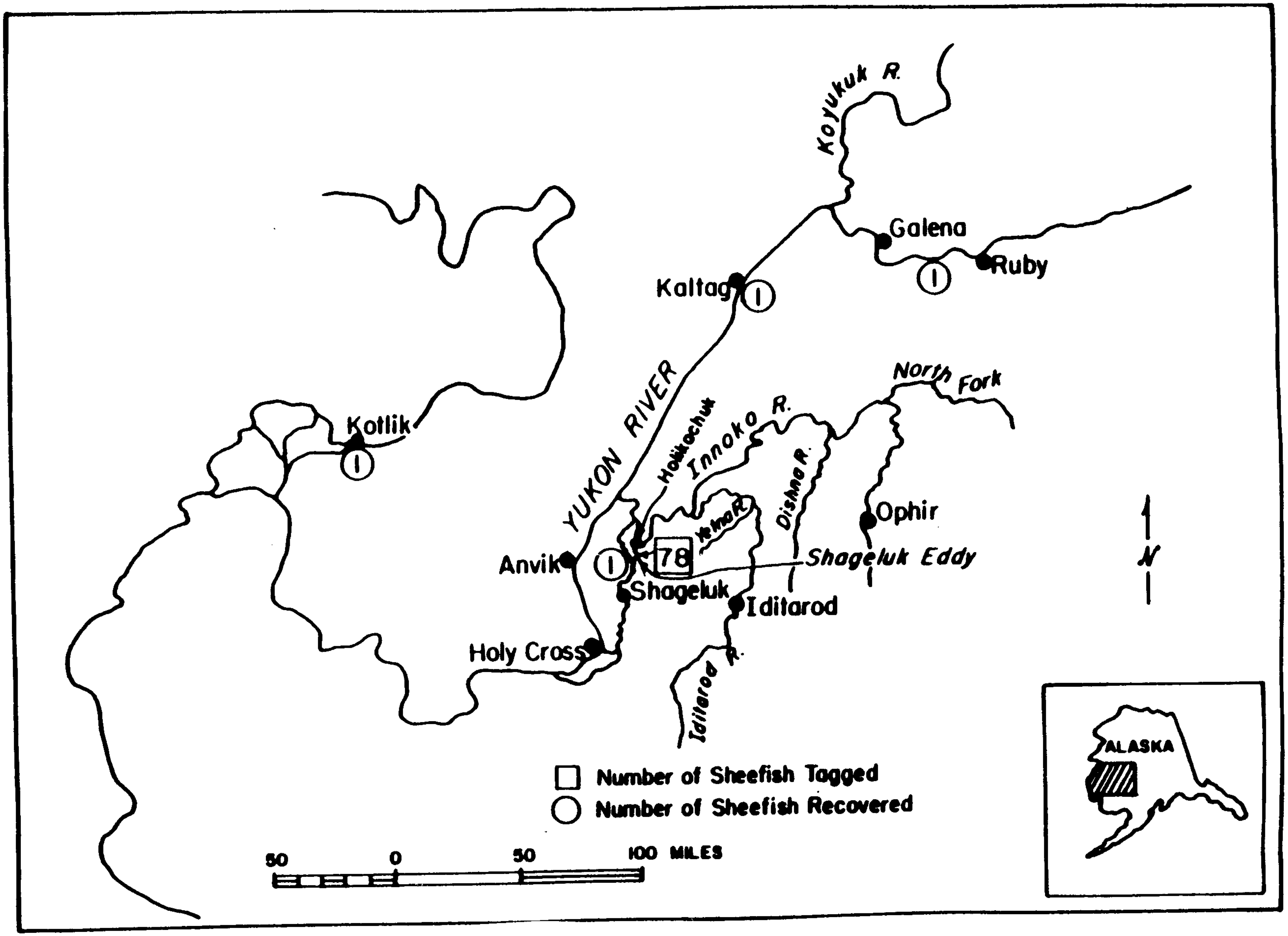

Figure 3. Tag and recovery locations of sheefish tagged at Shageluk Eddy, 1981-1982.

Lower Yukon River sheefish undertake summer and fall feeding migrations. Sheefish that have overwintered in the middle Yukon River migrate to mouths of tributary streams to feed soon after breakup. Sheefish that will spawn in the fall cease feeding by mid-summer and join the upstream migration of prespawning sheefish in the Yukon River. In the lower Yukon River, migrations of feeding sheefish into lake and slough systems occur after spring breakup and during late fall. Crawford (1979) reported large numbers of immature sheefish leaving Nanvaranak Slough in the lower Yukon drainage in late November. These fish probably represent a summer feeding concentration in Nanvaranak Lake. Crawford's observations and those of local lower Yukon River subsistence fishermen indicate a gradual migration of feeding fish from the lakes and sloughs of the lower Yukon River and from farther up the Yukon River into the estuarine environment of the Bering Sea. This movement is most concentrated through the North Mouth of the Yukon River. In 1978, 83% of the sheefish subsistence harvest was taken in October and November during this winter feeding migration to the ocean (Crawford 1979). A migration of these fish upstream from salt water has been observed in May prior to breakup. These fish are mainly prespawners and are migrating to summer feeding areas in the Yukon River drainage.

The upstream migration of spawning sheefish from the lower Yukon precedes the chinook salmon migration by at least a week. In 1974, peak sheefish catches during tagging efforts at Marshall (280 km upstream on the Yukon River) occurred during the last 2 days of May. Eighty-five percent of the 265 fish captured were prespawners (Alt 1975). Upstream of Marshall, the spawning migration slows. Many of the upstream migrants spend the early summer holding or feeding in sloughs, tributary streams, or in the main Yukon River and the migration is not a definable run until late August when fish reach Tanana on the Yukon River or until early September when fish reach Hughes on the Koyukuk River.

By late May, feeding sheefish have moved as far upstream as the lower 160 km of the Innoko River and 90 km up the Iditarod River (Alt 1981, 1982). During tagging studies on the Innoko River, prespawning sheefish were captured as early as 24 May (Alt 1983). Of 31 fish examined in May-June 1981, 80% of males and 10% of females were prespawners. In June of 1982, 22 sheefish were captured on the Innoko River, of which 94% of males and 75% of females were prespawners. During sampling in August and September, only one fish out of 10 was a prespawner, indicating that spawning fish had left to join the Yukon River spawning run. The higher percentage of males captured in the Innoko River may indicate that more females continue directly up the Yukon, rather than making a feeding detour in the Innoko River. Consistently more females than males have been captured during test netting in various sections of the Yukon River in the summer during the past 15 years.

Tagging studies and surveys on the Melozitna River in 1982 and 1983 indicated that sheefish feeding in the lower Melozitna River join the lower Yukon River spawning migration in late summer. By late July 1978 and early August 1980, most sheefish had already left the Melozitna River and traveled farther up the Yukon (Alt 1979, 1981, 1984). Similarly, it is believed that prespawning sheefish captured during the summer at mouths of other tributary streams (e.g., Tozitna, Yuki, Ray, Dall, and Hodzana Rivers and Hess and Beaver Creeks) will enter the mainstream Yukon River spawning run as fall approaches.

In late August and throughout September, the sheefish spawning migration takes on the appearance of a definite run. Subsistence fishermen report that the Koyukuk River spawning run peaks in the vicinity of Hughes in early September and at Allakaket in mid-September. Koyukuk migrating sheefish reach the Alatna River spawning grounds in mid to late September. During gill net tagging studies on the Alatna River in September 1968, peak catches occurred on 23 September. Fish were still migrating upstream into the lower Alatna on 24 September and sheefish also destined for the Alatna River were observed in the Koyukuk River downstream from Allakaket on 25 September (Alt 1969b).

Yukon River anadromous sheefish that spawn above the Dalton Highway bridge appear in subsistence gill net and fish wheel catches near Tanana Village in late August and early September and in the Rampart area and Dalton Highway Bridge by early to mid-September. During various years of test fishing and observing subsistence catches at Rampart, 19 Mile Research Site, and the Dalton Highway Bridge, spawning run peak catches occurred between 4 and 10 September. In 1974, sheefish were still migrating up the Yukon River at 19 Mile Research site on 4 October. A net set at this site from 24 September to 4 October caught 54 sheefish, indicating that the spawning run is quite protracted. Sample catch rates during the month long run generally ranged from 1 to 20 sheefish per day in fishwheels and gill nets (Alt 1973b, 1974, 1975).

A radio tagging study in 1985 provided specific data on average daily sheefish movements from the tagging location at 19 Mile Research Site (above Rampart) to spawning areas between Beaver and Ft. Yukon (Alt 1986). Five fish received surgically implanted radio transmitters. Individual fish moved from 8 to 22 km per day until they reached spawning grounds. Once in the vicinity of spawning grounds, only minor movements were noted (Alt 1986).

Similar migration speeds were determined for three sheefish tagged at Ohagamiut in the lower Yukon in June. These tagged fish were recovered in October of the same year on Koyukuk River spawning grounds, giving an average daily movement of 13.8 km while traveling a total of 990 to 1,100 km (Alt 1977b). The longest recorded sheefish migration in Alaska was 1,602 km (Alt 1977b). This fish was tagged on spawning grounds 88 km up the Alatna River in September and recaptured at the mouth of the Yukon River in the winter.

Discussions with local fishermen and the temporal and spatial distribution of tag recoveries have provided information on postspawning movements. The Yukon and Koyukuk Rivers sheefish postspawning migrations to winter feeding areas, like that of the Kobuk River, is quite rapid. Most tag recoveries in November and December occurred in the area from Nulato to the mouth of the Yukon River while December recoveries were all from the lower 250 km of the Yukon river (Alt 1977b). A radio tagged sheefish moved 135 km downstream from the spawning area in a maximum of 10 days (Alt 1986). Another radio tagged sheefish, which spawned in the Yukon River below Ft. Yukon in mid-October was captured in late March at the mouth of the Yukon River; a distance of 1,536 km.

Spawning:

Lower Yukon anadromous sheefish spawn in both the Koyukuk River drainage and Yukon River. The Koyukuk River stock spawns in various areas near Hughes on the Koyukuk River and in the vicinity of Siruk Creek in the Alatna River. No anadromous sheefish spawn in the upper Koyukuk River or its upper tributaries. However, the reported presence of sheefish in the upper Kateel River indicates that a local stock may occur. Specific spawning areas were located 0.5 km downstream from Hughes on the Koyukuk, and the area 9.5 to 12.5 km upstream of Hughes (locally called Six Mile). Ground surveys in 1968 indicated similar combinations of gravel, current speed, and water depth suitable for spawning as far upstream as 55 km above Hughes. However, aerial flights and discussions with local residents failed to demonstrate sheefish spawning in these areas. In the Alatna River, spawning grounds are located near Black Jack (48 km from the mouth of the Alatna) and from 1.5 km below to approximately 9.0 km upstream of Siruk Creek.

Koyukuk River sheefish spawn in late September and early October while Yukon River fish spawn in mid-October. During various years of research on the Koyukuk and Alatna rivers, the earliest that spawning was observed was on 27 September 1969. In some years, the river was partly frozen by 28 September and it is not known if fish had completed spawning by that time or if they spawned under the ice. Eggs were taken for hatchery rearing from Koyukuk River sheefish during various years from 1967-1982 and in most years the fish were ripe by the first 4 days of October. In 1976, fish were not ripe until 8 October. The duration of spawning activity of Koyukuk River fish is probably less than 2 weeks.

Spawning ground characteristics (bottom composition, water depth, and current) in the Koyukuk River are similar to conditions in the Kobuk River. The Koyukuk River is approximately 100 m wide and the bottom is comprised of differentially sized gravel. Water depth in spawning areas ranges from 1.2 to 2.4 m although it appears that some spawning in the Alatna River might occur in water less than 1.2 m deep. The current in the Koyukuk River near Hughes is generally slower than in the Kobuk River, however, sheefish were observed spawning in swifter water off gravel bars or off deep riffle areas. In the Black Jack and Siruk Creek spawning grounds of the Alatna River, current is similar to that of the Kobuk River and fish spawn in the main current. Water temperature on Koyukuk River spawning grounds during research and egg take activities ranged from 0.6 to 5.5°C. In 1967 for example, water temperature remained stable at 5.0°C during the entire spawning cycle. In 1968, fish had not yet begun spawning by 26 September when water temperature was 1.2°C.

A total of 2,615 sheefish were observed during aerial counts of spawning fish conducted in 1969 on the Koyukuk and Alatna Rivers (Alt 1970). Of these, 1,710 were counted near the Alatna River spawning grounds. This count probably represents only a small portion of the total spawning population especially in the main Koyukuk River. There were many deep holes in the vicinity of Hughes and although sheefish were sampled using hook and line and gill nets in these areas, none were observed from the air. Based on the extensive spawning areas available, the amount of spawning activity observed in 1967 and 1969, and the magnitude of the fall subsistence harvest, the Koyukuk River spawning fish may be as numerous as the Kobuk River stock.

Unsuccessful attempts to locate other spawning grounds of Yukon River anadromous sheefish were made throughout the 1970's (Alt 1973a, 1974, 1975, 1979). It was believed that spawning grounds were located in tributary streams; not in the main Yukon River. However, surveys and test-netting failed to find any spawning anadromous sheefish in the Ray, Dall, Hodzana, Chandalar or Porcupine Rivers, or in Hess, Beaver or Birch Creeks. One of the reasons for rejecting the main Yukon River as a possible spawning ground was that the water levels in slower moving portions of the Yukon River dropped 3 to 5 m from mid-October to breakup the following May. Therefore, sheefish would have to spawn over very deep water where eggs would be less likely to reach the bottom to lodge among the gravel (Alt 1975). Additionally it was thought the turbid character of the Yukon River would preclude spawning.

However, in 1985, a radio tracking study of 15 fish located the probable spawning grounds of the Yukon River stock of anadromous sheefish in the main Yukon River from below Beaver to 16 km downstream from Ft. Yukon (Figure 4) (Alt 1986). This conclusion is based on the following evidence:

1. The five radio-tagged sheefish that moved upstream all stayed in the main Yukon River. No tagged sheefish were located in tributary streams such as the lower Chandalar, Porcupine, or Hodzana Rivers;

2. All tagged fish were located in the main river during the peak of the normal spawning period in mid-October;

3. Average daily upstream movements were only 9.6 to 22.4 km per day. This migration rate would not allow most of the spawning fish sufficient time to ascend tributary rivers to spawn between the times they were located in the main rivers;

4. No prespawning sheefish have ever been captured in middle Yukon tributary streams during past ADF&G test netting; and

5. River conditions in the area where the sheefish were located in mid-October (gravel, current, water depth) appeared suitable for spawning.

Radio tracking evidence to support tributary spawning is:

1. Two tagged fish were not located between 25 September and 15 October and these fish could have ascended tributary streams to spawn. These fish could have gone up the Chandalar River, Porcupine River, or Birch Creek; and

2. Nine radio-tagged sheefish were never located upstream of the tagging area and, while it is believed that these fish died of tagging stress, they could have migrated upstream and spawned in tributary streams without being detected.

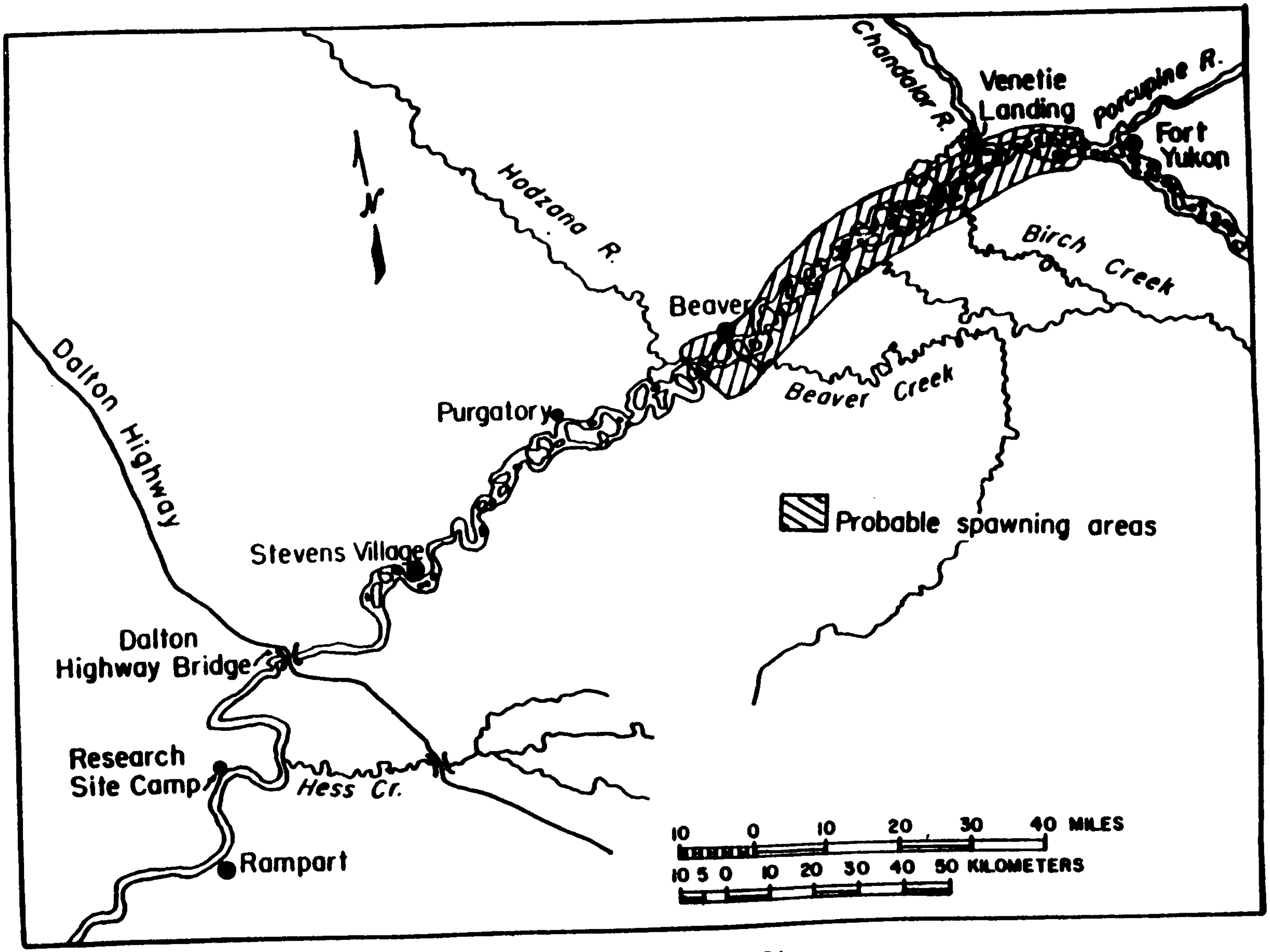

Figure 4. Spawning ground locations of Lower Yukon River anadromous sheefish.

The Yukon River in the area where sheefish appear to spawn is very braided, generally more shallow than the single channel portions of the river, and swifter. The areas where sheefish were located in mid-October contained deep, eddy-like holding areas near shore with riffle areas nearby where channel width was often constricted to less than 100 m. It is hypothesized that sheefish spawn in these riffle areas.

Gravel size off probable Yukon River spawning grounds below Beaver was similar to that described by Alt (1969a) for the Kobuk River. More silt was present between rocks on the Yukon River grounds than observed on Kobuk River spawning grounds but possibly the swift current removes this as water clears during late October. Because water depth would be shallower in these spawning areas in mid-October than during the rest of the year, eggs would have a better chance of settling to the bottom and lodging between rocks rather than being swept further downstream as might happen in the deeper main channel.

Water in the main Yukon River cools more slowly and freezeup occurs later than in tributary rivers. In 1985, during September radio tagging studies at 19 Mile Research Site above Rampart, water temperatures ranged from 3 to 5°C from 18 to 25 September. In mid-October, water temperature in the main Yukon River near the spawning areas was 0.6°C.

Nowitna River Sheefish

The Nowitna River has its source in the Kuskokwim, Sunshine, Von Frank, and Mystery Mountains of Central Alaska. It flows in a generally northeast direction for 400 km before emptying into the Yukon River upstream of Ruby at latitude 64°56'N and longitude 154°16'W (Figure 5). It is locally called "The Novi" or "Novi River". The Department performed an initial survey of the Nowitna in 1967 in response to reports of sheefish catches by recreational fishermen. Movements of Nowitna River sheefish were documented through a tag and recovery program conducted at the Nowitna River mouth between 1972 and 1974 (Alt 1973a, 1974, 1975).

Stock Status:

Sheefish in the Nowitna River constitute a separate nonanadromous stock. Prespawning sheefish were first captured at the mouth of the Sulukna River in 1973 and upstream in the Sulukna River in 1975 (Alt 1973a, 1974, 1978). Spawning grounds were identified in 1984 (Alt 1985). Some overlap of anadromous lower Yukon River sheefish with Nowitna fish is to be expected as not all members of the anadromous population overwinter in the delta of the Yukon River. All but two recoveries of fish tagged in the Nowitna River (36 of 373 tagged fish) were made in the Nowitna River or slightly downstream in the Yukon River (Alt 1974).

Distribution:

The range of Nowitna sheefish includes the mainstem Nowitna River and associated sloughs up to the mouth of the Sulukna River (approx. 280 km)

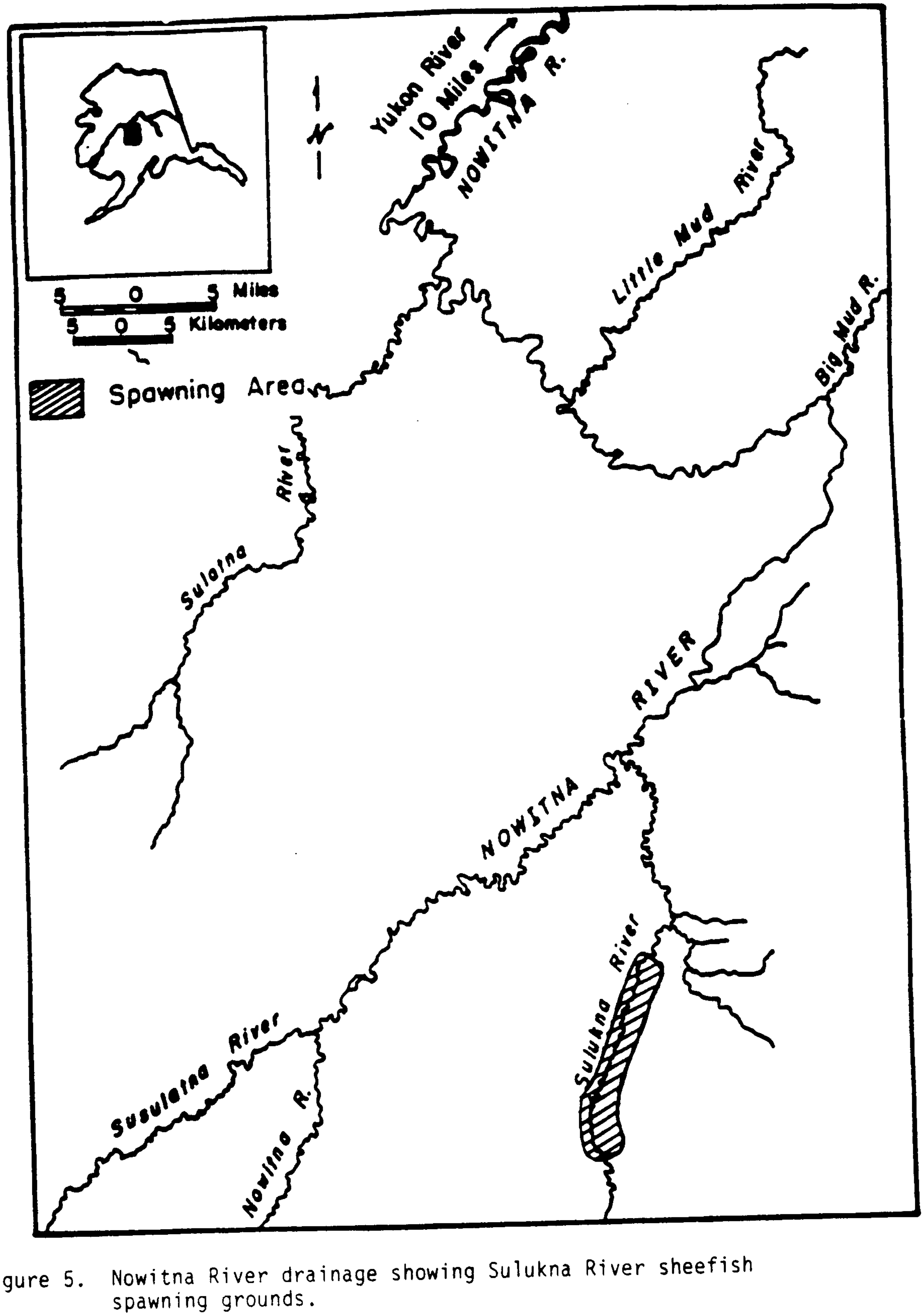

Figure 5. Nowitna River drainage showing Sulukna River sheefish spawning grounds.

(Alt 1973b). With the exception of the Sulukna River, adult sheefish are not found in tributary rivers of the Nowitna. Some nonspawning adults and immature sheefish have been sampled upstream as far as the Sulatna River, but these sheefish are most abundant in the lower 50 km of the river. In July 1978, large numbers of young of the year and age 1+ sheefish were found in the main river and sloughs in the lower 20 km of the Nowitna River. Early summer test netting results indicated an immigration of sheefish into the Nowitna from the Yukon River suggesting that some or all Nowitna River sheefish overwinter in the Yukon.

Movements:

Sheefish migrate into the Nowitna River from the Yukon River soon after breakup. During test netting at the mouth of the Nowitna River, peak sheefish catches occurred during late May and early June (Alt 1973a, 1974, 1978). By the second week of June, net catch rates had dropped to 2 fish per day or less, indicating the migration had passed and fish were dispersing to feeding areas. Peak test netting catch rates in sloughs of the lower Nowitna River occurred in mid-June. During July and September, the catch rate dropped to less than one fish per night in the lower Nowitna River. Only nonspawning sheefish were caught at this time, indicating that prespawners had already migrated beyond the lower river by July (Alt 1978).

Movement of sheefish up the Sulukna River to spawning grounds occurs throughout September. The postspawning downstream migration has not been documented, but fish probably reach the Nowitna mouth by late October. It is not known if part of the population overwinters in the lower Nowitna or if all overwintering occurs in the Yukon River. Young of the year fish migrate down the Sulukna from spawning grounds after breakup and by mid-summer are distributed in the lower river and associated sloughs (Alt 1979).

Spawning:

Prespawning sheefish were sampled as far as 20 km upstream from the mouth of the Sulukna River in 1973 and 1975, providing evidence that sheefish of the Nowitna stock spawn in the Sulukna River. A more extensive survey in mid-September 1984 pinpointed probable spawning grounds located from 32 to 56 km up the Sulukna River (Figure 5). Nets set during the 1984 survey averaged 5 sheefish per net night. This CPUE indicates a larger spawning abundance than other local stocks. Small groups of sheefish were observed in deeper pools between 32 and 59 km upstream with the largest group numbering 10 fish. Spawning sheefish were found in association with larger groups of humpback whitefish.

Gravel bars having the right combination of gravel bottom substrate, current, and water depth were found intermittently in the area from 32 to 56 km upstream. Bottom composition was estimated at 5% sand and silt, 25% small gravel, 50% medium gravel (25 to 50 mm diameter), and 20% gravel over 50 mm diameter. The Sulukna River 56 km upstream, where large numbers of sheefish were observed and captured, was 27 m wide, with water depth averaging 1 m. Current velocity was 4.2 km per hour.

All fish captured on the spawning grounds were mature. Milt could be expelled from some males on 12 September but eggs were still tight. Sheefish on Sulukna River spawning grounds in 1984 were smaller than fish spawning in the main Yukon River. Four females captured were 720 to 740 mm long and averaged 5.1 kg. Twenty-three males were 620 to 773 mm long and averaged 3.3 kg.

Minto Flats Sheefish

A local nonanadromous stock of sheefish exists in the Minto Flats watershed and other tributary streams of the Tanana River from its mouth upstream to Fairbanks (Alt 1973b). A tagging study to determine movements and define the stock structure of Minto Flats sheefish was conducted by the ADF&G between 1967 and 1971.

Stock Status:

Presently the Minto Flats stock is the only documented spawning stock of sheefish in the Tanana River drainage. Tagging studies conducted between 1967 and 1971 indicated that sheefish that spawned in the Chatanika River were the same fish that spent the summer feeding in Minto Flats (Alt 1968, 1969a, 1973b). One hundred sixty-eight sheefish were tagged in Minto Flats and the upper Chatanika River during 1967-1971. Of these, 27 (16%) were recaptured (Figure 6). All recoveries were made within the Tanana River system. One fish was recovered at Nenana and two in the lower Chena River at Fairbanks, indicating that more widespread movement occurs than was earlier believed.

Some evidence suggests that other spawning stocks may exist in the Tanana drainage. In 1986, two prespawning female sheefish were captured in the Chena River. The Bearpaw River, a tributary of the Kantishna River, may also have a spawning stock. A survey of the Bearpaw was conducted in late September 1975 after a report of large sheefish at the river mouth. No sheefish were captured during test netting activities, but suitable spawning habitat was found in the vicinity of Moose Creek above Dimond.

Distribution:

The range of Minto Flats-Tanana River sheefish includes the mouth of the Tanana River drainage upstream to the Chena River at Fairbanks. Scattered individuals have been captured as far as 320 km farther upstream in the Tanana River. Sheefish have been found in the lower reaches of Squaw Crossing Slough, Fish Creek, Chitanana, Cosna, and Zitziana Rivers, and Baker Creek. In the Kantishna system they are found as far upstream as the Muddy River and have occasionally been taken by subsistence fishermen in Lake Minchumina. They are found at the mouths of the Bearpaw and Toklat Rivers but none have been captured further up these rivers. In the Minto Flats area, sheefish occur in the Tolovana River upstream as far as Montana Creek, in the Tatalina River upstream as far as Washington Creek, in Goldstream Creek up to Minto Lake, and in the Chatanika River, upstream to the vicinity of Mile 31 on the Steese Highway. Near Nenana, sheefish are distributed in small numbers in the main Tanana as well as the lower Nenana River, Wood

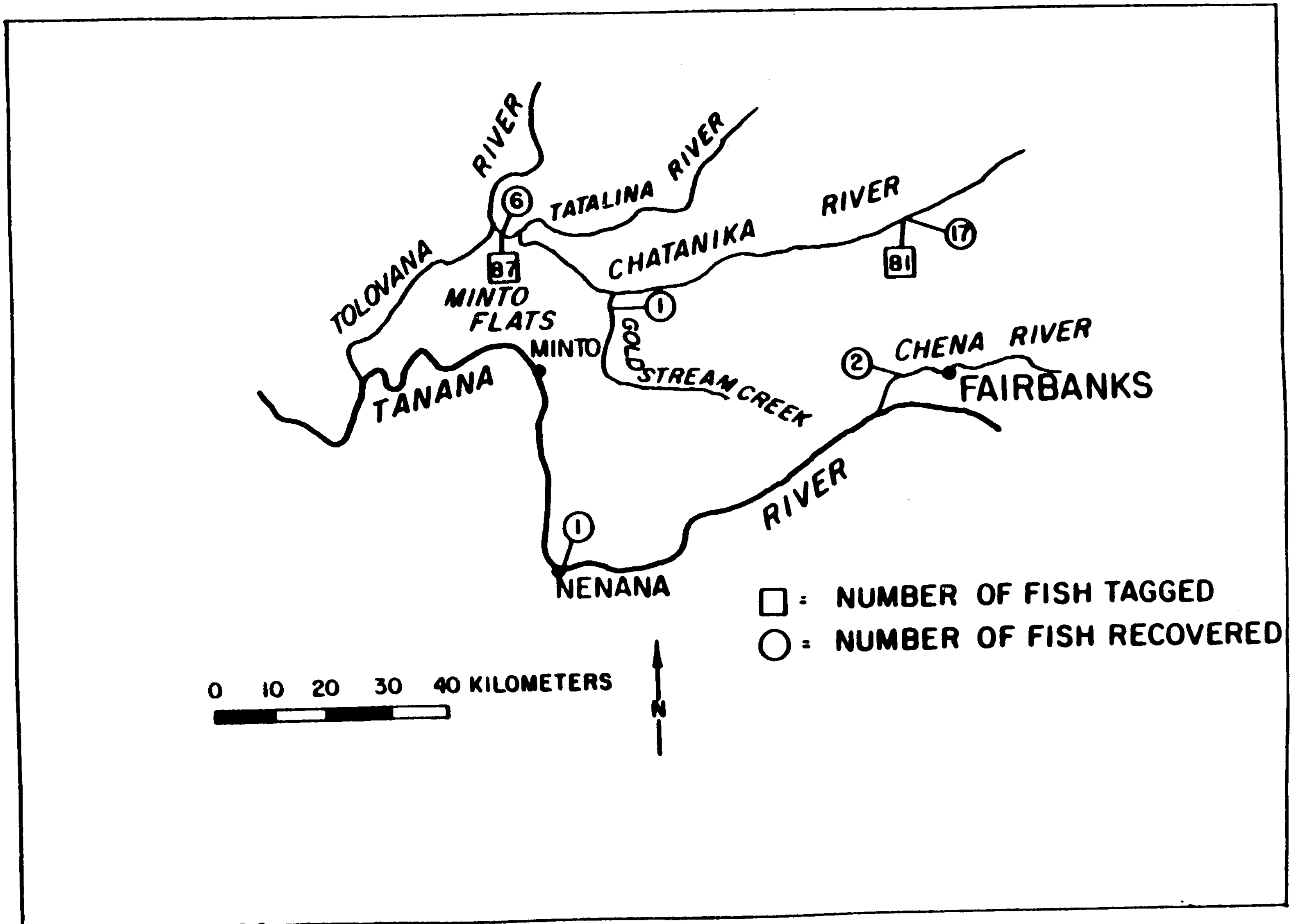

Figure 6. Minto Flats-Tanana River sheefish tag and recovery locations, 1967-1974.

River, and Dry Creek. Near Fairbanks, they are occasionally captured in lower Rosie Creek, Nelson Clearwater Creek, and Salchaket Slough. Sheefish have been sampled in the lower 32 km of the Chena River.

Movements:

Winter movements of Minto Flats sheefish are poorly understood and can only be inferred from negative information. Sheefish of the Minto Flats-Tanana drainage stock probably spend the winter months in the Tanana River because sheefish have never been captured in the lower Chena River during winter netting nor have any tagged Minto Flats sheefish ever been recovered in the Yukon River in the winter. Overwintering probably does not occur in Minto Flats because most areas of the Flats become anoxic in the winter (Alt 1973a). Northern pike are known to overwinter in restricted areas of the lower Chatanika River and Swanneck Slough. However, sheefish have never been captured during sampling in these areas. Therefore, it is assumed that most sheefish leave Minto Flats by at least mid-winter. By the process of elimination of other possible overwintering areas, the Tanana River is left as the likely choice.

Sheefish begin spring movements into the Chena River under the ice in small numbers in late April (Tack 1974). Sheefish also appear to move into Minto Flats in the early spring. In 1970, sheefish were captured in gill nets in open water leads in the Tolovana River at New Minto Village on 7-9 May. At this time, the remainder of Minto Flats waters were still ice covered. Based on recreational, subsistence, and test net catches, it appears that major movements of sheefish into the Chena River and waters of the Minto Flats occur within 2 weeks after breakup. In streams of the lower Tanana River (Baker Creek, Cosna River, and the Zitziana River), sheefish, both prespawners and immature, were present in mid-May (Alt 1979). Test netting in these rivers in July failed to capture any prespawning sheefish, indicating that prespwaners had already entered Minto Flats (Alt 1980). By mid-June, test netting results indicated that feeding sheefish are distributed throughout the slough and river system of Minto Flats (Kepler 1973).

An upstream sheefish spawning migration was observed in the lower Chatanika River in late June, 1967 (Alt 1968). Fish were observed surfacing (approximately every 50 meters) during these upstream movements. It is estimated that 200 fish (50% spawners) passed upstream into the Chatanika and Tolovana Rivers during three nights of observation (Alt 1968). Prespawning fish slowly continue their upstream migration to the spawning ground throughout the rest of the summer with an apparent migratory peak in mid-August in the lower canyon area of the Chatanika River (Kepler 1973).

The spawning migration reaches the vicinity of the spawning grounds in the upper Chatanika River in late August and September. Catches from a weir operated in the Chatanika River in 1968 indicated that spawning fish continue migrating to the upper Chatanika throughout September (Alt 1969a). Downstream postspawning migrations commence directly after spawning. Some spent fish were captured at the downstream weir trap by 2 October.

Results of test netting and angler reports during September indicated that outmigration of feeding sheefish from Goldstream Creek and the Tolovana River had already occurred. No sheefish have been captured in the Chena River during minimal test netting in September or October, indicating that these feeding sheefish have also left the system by the fall.

Spawning:

Sheefish of the Minto Flats stock spawn in the upper Chatanika River north of Fairbanks. They spawn in a number of swift pool-like areas in a 3.2 km area above "Humpy Heaven", approximately 7 km upstream of the Elliott Highway bridge.

Spawning occurs in late September and early October. On 2 October 1968, spent sheefish were sampled in a downstream weir trap located below the Elliott Highway Bridge (Alt 1969b). Six female sheefish were captured using electrofishing gear on 4 October of the same year. All fish were partially spent. During the last week of September of 1963 and 1964, sport caught sheefish taken in the vicinity of spawning grounds had not yet spawned. Water temperature during the spawning period in various years ranged from 2 to 4°C. Bottom composition in spawning areas was similar to that described for the Kobuk and Koyukuk Rivers. Spawning bars, however, were smaller and fish spawned in deep, fast moving water in pool areas of the Chatanika.

In 1968, 94 spawning fish were counted at the Chatanika River weir (Alt 1969b). An additional 16 spawners were harvested by sport fishermen. The spawning population was probably higher in 1963 and 1964 as recreational harvest levels on the spawning grounds approached 50 fish per year. After 1968, the number of spawning sheefish appears to have declined and, throughout the 1970's and 1980's, fewer sheefish have been captured by anglers on the spawning grounds or encountered by research biologists working on the upper Chatanika River.

In 1968, 21 Chatanika River spawning female sheefish averaged 800 mm in length and weighed an average of 6.1 kg (range 720 to 880 mm and 4.3 to 9.5 kg). Forty-seven males sampled in the same year averaged 706 mm and 3.9 kg (range 58 to 790 mm and 2.5 to 5.1 kg). The ratio of males to females captured in the weir in 1968 was 2.2:1.

Chatanika River sheefish sometimes hybridize with humpback whitefish. In 1968, six hybrids were captured at the Chatanika River weir (Alt 1971b).

Porcupine River Sheefish

A small nonanadromous stock of sheefish occurs in the Porcupine River and lower reaches of associated tributaries. Rearing sheefish were located in the Porcupine River during a preliminary survey of the watershed in 1970 (Alt 1971a). A tag and recovery study, stream survey, and sheefish life history study was conducted in the Porcupine River in 1971-1974 (Alt 1975). Although sheefish are found in the Porcupine River in the Yukon Territory Canada, no research has been conducted there (Bryan 1973).

Stock Status:

Sheefish found in the mainstem Porcupine River and lower reaches of associated tributaries belong to a separate nonanadromous spawning stock. Sheefish spawning grounds were located in the upper Porcupine River during stream survey and life history studies (Alt 1974).

Distribution:

Porcupine River sheefish are found in the mainstream Porcupine River and its associated sloughs from the mouth upstream to the Yukon Territory, at least as far as Old Crow and probably upstream to the Bell River. Sheefish have also been captured in the lower Sheenjek River and two separate captures have been made of nonspawning fish upstream in the Sheenjek River as far as Shoulder Mt. and the Koness River. Porcupine River sheefish may mix at the mouth of Black River with the local Black River sheefish stock during feeding and overwintering (Alt 1978). Porcupine River sheefish do not ascend the Coleen or Salmon-Trout Rivers. Some overwintering and feeding fish of the Porcupine River stock may occur at some stage of their life in the Yukon River adjacent to the Porcupine River mouth.

Movements:

Data from tag recoveries indicates little summer movement of Porcupine River sheefish. Sheefish were tagged at the mouth of the Porcupine, Black, and Coleen Rivers, and at Ward Camp (50 km upstream from the mouth of the Porcupine) between 1971 and 1974 (Figure 7). Tag recoveries were obtained mainly by the ADF&G sampling crew. Over 80% of the tag recoveries came from the same area as tagging occurred and only 17% of tag recoveries were made in subsequent years. Two fish tagged at Ward Camp were recovered by subsistence fishermen in subsequent years at Old Crow, Yukon Territory.

Nearly all sheefish captured in June at the mouth of the Porcupine River were immature or nonspawning fish. Therefore, it is assumed that prespawners have either overwintered farther up the Porcupine or migrated up toward spawning grounds before test netting was conducted. Prespawning males and females have been captured at Ward Camp in mid-June of various years.

Information on movements of young sheefish of the Porcupine stock is minimal. Test netting results indicate that the majority of rearing occurs in the vicinity of Ward Camp. Young of the year rearing fish have also been captured near the spawning grounds and as far downstream as the mouth of the Porcupine River. In general, young of the year fish seem to be located throughout the Porcupine River.

Spawning:

Porcupine River sheefish spawn in the main Porcupine River 0.6 km below the mouth of the Coleen River. Prespawning sheefish were captured by gill net and hook and line in this area on 26 September 1973. The bar over which spawning probably occurred was approximately 100 meters long,

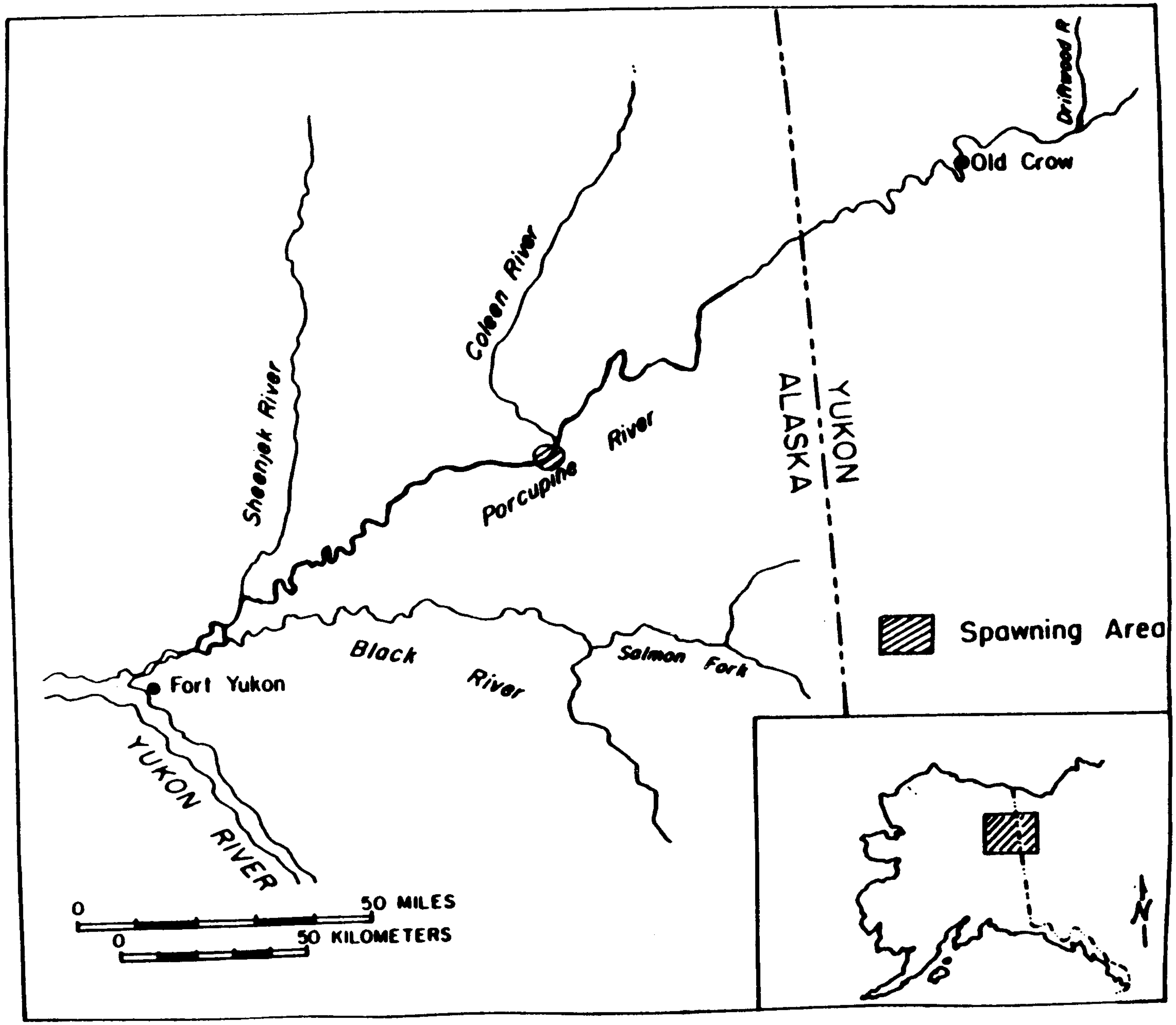

Figure 7. Porcupine River system with location of sheefish spawning grounds.

and water was 2-3 m deep. Current and spawning gravel composition were similar to that found on other spawning grounds. Porcupine River sheefish probably also spawn at other locations. Bryan (1973) reported capturing young of the year sheefish 500 km upstream in Canadian sections of the Porcupine River, indicating that a spawning area exists somewhere upstream.

Sheefish, especially females, generally do not spawn every year. However, on 15 June 1974, a 660 mm prespawning female with retained eggs was captured on the Porcupine River, indicating that this fish had spawned the previous year.

Salmon Fork of Black River Sheefish

A small nonanadromous stock of sheefish occurs in the Salmon Fork of the Black River. The Black River has its headwaters in Canada and flows in a westerly direction until it empties into the lower Porcupine River. A Department of Fish and Game study of this stock was performed in 1977 (Alt 1978).

Stock status:

Sheefish of the Black River system including the Salmon Fork and Grayling Creek constitute a separate nonanadromous spawning stock (Alt 1974). Existence of separate spawning grounds and the small average size of spawners are the main reasons for classifying these fish as a stock separate from the Porcupine River fish. Sheefish of this stock probably mix with sheefish of the Porcupine River at the mouth of the Black River during feeding and overwintering. Based on subsistence catches and on test net catch rates, it appears that the abundance of Salmon Fork spawners is quite low (Alt 1978).

Distribution:

Sheefish in the Salmon Fork of the Black River are distributed mainly in the Black River from its mouth upstream to the mouth of Grayling Creek and upstream in the Salmon Fork to Tetthajik Creek. Probably a small number of individuals enter the Porcupine River as well as the middle Yukon River. Spawning grounds are located approximately 125 km upstream of Chalkyitsik just south of the Arctic Circle in extreme east central Alaska (Figure 8). The major overwintering grounds for this stock are probably in the Black River.

Movements:

Residents of Chalkyitsik report a movement of sheefish up the Black River after spring breakup. These fish move into feeding areas in the vicinity of Chalkyitsik during the summer. One immature feeding sheefish was captured as far upstream as Grayling Creek in August and an occasional nonspawning sheefish has been netted by subsistence fishermen in the Salmon Fork River below Kevinjik Creek in the fall.

Subsistence catch reports indicate that sheefish reach the spawning grounds no later than 28 August. The spawning run continues at a low

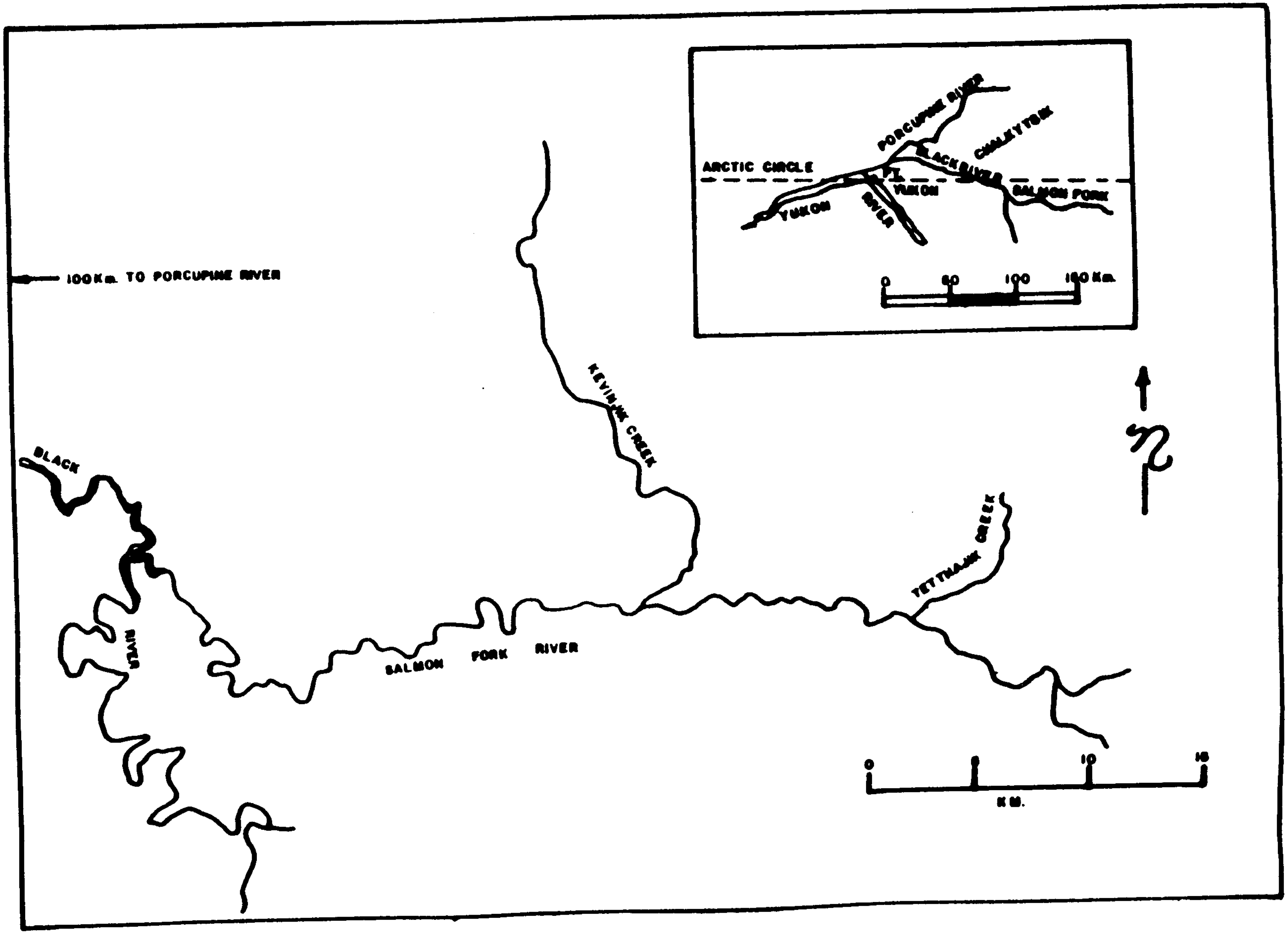

Figure 8. Salmon Fork of the Black River.

level throughout September with test gill net catches seldom exceeding one sheefish per net night. Nonspawning sheefish moving downstream to overwintering areas are caught by subsistence fishermen near Chalkyitsik in the fall. No information is available on the postspawning migration of adult sheefish.

Spawning:

The exact location of sheefish spawning grounds in the Salmon Fork of the Black River was not found during studies conducted in 1977 (Alt 1978). No large concentrations of sheefish were located during aerial surveys, test netting, or boat surveys conducted in an area 10 km below to 20 km above Kevinjik Creek. However, the greatest test net catches of prespawning sheefish occurred in an area approximately 3 km above Kevinjik Creek and an area 4 km below Kevinjik Creek. Seventeen prespawning sheefish were sampled during 18 nights of test netting in September 1977. Judging by gonadal development, it appeared that these fish would have spawned in early October.

The Salmon Fork River near Kevinjik Creek is considered the most likely sheefish spawning area because of the presence of suitable habitat. The river 10 to 20 km above Kevinjik Creek contains 40% riffles and 60% pool area. The current in most pools is too slow to keep the gravel cleared of algae and most riffle areas are too shallow (<1 m) for sheefish spawning. It appears that the best spawning habitat is located in an area 3 km downstream from Kevinjik Creek. Here the river constricts to 30 m wide, forming a chute with a current velocity of 1.22 m/sec, and having an average depth of 1.5 m. Bottom type in this area is 5% sand and silt, 5% small gravel, 10% medium gravel, and 80% large gravel and rubble. Most of the large and coarse gravel is over 50 mm in diameter and includes rocks over 200 mm. Another possible spawning area with similar habitat characteristics is located upstream of Kevinjik Creek. The area 3 km below Kevinjik Creek was monitored during the evening for sheefish spawning activity between 25 and 30 September, but none was observed.

Mean size of spawning sheefish sampled from the Salmon Fork of the Black River was quite small (Table 3). Males (n=21) averaged 592 mm fork length (range = 530 to 670 mm) and 1.86 kg (range = 1.48 to 2.61 kg), and females (n=11) averaged 674 mm fork length (range = 585 to 794 mm) and 3.41 kg (range = 1.93 to 4.23 kg). By comparison, the mean weight of female spawning sheefish sampled in the Yukon River at Rampart was 6.69 kg. Females sampled from the Salmon Fork River are smaller and have fewer eggs on average than females from any other Alaskan sheefish stock. The smallest Yukon River anadromous female sampled had egg counts of 105,900 compared to only 36,000 eggs for a 605 mm Salmon Fork River female (Table 4).

Upper Yukon River Sheefish

Sheefish in the upper Yukon River and associated tributaries are considered a separate nonanadromous stock (Alt 1969b, 1973a). Department of Fish and Game sampling of sheefish in the upper Yukon River has been performed over a series of years (Alt 1965, 1967, 1969b, 1971a, 1973a, 1973b, 1974, 1979).

Table 3. Mean fork lengths at age (mm) for eight stocks of Alaskan sheefish.

AGE	Kuskokwim River (n=187)	Kobuk-Selawik Rivers (n=547)	Lower Yukon River (n=204)	Upper Yukon River (n=66)	Minto Flats-Tanana River (n=98)	Black River (n=54)	Porcupine River (n=102)	Nowitna River (n=149)
1	188	151	149	126	170		142	149
2	326	239	238	215	285		236	248
3	417	307	311	285	377		306	336
4	496	369	384	345	466		375	416
5	563	430	459	406	534	470	431	429
6	633	489	530	486	603	521	485	559
7	676	546	598	548	658	581	530	620
8	726	598	668	594	704	589	562	680
9	777	652	724	644	753	615	606	722
10	810	705	779		797	686	640	768
11	847	759	837		828	683	674	816
12	936	806	896		800	733		856
13	970	855	948			794		907
14		895	1010					930
15		937	1040					
16		978						
17		1016						
18		1072						
19		1101						
20		1094						

Table 4. Egg counts of selected female sheefish from the Yukon River at Rampart and the Salmon Fork of the Black River.

Location	Weight (kg)	F.L. (mm)	Age	Egg Diameter (mm)	No. Eggs
Rampart	5.23	745	10	2.5	105,900
	5.23	750	10	2.5	127,800
	5.23	775	10	2.4	147,200
	6.48	777	11	2.4	170,000
	7.50	877	12	2.3	197,800
	9.66	915	...	2.5	230,000
Salmon Fork River	1.95	585	8	2.4	27,000
	2.16	605	8	2.5	36,000

Stock Status:

No tagging studies have been conducted on sheefish found in the upper Yukon River, but indirect evidence indicates these fish belong to a separate stock. This evidence includes: test netting and observation of local subsistence catches that document sheefish harvests upstream of Ft. Yukon; the presence of young of the year and rearing fish at mouths of tributary rivers; the lack of tag recoveries in the upper Yukon River of sheefish tagged on the Porcupine or middle Yukon rivers; and differences in biological characteristics of the stocks (Alt 1967, 1973a, 1973b, 1974).

Electrophoretic protein analyses were conducted on fish from the upper Yukon River (Kandik River), middle Yukon, and Koyukuk River in 1972 (Alt 1974). The enzymes used in these analyses were lactate dehydrogenase (LDH), isocitrate dehydrogenase (IDH), glycerol-3- phosphate dehydrogenase (GPDH), and malate dehydrogenase (MDH). Based on these analyses it was concluded that sheefish are monomorphic with the exception of two individuals from the middle Yukon (Rampart) and therefore separate stock status of sheefish from these areas could not be confirmed (Alt 1974).

Distribution:

Sheefish of the upper Yukon River stock are distributed throughout the main Yukon River from Circle to the Canadian border. Sheefish are also found in the Canadian portion of the upper Yukon River as far upstream as Johnson's Crossing in the Teslin River system and the Stewart River. Canadian sheefish are generally not abundant and may constitute yet another stock (Dymond 1943; Carl et al. 1959). Sheefish in the upper Yukon River are generally located near mouths of tributary rivers. During ADF&G research activities, sheefish have been caught by test net, seine, or hook and line at the mouths and extreme lower reaches of Thanksgiving, Webber, Fourth of July, Coal, Mission, and Eagle Creeks, and the Charley, Kandik, Nation, Tatonduk, Seventy Mile, and Forty Mile Rivers (Alt 1967, 1971a, 1979).

Movements:

Little detailed information on upper Yukon River sheefish movements is available. Local subsistence fishermen report an upstream migration in the Yukon River in the early summer. This would indicate that overwintering takes place in the Yukon River with fish undertaking a movement to feeding areas after breakup. Sheefish are present at mouths of tributary rivers such as the Kandik, Nation, and Tatonduk in small numbers throughout the summer and fall, indicating that these are feeding areas. A late summer, migration to spawning areas may occur but was not detected during studies in late September 1978 (Alt 1979). Prespawning fish had probably already reached spawning grounds at the time of sampling.

Only a few young of the year sheefish were captured near the mouths of tributary streams in June. However, considerable numbers were sampled in late July and August (Alt 1969b). This indicates that young of the year fish may be moving downstream from spawning areas into summer feeding areas at this time.

Spawning:

The only documented spawning grounds of sheefish of the upper Yukon stock are located approximately 12 km up the Tatonduk River near Pass Creek. Sheefish may possibly spawn in lower reaches of other major tributary rivers but such areas have not been located. Surveys in June of 1970 revealed that suitable spawning habitat was available in the lower 16 km of the Charley River, the lower 65 km of the Kandik River, the vicinity of Hard Luck Creek in the Nation River, the lower 16 km of the Tatonduk River, and a section of the Seventy Mile River above the canyon. In 1964, one prespawning sheefish was sampled at the mouth of the Charley River in early September, but no prespawning fish were caught farther upstream. The capture of young of the year sheefish (as small as 48 mm) at mouths of the five major tributary rivers in August of 1964 provides indirect evidence of spawning in other tributaries beside the Tatonduk River. However, rearing fish from the Tatonduk may disperse to suitable slough areas further downstream and upstream in the Yukon River. The possibility also exists that some sheefish of the upper Yukon River stock spawn in the main Yukon River.

Kuskokwim River Sheefish

Sheefish found within the drainage of the Kuskokwim River system are considered to belong to a single stock. These sheefish overwinter in the lower Kuskokwim River and Kuskokwim Bay, feed throughout the lower and middle Kuskokwim, and spawn in two locations in the upper Kuskokwim River. Some sheefish of this stock have been captured in the estuarine environment off the mouth of the Kuskokwim (Rae Baxter, ADF&G Biologist, pers. comm.) and thus can be considered estuarine anadromous. Sport Fish Division research on Kuskokwim River sheefish was initiated in 1967. The goal of this study was to determine movements and stock status of sheefish in the Kuskokwim River and to monitor fisheries.

Stock Status:

A tagging study was conducted to determine stock status and movement patterns of Kuskokwim sheefish (Alt 1977a). The original hypothesis was that Holitna River sheefish were a local resident stock and sheefish found in the lower Kuskokwim River constituted another stock. Between 1967 and 1971, 64 sheefish were tagged below Bethel, 452 fish were tagged 30 km up the Holitna River, 16 were tagged at the mouth of the Tatlawiksuk River, and 52 sheefish were tagged on spawning grounds at Highpower Creek 1,221 km up the Kuskokwim River. By 1974, 57 of the 500 tagged fish had been recovered, with recoveries being made throughout the range of sheefish distribution in the Kuskokwim River (Figure 9), (Alt 1970, 1977a).

The pattern of tag recoveries through the years documented movements of sheefish that indicate Holitna River and lower Kuskokwim sheefish share overwintering grounds in the lower Kuskokwim River, feeding areas throughout the lower and middle Kuskokwim, and spawning grounds in the upper Kuskokwim River at Highpower Creek and Big River. Recoveries of fish tagged on the upper river spawning ground were made mainly on the lower Kuskokwim. Sheefish tagged near Bethel were recovered mainly in

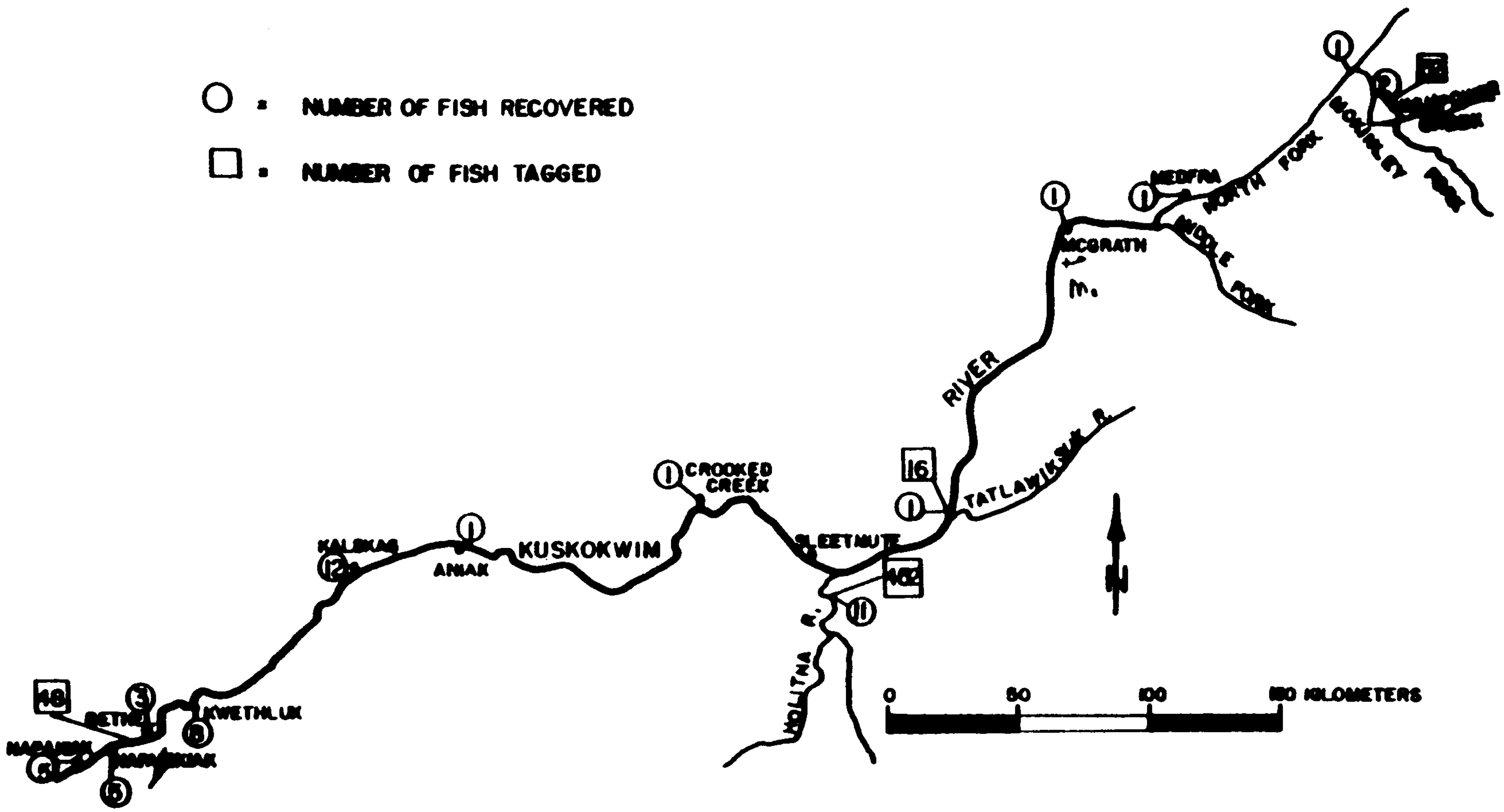

Figure 9. Kuskokwim River-Holitna River sheefish tag and recovery locations.

the same vicinity as tagged as well as near villages on the upstream spring and downstream fall migration routes. Of particular interest was the recovery upstream of the Holitna River in the Kuskokwim River of a fish tagged the previous year in the Holitna. This fish was a prespawner, providing the first indication that some Kuskokwim sheefish might spawn farther upstream in the Kuskokwim.

Based on the limited amount of spawning area available on Highpower Creek and Big River and the relatively low fishery catch rates, it is assumed that total Kuskokwim sheefish abundance is smaller than that of the anadromous lower Yukon and Kobuk-Selawik stocks. However, Kuskokwim sheefish are probably considerably more abundant than resident stocks of the Yukon River. Attempts to estimate population abundance for both Holitna River feeding fish and Highpower Creek spawners were unsuccessful.

Stock status of the Kuskokwim sheefish has probably changed little over the past 20 years. An age and growth comparison between fish sampled in 1967-1971 and fish sampled in 1978-1980 documented little change in age composition and size of fish (Alt 1980).

Distribution:

Kuskokwim River sheefish occur from the estuarine environment of Kuskokwim Bay upstream 1,221 km to Highpower Creek (Figure 10). The mainstem Kuskokwim River is used by sheefish for overwintering, feeding, and as a migration route to summer feeding and spawning grounds further upstream. Sheefish are usually only found at the mouths and lower reaches of Kuskokwim River tributary streams. Sheefish are found throughout the extensive lake-slough-stream system of the Kialik and Johnson rivers downstream of Bethel. During stream surveys in the lower Kuskokwim River, sheefish were found only in the lower Aniak and Kasigluk Rivers (Alt 1977a). However, local residents reported capturing small numbers of sheefish at the mouths of the Kwethluk, Kisaralik, and Tuluksak Rivers. In the Aniak River, feeding sheefish are occasionally found as far as 10 km upstream at the mouth of Doestock Creek. Between Aniak and Sleetmute, sheefish occur in small numbers at the mouths of the Owhat, Kolmakoff, Holokuk, Oskawalik and George Rivers. The Holitna River at Sleetmute has a large summer feeding concentration of sheefish at the mouth of the river as well as at various points upstream as far as the Hoholitna River (Figure 10) (Alt 1981). The farthest upstream documented concentration of sheefish in the Holitna River was 88 km upstream at the mouth of Titnuk Creek (Alt 1981).

Between Sleetmute and McGrath, summer concentrations of feeding sheefish have been located at the mouth of the Tatlawiksuk, Nunsatuk, Selatna, Katlitna, and Takotna Rivers. During sampling, no sheefish were captured at the mouths of the Stony or Swift Rivers and local fishermen report that they seldom take sheefish in these waters.

Almost all sheefish sampled upstream of McGrath are spawners. Sheefish that enter Big River continue upstream to spawn in this glacial tributary stream and Highpower Creek (Alt 1981). Sheefish in Highpower Creek are distributed mainly in the lower 1.5 km of the stream (Alt 1972).

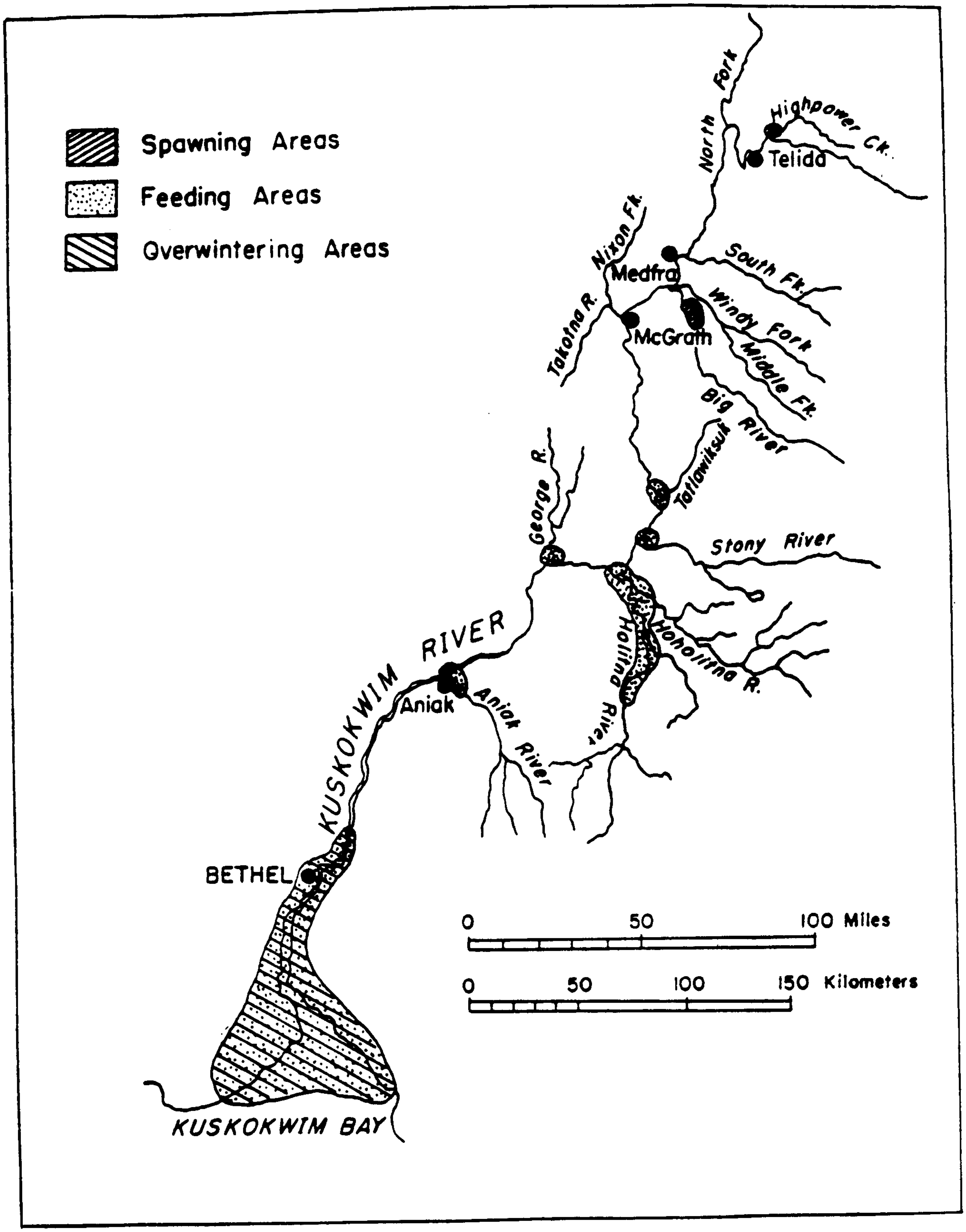

Figure 10. Location of important overwintering, feeding, and spawning areas of Kuskokwim River sheefish.

Upstream of Highpower Creek, the main Kuskokwim (McKinley Fork) is glacial, shallow, and very swift and probably does not contain sheefish.

Movements:

Major information on movements of Kuskokwim River sheefish was gathered by tagging and test netting studies. Under-ice movements of Kuskokwim River sheefish are similar to those of the anadromous Yukon River stock. By freezeup in October, many of the nonspawning fish have migrated downstream from feeding areas in the middle Kuskokwim River to overwintering areas in the lower Kuskokwim River (Rae Baxter, ADF&G Biologist, pers. comm.). As winter progresses, spent fish from the Highpower Creek and Big River spawning grounds reach overwintering grounds in the lower Kuskokwim. Sheefish that have summered in lower Kuskokwim River tributaries (Kialik and Johnson rivers) move into the main Kuskokwim as the tributary streams become low in dissolved oxygen (Rae Baxter, ADF&G Biologist, pers. comm.). Test and subsistence net results indicate that some sheefish reach the estuarine Kuskokwim Bay after early January (ADF&G unpublished files, Bethel) and that overwintering sheefish are also present in the main Kuskokwim from above Bethel downstream to the mouth (Alt 1977b). According to residents of middle and upper Kuskokwim River villages, sheefish do not overwinter in this portion of the Kuskokwim. There is evidently little mid-winter movement of sheefish, but residents of lower Kuskokwim River villages report an upstream migration beginning in late March and April. The temporal distribution of tag recoveries supports the conclusion that some upstream late winter under-ice migration occurs.

As breakup occurs in the Kuskokwim River in late May, the upstream migration of sheefish to feeding and spawning ground is well underway. During test netting in 1975 and 1976, sheefish were first caught in the Aniak River in late May. In 1975, a subsistence gill net set below Aniak on 28-30 May took 103 sheefish (Alt 1977b). Subsistence fishermen state that the peak of the early upstream migration past Aniak is generally during the first half of June. The large average size of these sheefish (10 kg) and state of maturity indicated that these fish were mainly prespawners and that, as with Yukon River sheefish, prespawners are in the vanguard of the upstream migration. However, these fish were caught in chinook salmon gear (15 cm mesh) to which smaller sheefish were probably not vulnerable.

Migrating fish do not reach the Holitna River until June with the main migration of sheefish occurring in late June. Sheefish migrate upstream in the Holitna River to feeding grounds 30 km upstream (Cutbank) in late June and early July, and to the lower Hoholitna and the mouth of Titnuk Creek by early July.

The summer movement of feeding sheefish into the extensive stream-lake-slough systems of the lower Kuskokwim River occurs soon after breakup. The movement of sheefish fry from spawning areas in the upper Kuskokwim to rearing areas in the lower river begins after breakup and continues throughout the summer.

The movement of feeding fish into mouths of tributary streams between Sleetmute and McGrath begins in late June and peaks in July according to local recreational and subsistence fishermen. It appears that upstream of Sleetmute, the earliest migration is of nonspawning fish with prespawning sheefish moving up later. In the vicinity of McGrath and upstream of the mouth of the Takotna River, nearly all sheefish are prespawners.

A definite upstream spawning migration occurs as sheefish pass through the Aniak area in late May, but by early June, fish become scattered and movements are less defined as fish reach the Sleetmute area in July. Some prespawners move up to the Cutbank on the Holitna to feed during July. Others hold at the mouth of the Holitna to feed and then continue the spawning migration up the Kuskokwim River through July and August. Sheefish that reach McGrath and Medfra in July and August are nearly all spawners (Alt 1977b). Spawners enter Big River as early as late July, although the major spawning migration occurs in August and September (Alt 1971b). The spawning migration reaches the Highpower Creek spawning area in early September according to Telida residents. Test net results on 19 to 28 September 1971, revealed the presence of large numbers of spawners in lower Highpower Creek. The timing of arrival of sheefish onto spawning grounds in Big River has not been documented, but large numbers of spawners were already present during test netting operations in late September and early October 1980 (Alt 1981).

No information on the postspawning downstream migration is available because the river is freezing up during this time and netting is not possible. However, the migration has usually passed upper and middle Kuskokwim villages by the time subsistence fishing activities resume in November.

Spawning:

Sheefish of the anadromous Kuskokwim River stock are known to spawn in only two small areas in the upper Kuskokwim River. These areas are the lower 200 m of Highpower Creek and a 3 km section of Big River (64 to 67 km from the river mouth) (Figure 10) (Alt 1972, 1981). Reports prior to the initiation of research indicated that Kuskokwim sheefish spawning grounds were located in the upper Holitna River. However, no mature sheefish were caught during extensive sampling in the Holitna River in late September 1968, even though suitable spawning habitat was available in the vicinity of Titnuk Creek (Alt 1969a).

Highpower Creek is a small 65 km long stream that drains a muskeg-black spruce area of the upper Kuskokwim River. The stream mouth is located 16 km upstream from Telida and 1,221 km from the ocean. Some glacial water from the McKinley Fork of the Kuskokwim River enters Highpower Creek and thus water color is somewhat turbid even at low water levels. The lower 38 km of the stream were surveyed in 1971 and the only suitable spawning habitat was located in the lower 1.5 km of Highpower Creek. Bottom composition in the remainder of the stream was sand, silt, and some small gravel, but the stream was quite shallow.

The spawning habitat is subjectively judged as poor when compared with spawning grounds on the Kobuk and Koyukuk Rivers. Gravel in Highpower Creek is of a more uniform size than that of the Kobuk and Koyukuk River spawning grounds. The current velocity in the major spawning area is 1.2 m/s. The mouth of Highpower creek, where most spawning occurs, is 50 m wide, and 1.7 to 2.7 m deep (Alt 1972). The temperature was 3.7°C on 1 October 1971 at the beginning of spawning and dropped rapidly to 0.8°C on 3 October as very cold air temperatures caused slush ice to form. Spawning began at the mouth of Highpower Creek on 30 September. The peak of spawning activity was 1930-1940 hours and activity had ceased by 2245 hours. Aerial counts to enumerate spawning sheefish at Highpower Creek were unsuccessful.

The Big River spawning grounds were not located until 1980. Big River has its source in the 9,345 foot high Revelation Mountains of the Alaska Range. It flows north for 200 km and empties into the Kuskokwim River at 62°58'N lat and 155°2'W long. The spawning grounds are located 64-67 km upstream from the mouth. This section of Big River, located northwest of Lone Mountain, is at the upper end of the meandering portion of the river and has mud banks in contrast to the more braided character of the river further upstream. The North Fork and Lynn Fork of the Big River are glacial, and the river carries a heavy load of suspended silt from June to early October. Water clarity is dependent on glacial runoff and in normal years the river has cleared by early October when sheefish spawn.

Sheefish were not actually observed spawning on the Big River. However, based on location of prespawning sheefish and physical characteristics of the stream, it appeared that sheefish would spawn from the last large meandering bend of Big River upstream for a distance of 4.8 km (Figure 11). Of this 4.8 km section, the area shown as net site K, and sites Z-L had the best spawning habitat. This area had a gravel bottom composed of differentially sized gravel, a current of 1.3 m per second which kept the bottom cleared of algae and glacial silt and water depths of 1-2 m. Bottom substrate in the probable spawning area is composed of 5% sand and silt; 15% gravel less than 12 mm diameter; 30% gravel 12 to 25 mm, and 50% coarse gravel and rocks. Water depth along some of the cut banks was over 2 m deep. Big River ranges in width from 45-80 m and is generally confined to a single channel with some interspersed gravel bars (Alt 1981).

Although no spawning observations were made on Big River, it was apparent that spawning would commence soon after sampling was suspended on 3 October. Fish held for a potential egg take and those taken by gill nets in early October were freely running milt, and eggs could be expressed with little pressure.

According to McGrath residents, the area of Big River where sheefish spawn receives a constant flow of water during winter from small clear streams and water levels where eggs are incubating drop very little during winter. In contrast, adjacent glacial streams have very low flow by spring.

Female sheefish sampled in Highpower Creek were smaller than females in the Big River spawning group. In Highpower Creek, the average size of female sheefish was 810 mm while Big River females averaged 895 mm. Male sheefish in both spawning areas were similar in size. A possible

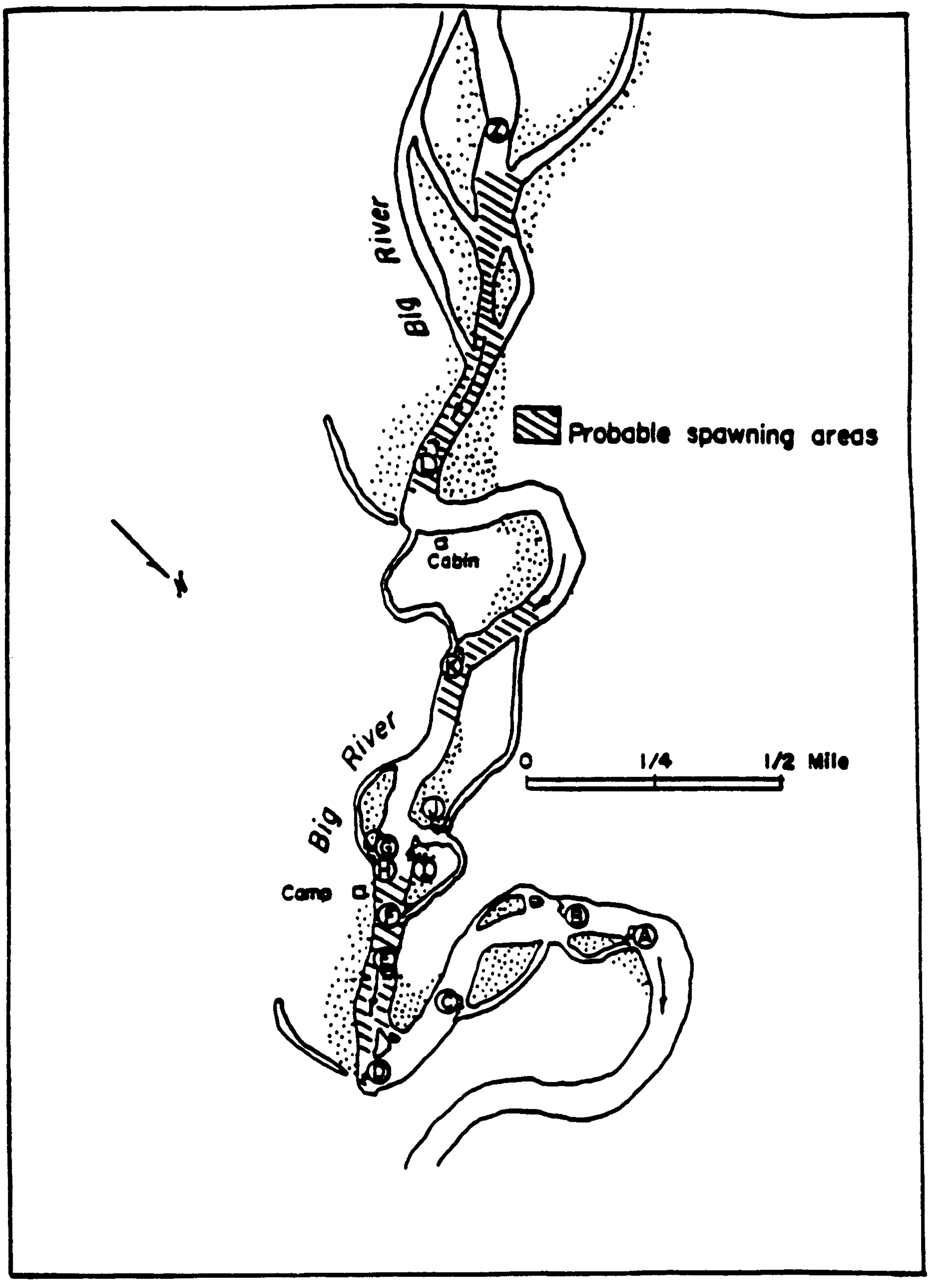

Figure 11. Big River netting and spawning areas, 1980. Sites A-L = netting areas; Z = hook and line capture.

explanation for the small size of female sheefish in Highpower Creek is selective harvest of larger sheefish by chinook salmon subsistence gill nets downstream. The average length and weight of 103 sheefish (mostly females) sampled from a subsistence fishery at Aniak was 840 mm and 10 kg, respectively.

At the Big River spawning site, 6 female and 28 male sheefish were caught for a sex ratio of 1:4.7 (Alt 1981). Females averaged 895 mm (range 780 to 1,033) and 9.27 kg (range 5.3 to 12 kg) and males averaged 715 mm (range 560 to 860) and 4.05 kg (range 2.0 to 6.3 kg). These fish ranged in age from 4 to 12 with the majority age 7 and 8. Fish of the younger age groups were all males and no males over age 10 were found. The mature age 4 males represent the youngest age at which sheefish are known to spawn in Alaska.

Fecundity samples were taken from two Big River females. A 1,033 mm female contained 286,840 eggs representing 27.4% of her body weight. A 968 mm fish contained 248,840 eggs representing 25% of her body weight. Egg to body weight of sheefish in the Kobuk-Selawik and lower Yukon females was approximately 20% (Geiger 1969; Alt 1978).

Koyuk River Sheefish

A small anadromous stock of sheefish occurs in the Koyuk River in Norton Sound. According to local residents, this stock overwinters in the estuarine Koyuk Bay and moves upstream after breakup. They report catching up to seven fish per day in subsistence nets during the spring migration. An aerial river survey was performed in 1970 (Alt 1971a). The only portion of the river with a gravel bottom was the lower Peace River and the lower East Fork River. Gill nets set in the lower Koyuk River on 26 and 27 July caught two sheefish, a 550 mm age 5 prespawning male and a 780 mm age 7 nonspawning female. No other information is available for this population.

Age and Growth

During the course of sheefish investigations, age and growth data were obtained from eight Alaska sheefish stocks. Because of relatively small sample sizes, differences in time or life stage of capture, and differences in capture methods; only general observations concerning age conposition and growth rates about these stocks can be made.

In all known cases, female sheefish live longer and attain a larger maximum size than males. For example, mean length of males sampled on the Kobuk River spawning grounds from 1965 to 1977 ranged from 770 to 801 mm while mean lengths of females ranged from 910 to 967 mm (Table 5). Of 273 females examined on the Kobuk River spawning grounds, 151 (55%) were older than 14, while only 6 of 447 males (1.3%) were older than age 14 (Alt 1978).

Length-weight relationships were calculated for a sample of 315 sheefish obtained in 1965-1966 from Selawik and the Kobuk Rivers (Alt 1969a). These relationships for males and females in each area are as follows:

Table 5. Mean fork length and weight of spawning sheefish sampled in the Kobuk River, 1965-1968 and 1976-1977.

	MALES					FEMALES				
Year	No.	FL (mm)	Range	Wt(kg)	Range	No.	FL(mm)	Range	Wt(kg)	Range
1965	32			5.1	2.6-8.0	36			9.7	5.4-16.1
1966	65	771	650-950	4.8	2.7-9.1	88	943	820-1,140	9.4	4.8-22.3
1967	104	774		4.8		99	961	850-1,130	10.7	
1968	276	770	667-901	5.1	2.7-8.5	193	967	760-1,120	12.3	
1976-77	47	801	600-876	5.1	3.2-6.8	48	910	810-1,029	8.2	5.9-12.5

From Geiger 1969.

Selawik - males	$W = 6.826 \times 10^{-7} L^{3.1355}$
Selawik - females	$W = 2.906 \times 10^{-6} L^{3.2859}$
Kobuk - males	$W = 5.443 \times 10^{-6} L^{2.8402}$
Kobuk - females	$W = 7.136 \times 10^{-8} L^{3.4844}$

where: W = weight in grams; and
L = standard length in mm.

Size and age at maturity is also consistently less for males than females. Kobuk-Selawik male sheefish first mature at age 7 while females first reach maturity at age 9. By age 11, all sampled Kobuk-Selawik males had spawned at least once, whereas 100% of females were not mature until age 14. The smallest mature male sampled on the Kobuk-Selawik River spawning grounds weighed 2.5 kg while the smallest female weighed 4.8 kg. The youngest documented sheefish age at maturity was for the Kuskokwim River where males matured between 4 and 8 years of age and females matured between age 6 and 9 (Alt 1981).

During research on Kobuk-Selawik sheefish, specimens up to age 20 and in excess of 1,100 mm and 15 kg have been sampled. These are the oldest ages and largest sizes documented for sheefish in Alaska. The stock with the next highest documented maximum age and length sample is the lower Yukon stock where fish up to age 15 and in excess of 10 kg have been sampled (Table 3). In most cases, sampling of each stock has been conducted on the spawning grounds, so (even though samples sizes are small in some cases) the maximum size and age structure can be considered to be indicative of the stock. Since the average rate of growth of Kobuk-Selawik sheefish is similar to that of other sheefish stocks (Figure 12), the larger documented maximum size of these fish must be due to the older maximum ages obtained. The fastest documented sheefish growth rates occurred in the Kuskokwim and Minto Flats sheefish stocks (Figure 12). Average length at age for these stocks was consistently 100 to 150 mm greater than those of the upper Yukon, Black, Porcupine, and Kobuk-Selawik River stocks (Table 3). For example, age 7 sheefish in the Kuskokwim River and Minto Flats averaged 676 and 658 mm, respectively; while mean length of 7 year old fish sampled from the upper Yukon, Black, Porcupine, and Kobuk-Selawik Rivers were 548, 581, 530, and 546 mm, respectively. Even the fastest documented Alaskan sheefish growth rates were much lower than those of sheefish from the Caspian Sea, U.S.S.R, where sheefish reach 1,000 mm by age 7 (Podlesnyi 1947).

Food Habits

Food habits of sheefish vary with area, life stage, and time of year. Juvenile sheefish feed primarily or insects and crustacea. The prey spectrum of 66 juvenile sheefish averaging 84 mm in length sampled from the estuarine area of the Yukon River mouth was dominated by estuarine-marine epibethos including misids (*Neomysis* sp.) and haustroiid amphipods, freshwater-estuarine chironomids, and cyclopoid and calonoid copepods. Ninety percent of young of the year sheefish sampled on the upper Yukon River had been eating insects (Alt 1965) (Table 6). The

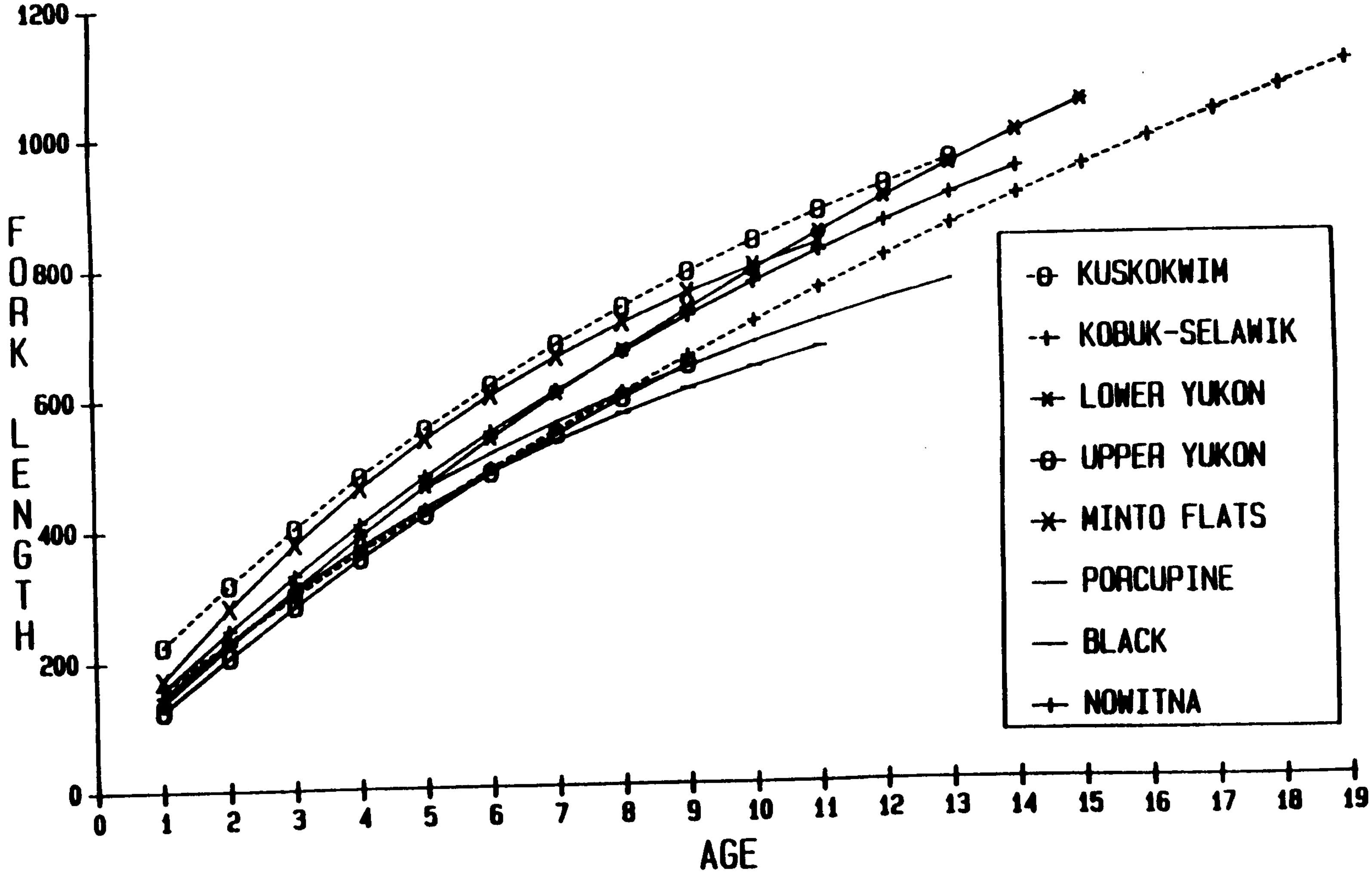

Figure 12. Growth curves of eight Alaska sheefish stocks.

Table 6. Percent occurrence of food items in sheefish from upper Yukon River by size of feeding fish.

Food organism	Upper Yukon River		
	Under 10 cm std. length (N=21)	10-20 cm std. length (N=12)	Over 27 cm std. length (N=34)
Fish: Total percentage	61.9	75.0	100.0
King salmon (fingerlings)	-	-	50.0
Broad whitefish	-	16.7	17.6
Least cisco	-	8.3	2.9
Arctic lamprey	-	-	8.8
Northern pike	-	-	8.8
Longnose Sucker	4.7	16.7	-
Burbot	-	-	5.9
Lake Chub	-	8.3	2.9
Unidentified fish remains	61.9	58.3	23.5
Insects: Total percentage	90.0	67.0	5.9
Ephemeroptera nymphs	23.8	33.3	-
Plecoptera nymphs	14.3	25.0	-
Diptera larvae	9.5	-	-
Hemiptera nymphs	4.8	-	-
Hemiptera adults	-	-	5.9
Coleptera larvae	-	-	2.9
Coleptera adults	4.8	-	-
Neuroptera adults	-	8.3	-
Odonata nymphs	-	8.3	-
Unidentified insect remains	61.9	16.7	-

primary insect species were ephemeroptera and plecoptera nymphs. Sixty-two of these young of the year sheefish had eaten some fish as well. This indicates that juvenile sheefish in the upper Yukon River become partially piscivorous at an earlier age than sheefish in Russia and Canada. Dirilov (1962) mentioned that 2 year old sheefish in the Vilyui River feed on fish, leeches, and tendipedid larvae and Kikolsky (1954) stated that sheefish become piscivorous in their second year of life. Fuller (1955) concluded that in Great Slave Lake, Canada, sheefish do not change to a fish diet until their third year of life.

In general, adult sheefish are piscivorous with lampreys, whitefish, northern pike, longnose suckers, and salmon smolts being the primary food items. On the upper Yukon River, the proportion of insects in stomach samples decreased and the proportion of fish food items increased with increasing size of sheefish (Table 6). One hundred percent of sheefish stomach samples taken from sheefish larger than 27 cm standard length contained fish remains, whereas only 5.9% contained insects. The primary food item of sheefish sampled from both the freshwater and estuarine environment (Selawik Lake, lower Selawik River, and lower Tuklomarak River) was least cisco (Table 7) (Alt 1969a). Crustacea, including *Mysis relicta* and *Mesidontea entomon* were present in over 10% of stomachs examined. Salmon smolts were the primary food of 129 sheefish sampled in the lower Holitna River in June and July (Alt 1972). Arctic lampreys, longnose suckers, and whitefish species were the major food items eaten by adult sheefish sampled in the Porcupine, Nowitna, and lower Yukon Rivers (Alt 1975). Migrating sheefish in turbid rivers such as the Yukon and Tanana often congregate near the mouths of clearwater tributary streams to feed. In Minto Flats, northern pike are a primary food item of sheefish. Fifteen of 19 sheefish sampled in mid-summer 1967 contained only northern pike and one 6.4 kg female sheefish had eaten 52 northern pike (Alt 1968).

The period of greatest feeding activity of Selawik River sheefish was immediately after breakup when nearly all stomachs examined contained food; mainly least cisco between 125 and 200 mm long weighing 100 to 200 grams. Through the course of the summer, the percentage of stomachs containing food decreased. Of 92 stomachs examined in late June, 54 contained food and 38 were empty. As fall approaches, prespawning sheefish generally cease feeding. Stomach were empty in all of 104 sheefish sampled during the 1965 and 1966 spawning migrations and on the spawning grounds in the Kobuk River. However, three of six sheefish sampled on spawning grounds of the Porcupine River contained whitefish remains (Alt 1975). This is the first Alaskan record of sheefish feeding on the spawning grounds.

Fisheries

Sheefish in Alaska are harvested by subsistence, commercial, and recreational users. The major harvest of sheefish in Alaska is by subsistence fishermen. For the lower Yukon River, subsistence harvest estimates are available for only a few years, but it appears that harvests have declined from peak levels in the mid-1960's as dog teams were replaced by snow machines as the main mode of transportation in rural villages. Alaska Department of Fish and Game records estimate the 1963 and 1964

Table 7. Stomach contents of Selawik River sheefish sampled in 1965. Of 283 stomachs examined, 202 contained food.

Food Organism	Number of Organisms	Number of Stomachs in Which Items Occurred	Stomachs in Which Organisms Occurred: Percent Occurrence in Feeding Fish
Fish:			
Least Cisco *Coregonus sardinella*	316	86	42.6
Rainbow smelt *Osmerus dentex*	26	18	8.9
Ninespine stickleback *P. pungitius*	63	14	6.9
Coregonus species (*C. nasus and C. pidschian*)	37	14	6.9
Broad whitefish *C. nasus*	13	7	3.5
Burbot *Lota lota Maculosa*	7	6	3.0
Humpback whitefish *C. pidschian*	4	4	2.0
Black fish *Dallia pectoralis*	3	2	1.0
Arctic char-Dolly Varden cx.- *Salvelinus alpinus (malma)*	1	1	0.5
Unidentified fish remains	-	64	31.7
Crustacea:			
Isopod *Mesidotea entomon*	263	29	14.4
Opossum shrimp *Mysis relicta*	870	22	10.9
Amphipods	3	3	1.5
Insects:			
Diptera larvae	3	2	1.0
Tricoptera adult	1	1	0.5
Unidentified insect remains	-	1	0.5

sheefish subsistence harvest in the lower Yukon River at 6,129 and 4,177 fish, respectively. Subsistence sheefish surveys conducted at Rampart on the Yukon River during sheefish tagging studies from 1972-1974 estimated a harvest of between 1,500 and 2,000 sheefish annually. With the completion of the Dalton Highway to the Yukon River in 1973, an increasing number of recreational dog mushers from Fairbanks began subsistence salmon fishing in the Yukon River near the mouth of the Ray River. Up to 1,000 sheefish annually are captured incidentally in this gill net and fish wheel fishery. On the upper Yukon River, small numbers of sheefish are also harvested incidentally during salmon subsistence fishing activities.

Crawford (1979) conducted a detailed winter-spring sheefish subsistence study in the lower Yukon River and documented a harvest of 3,394 sheefish by 71 fishing families. Estimated total harvest for the area was 5,438 fish. Residents of Kotlik, Sheldon Point, Alakunuk, Emmonak, and New Hamilton took 85% of the lower Yukon sheefish harvest. Fish were captured by gill net and sometimes by hook and line jigging through the ice. Harvested sheefish ranged in length from 287 to 862 mm and in age from 3 to 11 with age 7 being the modal age.

In 1968, the estimated sheefish subsistence harvest in the Koyukuk River was 2,500 fish (Alt 1969a). Most of these fish were spawning sheefish harvested by residents of Hughes and Allakaket.

The most detailed record of sheefish harvest over the course of a year is from the Kobuk River, 1965. The total estimated harvest was 34,000 to 37,000 fish (Alt 1969b). Subsistence users harvested over 85% of this total, recreational fishermen harvested fewer than 5%, and the commercial fishery accounted for the remaining 10% of the harvest. Although harvest data are scanty since 1965, it appears that the peak of the Kobuk River subsistence fishery occurred in the 1960's. The estimated sheefish harvest in 1967 was 31,200 sheefish (M. Geiger, ADF&G Anchorage, pers. comm.). As with the lower Yukon River, the decline in the use of dog teams in villages accounts for the decline in sheefish harvest.

The largest portion of the subsistence fishermen use hook and line gear through the ice at Selawik Lake and Hotham Inlet (Kobuk Lake). A small amount of under-ice gill netting occurs in the lower Selawik River and Hotham Inlet in October and November, but the majority of the harvest occurs during the jigging fishery in the lakes during April and May. Residents of Kotzebue, Noorvik, Kiana, Selawik, and Buckland participate in this fishery, generally making day trips by snow machine, dog sled or airplane to the lakes. Because schools of sheefish are migratory in the lakes, fishermen spend a good deal of time locating them. When schools are located, hundreds of fish can be caught in a few hours. Fish are usually frozen on the ice and are used for dog and human consumption. In the winter of 1987, sheefish ranging in age from 4 to 18 were sampled from this fishery (Table 8). These fish averaged 684 mm and 3.5 kg. The size and age composition of this sample is similar to that obtained in 1978 (Alt 1979).

Open water subsistence fisheries also occur in Selawik Lake, Selawik River, and Tuklomarak Lake beginning immediately after ice out,

Table 8. Age and size composition of 138 sheefish sampled from the Selawik Lake winter subsistence fishery, 1987.

Age	Number	Average Length (mm)	Average Weight (kg)
4	2	493	0.91
5	9	536	1.22
6	31	570	1.64
7	26	615	2.12
8	17	660	2.68
9	9	745	3.81
10	7	804	4.98
11	13	795	5.05
12	16	842	6.51
13	3	870	6.98
14	2	910	8.72
15	1	935	10.42
16	0	...	...
17	1	1,020	13.59
18	1	1,160	14.95
Mean		684	3.5

generally by late May or early June. These fish are harvested by gill nets and jigging (hook and line). In the upper Kobuk River, some spawning sheefish are harvested by subsistence fishermen using beach seines. Sheefish are also harvest by subsistence fishermen using gill nets, especially at Noorvik and Kiana during the postspawning downstream migration.

In the Kuskokwim River, the majority of the sheefish harvest is by subsistence fishermen using gill nets. The subsistence fishery is directed at sheefish during the early spawning run in the portion of the river from Bethel to Aniak, and Crooked Creek. Some fishermen in the lower Kuskokwim and residents of Telida target specifically on sheefish. The remainder of the subsistence harvest occurs incidentally to subsistence salmon fishing during the open water period, and under-ice whitefish and northern pike fisheries. Little data on the magnitude of the subsistence harvest are available. Sheefish harvest estimates collected during salmon subsistence surveys by the Department of Fish and Game provided minimum harvest estimates of 2,301 sheefish in 1963 and 1,244 fish in 1964. Many subsistence fishermen have switched to commercial chinook and chum salmon gill net gear for subsistence fishing and this has probably skewed the harvest toward the larger prespawning females. This type of gear may be responsible for the small percentage of females on the spawning grounds (Alt 1972, 1981).

Relatively minor subsistence fisheries also occur on Minto Flats, Black River, Nowitna River, and Porcupine River sheefish stocks. Most of this subsistence catch is incidental to salmon, whitefish, or northern pike fishing activities. In Minto Flats the estimated sheefish subsistence harvest in 1979 was 100 fish (Alt 1971b). Kepler (1973)) reported a subsistence harvest during July and August 1972 in Minto Flats of 200 fish, of which 50% were sheefish or whitefish.

Commercial fisheries directed at sheefish occur only on the lower Yukon River and Kotzebue Sound areas. Some sheefish are caught incidentally in commercial salmon fisheries in the middle Yukon, Kuskokwim, upper Yukon, and Tanana Rivers. From 1980 to 1986, two to four commercial permits were issued per year for the lower Yukon River. Quotas ranged from 230 to 450 kg. Permit holders generally took less than the allowable harvest. In 1986, for example, commercial fishermen in the lower Yukon River from Mt. Village to Pilot Station sold 2,640 kg of whitefish but no sheefish. Presently, the lack of a market is the main drawback to establishing a viable commercial fishery. Fish caught in these limited experimental commercial fisheries are usually sold in local villages.

Prior to 1985, the Kotzebue Sound commercial fishery was confined to Hotham Inlet and most fish were harvested by gill nets set under the ice in late October, November, and December. In 1985, a few sheefish were harvested in Selawik Lake during a northern pike and whitefish commercial fishery. The sheefish harvest quota (1,136 kg) is generally achieved by this commercial fishery. Most fish are frozen and sold in Kotzebue, Nome, Anchorage, or Fairbanks. Average weights of commercially sold sheefish were 3.0 kg, 3.2 kg, and 3.7 kg in 1965, 1967, and 1986, respectively. In 1965 3,940 commercially caught sheefish were sold and, in 1967, 2,375 fish were sold (M. Geiger, ADF&G Anchorage, pers. comm.). During some years, markets are not available and commercially caught sheefish are used by the fishermen. For example, in 1971 only 456 commercially caught sheefish were sold.

The only significant sheefish recreational fisheries occur in the Kobuk-Selawik Rivers, the Tanana River drainage, and the lower Yukon and Kuskokwim River drainages. In other areas, such as the Porcupine, Black, and Nowitna Rivers, sheefish are occasionally caught by sport fishermen who are targeting on northern pike or grayling. Sheefish sport harvests have generally increased since 1977 (Mills 1978-1986) (Table 9), but total recreational sheefish harvest is usually only a fraction of the subsistence harvest.

By far the largest recreational fishery for sheefish occurs on the Kobuk River. An estimated 60-70% of the sheefish harvest reported by Mills (1985) from Kotzebue Sound streams are harvested from the Kobuk River. Anglers catch sheefish in the lower Kobuk River delta and the lower 80 km of the river during June and in the vicinity of Ambler during July. In August and September, most anglers fish near the spawning grounds above Kobuk village. Recreational fishing at Selawik is generally best in early summer when spawning and feeding sheefish migrate from Selawik Lake, and in late August and early September when fish again enter Selawik Lake after spending the summer feeding in adjacent waters.

Prior to 1980, unguided anglers comprised the majority of sport fishermen on the Kobuk River. However, during the past 6 years, there has been an increase in both guided and local sport fishermen. Local fishermen and other nonguided anglers keep most of the fish they catch, while guided anglers and people floating the river are mainly hook and release fishermen.

A sample of sport caught sheefish from the upper Kobuk River in 1982 weighed an average of 9.1 kg for females and 4.89 kg for males. Fish as large as 15.9 kg are caught each summer, and in 1986, a 24.1 kg sheefish was caught on the Kobuk River.

The Kuskokwim River drainage supports a relatively large sport fishery for sheefish. Most fishing occurs in the Holitna River. Total annual recreational harvest probably ranges between 200 and 500 fish. In 1971, a creel census was conducted on the Kuskokwim recreational fishery from June through August (Alt 1972). During this time, an estimated 244 angler trips (962 angler hours) were expended to harvest an estimated 403 fish. Nearly all fishing effort occurred in July. Fishermen harvested 1.2 fish per angler day (0.3 fish per angler hour) and released 4 fish for every fish retained. Size of sheefish harvested ranged from 1.0 to 17 kg (Alt 1972).

As with the Kobuk River, there has been a trend toward an increase in numbers of guided fishermen on the Kuskokwim River, especially on the Holitna River. There are presently two guides operating on the Holitna River and up to five guides from Bristol Bay lodges who bring anglers to the Holitna River to fish. Total sport fishing effort appears to have

Table 9. Sheefish recreational harvest 1977-1985 (Mills 1978-1986).

	Sheefish Harvest								
Water	1977	1978	1979	1980	1981	1982	1983	1984	1985
Kobuk-Selawik R.	656	506	709	1,713	1,263	2,222	2,079	3,050	1,645
Tanana Drainage:	158	234	279	96	93	127	157	339	420
Minto Flats	68	90	182	26	11	10	63	0	35
Chatanika R.	14	54	26	25	0	31	94	143	0
Chena R.	37	18	26	21	50	10	0	156	210
Tanana R.	0	0	0	0	0	0	0	13	0
Other streams	39	72	45	25	32	76	0	13	140
Lakes	0	0	0	0	0	0	0	13	35
Yukon/Kuskokwim Drainages:	433	551	554	602	883	932	1,087	559	420
Total:	1,247	1,291	1,542	2,411	2,239	3,281	3,323	3,947	2,485

increased on the Kuskokwim. However, since most guided fishermen release the majority of fish caught, the total harvest has probably not increased.

In the Tanana drainage, the total sheefish harvest has ranged from 93 to 420 fish between 1977 and 1985 (Mills 1977-1986). Most fish were caught in Chena River, Minto Flats, and the Chatanika River (Table 9). The estimated recreational harvest of sheefish on the upper Chatanika River spawning grounds in 1963 and 1964 was 50 fish per year (Alt 1967). Most fish caught in Minto Flats are taken by anglers targeting on northern pike. During angler interviews conducted in Minto Flats in July 1967, 15 sheefish were observed. In 1968, an estimated 40 sheefish and 6,199 northern pike were caught by 430 anglers (Alt 1969b). These anglers released most of the northern pike they caught but retained all sheefish. In recent years, the largest sheefish harvests in the Tanana River drainage have come from the Chena River (Table 9).

Sheefish Enhancement

Efforts to raise sheefish in hatcheries and to stock them into new areas were begun in 1967. The goal of this enhancement program was to provide additional and more diversified angling opportunities for residents of interior Alaska through the development of hatchery enhancement techniques for sheefish. Specific objectives of the program from 1967-1986 have been: 1) to stock barren lakes and ponds in interior Alaska; 2) to stock lakes and ponds containing populations of chubs, suckers and other prey and competitor species; 3) to supplement current low natural populations in local rivers with hatchery reared sheefish fingerlings; 4) to assess growth and survival of stocked fish; and 5) to survey new waters for possible enhancement. A report titled "Sheefish enhancement study in Alaska 1967-1986" summarizes progress and problems related to egg takes, hatchery procedures, transport, stocking, and assessment of sheefish growth and survival during the first 20 years of the program (Alt and Parks 1987).

While the hatchery program was quite successful during the late 1960's, the failure of the Fire Lake Hatchery (Anchorage) to successfully hatch and rear eggs during almost the entire period 1970-1979 coupled with difficulty of obtaining viable fertilized eggs caused a slowdown in the enhancement program (Alt and Parks 1987). With completion of an experimental hatchery at Clear Air Force Station in interior Alaska in 1980, the production goals of the enhancement program were met in most years from 1980-1986. The major breakthrough in culture techniques was the success of the hatchery in rearing sheefish to fingerling size using commercially prepared hatchery food. Rearing of sheefish to be used as a hatchery brood stock was begun in 1981. A few eggs were obtained from the brood stock in 1984 and 1985, and in 1986 egg take goals were met almost entirely with hatchery brood stock.

Growth and Survival:

Growth and survival of stocked sheefish has been variable. Sheefish in some waters have experienced excellent growth and moderate survival while in other waters sheefish mortality has been almost 100% or growth has been slow (Alt and Parks 1987). Prior to 1980, sheefish had been stocked in small lakes and ponds of 1-35 surface hectares. In 1982, Harding Lake (980 ha) was stocked with 142,000 fingerlings with subsequent stockings of 211,000 and 88,000 fingerlings in 1984 and 1986, respectively. In extensive test sampling, no sheefish have been recovered. The lake contains burbot, pike, and lake trout. Predation by these fish or birds and/or poor stocking survival are possible explanations for the apparent low survival. In general, sheefish in barren lakes such as Four Mile Lake, Gull Lake, Walden Pond, Bullwinkle Lake, Island Lake, and Earthmovers Pit have had better survival and provided better fisheries than lakes and ponds that contained prey-competitor species (Alt 1980, 1981; Alt and Parks 1987). However, sheefish generally grow to a larger size in lakes containing a forage species. The largest sheefish caught from a stocked lake was a 6.3 kg fish from Lost Lake.

In 1985, 160,000 sheefish fingerlings, 70 to 90 mm FL, were stocked in the upper Chatanika River in the vicinity of spawning grounds of the native stock (Hallberg et al. 1986). This was the first stocking of hatchery produced fingerling sheefish into an open system. Growth and survival of these fish will be estimated in future years through test sampling and monitoring of the sport harvest.

Harvest:

The largest harvest of enhancement sheefish has been from Four Mile Lake near Tok. Size of fish captured in this lake has ranged from 0.2 to 4.3 kg. Harvest and effort estimates are not available for most individual stocked waters, but Mills (1986) reported a total harvest of 35 sheefish from stocked lakes or 8.3% of the total Tanana River drainage sheefish harvest.

Suggestions for Future Research

Much of the basic life history of major sheefish stocks in Alaska including distribution, movements, age and growth, food habits, spawning, and fisheries has been researched. However, limited quantitative population dynamics data are available. Stocks appear to be healthy and harvests by all user groups are relatively static, but no sustainable yields for any sheefish stock in Alaska have been determined, and the quantitative data needed to make these determinations are largely unavailable.

Detailed information on numbers of spawners in each stock, and mortality, exploitation, and recruitment rates are needed before harvestable surplus can be determined and optimum yield management strategies implemented. Given the apparently stable status of most sheefish stocks, collection of more detailed population dynamics information at the present time may not be a high priority research goal. However, retaining familiarity with trends and current use of sheefish by the subsistence, recreational, and commercial users as a minimum activity is suggested. Enlargement of the sheefish data base is recommended for situations where new commercial fisheries develop and where new road access or increased publicity results in greatly increased harvest. Because the Kobuk-Selawik stock is the most important in the state, both in terms of numbers of fish and size of the fishery, this information should first be gathered here. Increased harvest or industrial activity that could affect resident sheefish stocks should also receive priority attention. Since sheefish spawn in such restricted areas, industrial development could have a major impact. Coordination and cooperation with Federal (U.S.Fish and Wildlife Service, Park Service, and Bureau of Land Management), State (Department of Natural Resources) and private agencies (village and regional native corporations) should be sought in formulating sheefish management plans as all populations are resident within, or pass through, land owned or managed by one of the these agencies.

Specific suggested sheefish research and management activities are as follows:

1. Kobuk River: Conduct aerial counts of spawning sheefish in conjunction with Division of Commercial Fisheries salmon escapement counts. Harvest estimates on commercial, subsistence, and recreational fisheries in the Kobuk River and Kotzebue Sound areas should be collected. An age-weight-length sample of Kobuk River sheefish should be collected in 1987 for comparison with data collected in 1965-69 and 1976-78;

2. Minto Flats: The recreational and subsistence fishery in Minto Flats should be monitored in conjunction with northern pike creel census studies. Presence of Chatanika River enhancement sheefish in the Flats can be determined through scale pattern analysis;

3. Enhancement: Growth and survival of large fingerlings stocked in various lakes in 1986 should be evaluated. The feasibility and need for stocking sheefish in river systems other than the Chatanika should be evaluated.

4. Kuskokwim River: An age-weight-length sample of sheefish in the Holitna River should be collected during 1988 to compare with data collected during 1967-71 and 1978-80. Counts of spawning sheefish in the Kuskokwim River spawning areas, Big River, and Highpower Creek, should be made. In 1990, age-weight-length data from prespawning sheefish in both spawning areas should be collected to compare with 1971 and 1980 data.

5. Upper Yukon-Porcupine Rivers: ADF&G should cooperate with USFWS and NPS to monitor sheefish harvest.

6. Selawik River: A four year study should be undertaken to estimate population abundance and dynamic rates to determine sustainable yield of the Selawik sheefish stock and to determine if enough surplus yield exists to support a commercial fishery. Prespawning sheefish should be tagged in the upper Selawik River to see if any are recovered on the Kobuk River spawning grounds in subsequent years.

7. Lower Yukon River: Abundance of spawners of the anadromous lower Yukon stock upstream of Hughes on the Koyukuk River should be determined.

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