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THE EFFECTS OF GLOBAL WARMING ON THE DISTRIBUTION OF STEELHEAD TROUT (*Oncorhynchus mykiss*) POPULATIONS ON THE ALASKA PENINSULA, ALASKA.

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ABSTRACT

An investigation to determine the distribution, age and size structure, and sex composition of steelhead trout (Oncorhynchus mykiss) populations of the Alaska Peninsula, Alaska was conducted during summer and fall 1992. Water temperatures of selected drainages on the Peninsula were also collected. The study was an expansion of a long term investigation initiated in 1991 as part of the global climate change component of the Fishery Resource Monitoring Program (FRMP). The FRMP is designed to assess possible effects of climatic warming on fishery resources.

The presence of steelhead trout on the Alaska Peninsula is not documented north of the Chignik River system. It is hypothesized that steelhead trout will extend their range northward and their growth rate will change as a result of increased water temperatures from long term environmental global warming. Study objectives were to: (1) document the presence of steelhead trout in drainages of the Alaska Peninsula and monitor long term changes in their distribution; (2) describe length, weight, and age structure and sex composition of steelhead trout populations in drainages where they exist; (3) monitor long term changes in air and water temperatures and correlate these changes with growth and distribution of steelhead trout on the Alaska Peninsula.

During 1992, six drainages were sampled: Meshik River, King Salmon River-Mother Goose Lake, Chignik River, Sandy River, Sapsuk River, and Russell Creek. King Salmon-Mother Goose Lake drainage was added to the sampled rivers in 1992 after reviewing the 1991 sampling design. Approximately 16,000 fish representing 14 species were captured in all the drainages combined. Twenty-

three juvenile and six adult steelhead trout were captured in the Sandy River drainage. One juvenile and five adult steelhead trout were captured in the Russell Creek drainage. No steelhead were caught in the other four rivers. Juvenile steelhead trout lengths ranged from 49-158 mm, weights from 1-49 g, and ages from 0-2 years. Adult steelhead trout lenghts ranged from 328-680 mm, weights from 350-3,800 g, and ages from 2.2-2.4. The youngest first time spawner was age 2.1, while most fish spawned for the first time at age 2.2. Three adults were repeat spawners and appeared to have spawned annually.

Thermographs were recovered from the Chignik River, Sapsuk River, and Russell Creek drainages in 1992. Minimum temperatures ranged from -0.2 to -0.4 °C. Maximum temperatures ranged from 12.8 to 15.8 °C. Thermographs placed in the Meshik River and Sandy River drainages could not be found and were presumed lost during spring ice break-up. A thermograph was placed in the King Salmon-Mother Goose Lake drainage for the first time in 1992.

INTRODUCTION

In 1991, the U.S. Fish and Wildlife Service formed the Fishery Resources Monitoring Program (FRMP) to improve understanding of the status, trends, and causes and effects of changes in the Nation's fish populations and their habitats. The FRMP consists of a fishery inventory component to determine the status and trends of the U.S. fishery resources and a climate change component to detect and assess changes in fishery resources and habitats caused by global climate change. This study is funded under the climate change component. It is designed as a long-term monitoring program to document changes in the distribution and growth of steelhead trout (Oncorhynchus mykiss) and correlate these changes with water temperatures of selected drainages on the Alaska Peninsula in Southwest Alaska.

Steelhead trout in Alaska are found in coastal river drainages in Southeast Alaska, northward and westward around the Gulf of Alaska, and into Southwest Alaska on the Alaska Peninsula (Alaska Department of Fish and Game 1985; Didier et. al 1991). Steelhead trout are most common in the southeast portion of their Alaskan range. Most of the information concerning steelhead trout in Alaska comes from Southeast Alaska, northern Gulf of Alaska, Cook Inlet, and Kodiak Island.

Little data exist concerning steelhead trout in Southwestern Alaska. No directed studies have been conducted, and the information that does exist is incidental or anecdotal and not readily available. Observations of steelhead trout by fishery biologists and recreational, commercial, and subsistence fishermen suggest that steelhead trout occur in several drainages (Irving 1991). However, data from steelhead trout have been collected in few of these drainages (Alaska Department of Fish and Game 1985). Documented populations occur only from the tip of the Alaska Peninsula north to the Chignik River drainage.

Water temperatures affect the metabolism and behavior of steelhead trout (Shepard 1972; Reiser and Bjornn 1979; Barnhart 1986; Pauley et al. 1986). These effects vary depending on season and life stage. Steelhead have evolved within specific water temperature regimes. Any significant change in temperature may cause disease, affect growth and survival, or alter the distribution, migration, and maturation.

It is hypothesized that steelhead trout populations will extend their range northward on the Alaska Peninsula in response to increased water temperatures from long term global warming. This study will provide a baseline for documentation of the presence/absence of steelhead trout in selected drainages. Baseline water temperature data will also be collected to document changes in the thermal regimes of the drainages. Growth of steelhead trout will also be monitored for changes in temperature sensitive relationships of length, weight, and age.

The King Salmon Fishery Assistance Office initiated sampling for this study in 1991 (Irving 1991). Sampling was scheduled for the Meshik River, Chignik River, Sapsuk River, and Russell Creek drainages in 1991. However, weather and logistical constraints allowed sampling only in the Chignik River and Russell Creek drainages. Sampling resulted in the capture of one juvenile steelhead trout from the Russell Creek drainage. Sampling in 1992 was an expansion and refinement of the study begun in 1991.

Study objectives are:

(1) Document the presence of steelhead trout in drainages of the Alaska Peninsula and monitor long term changes in their distribution.

(2) Describe length, weight, and age structure and sex composition of steelhead trout populations in drainages where they exist.

(3) Monitor long term changes in air and water temperatures and correlate these changes with growth and distribution of steelhead trout on the Alaska Peninsula.

STUDY AREA

The drainages sampled are located on the Alaska Peninsula in Southwestern Alaska (Figure 1). These systems begin in the Aleutian Range and drain into the Bering Sea or Pacific Ocean. The lower reaches of these drainages are partially subject to tidal influence. The upper reaches of several of the rivers are braided, and most of the drainages contain large lakes. Substrates in the systems consist of silt, sand, gravel, and cobble. The riparian habitat is usually tundra with areas of willow (*Salix* sp.) and alder (*Alnus* sp.).

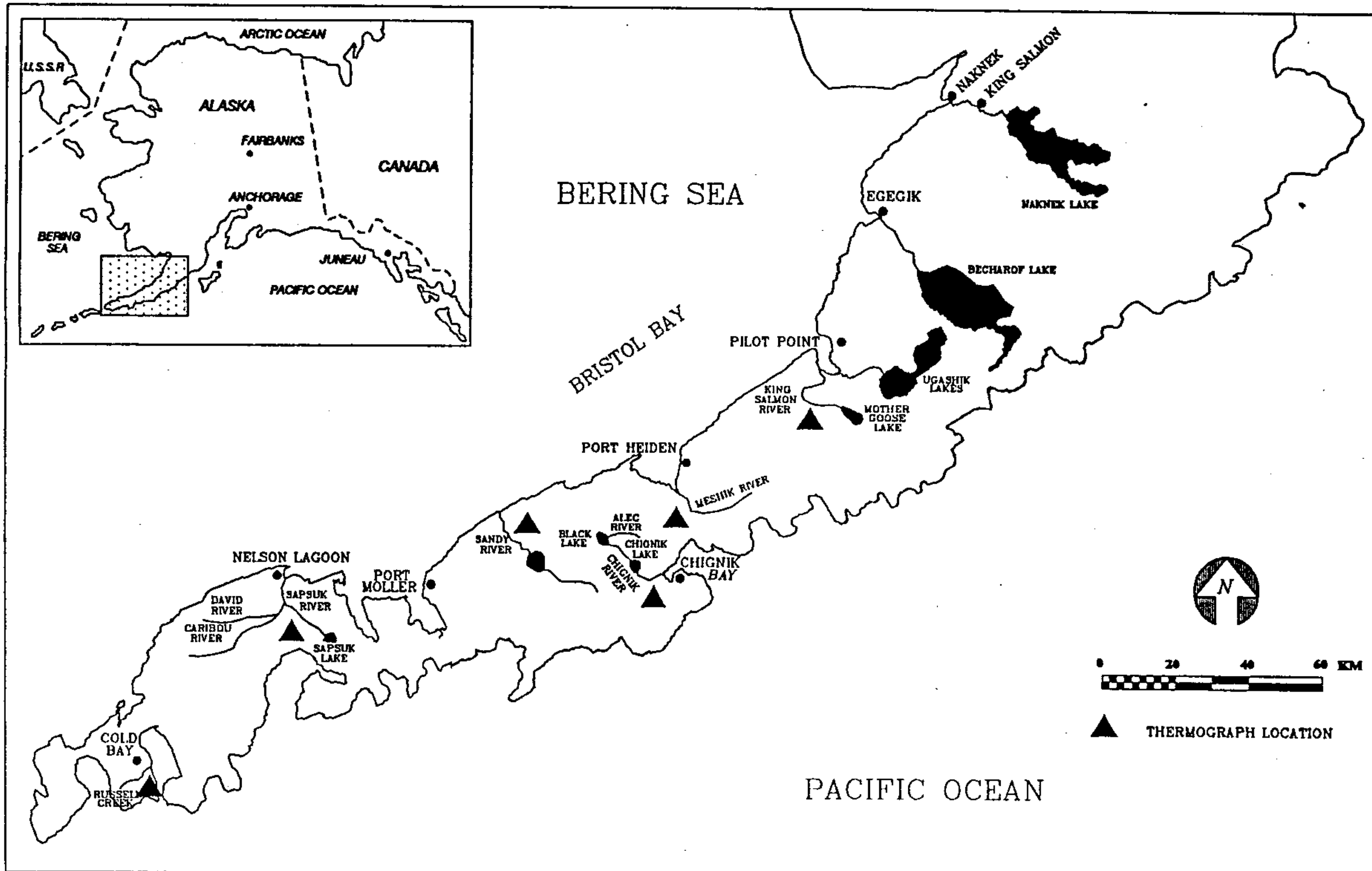

Figure 1.-Drainages on the Alaska Peninsula that were sampled in 1992 and are proposed for sampling in 1993.

METHODS

The duration of the initial study is designed to last 2-5 years and establish a baseline of steelhead trout distribution on the Alaska Peninsula. Subsequent monitoring will occur every 2-5 years thereafter to document changes in steelhead trout distribution and water temperature. Six index drainages were chosen: the Meshik River, King Salmon River-Mother Goose Lake, Chignik River, Sandy River, Sapsuk River, and Russell Creek. The Meshik River and King Salmon River drainages were used as controls because steelhead trout had not been reported from these systems (Irving 1991). These two drainages will be used to monitor the colonization of steelhead trout populations into systems north of their existing range.

Wheeled and float-equipped aircraft transported field crews, rafts, and gear into all drainages except Russell Creek. Russell Creek is accessible by road. Each system was sampled for 6-11 days except Russell Creek. Sampling for steelhead trout on Russell Creek was conducted in conjunction with a coho salmon tagging study. Sampling in Russell Creek occurred over a 36 day period. Directed sampling for juvenile steelhead trout occurring during 8 of these days. Sampling on all the drainages began at the highest accessible point. The mainstem of each drainage was sampled throughout its course, and all tributaries were sampled in their lower reaches.

Adult steelhead generally enter the stream in the fall and early spring and return to salt water by late spring. Due to weather, steelhead populations could only be sampled during the summer and early fall. Therefore, sampling focused on the capture of juvenile steelhead trout. Baited minnow traps, a 15 m beach seine (8 mm bar mesh), a fyke net (8 mm bar mesh), and a Smith-Root

Model 15-A backpack electrofisher were used to collect juvenile fish. A variety of stream habitats were sampled including runs, riffles, pools, root wads, sloughs, and along undercut banks. Lakes were only sampled along the shoreline. Hook and line was the only sampling method used for adult fish except in Russell Creek where a 50 m beach seine (38 mm bar mesh) was also used.

All fish captured were enumerated by species. Fork length (mm) was measured from all juvenile and non-anadromous fish. Because male steelhead trout under go morphological changes as they approach spawning, mid-eye to fork length (mm) was measured on adult anadromous fish. Weights (g) were measured from all steelhead trout with 50 g, 3 kg, or 6 kg Pesola spring scales. Scales for age estimates were collected from the preferred area (Jearld 1983) from all steelhead trout. Ages were determined by two readers, and disagreements were resolved by conference. Regenerated scales were discarded. The European method (years in freshwater.years in the ocean) was used to designate age for adult fish (Koo 1962). The sex of adult steelhead trout was determined by secondary sex characteristics.

Water temperature (°C) was recorded with Ryan Tempmentor Model 1.1 thermographs every two hours. Thermographs were housed in a steel pipe container, placed in a deep, non-tidal stream area, and anchored to the substrate. A thermograph was placed in each of five drainages during the fall of 1991. In 1992, a thermograph was placed in the King Salmon River-Mother Goose Lake drainage for the first time. During 1992, the data were recovered from the thermographs installed in 1991 and the thermographs were reset. In drainages where thermographs were lost, a new thermograph was installed. Thermographs will be maintained in each drainage during the years fish are collected, except in Russell Creek where a thermograph will be maintained for the duration of the global warming program. Air temperature data from the National Weather stations at Cold Bay and King Salmon, Alaska will also be used to identify temperature trends in the analysis.

RESULTS

During sampling conducted between June 15 to October 13, 1992, 15,801 fish representing 14 species were captured in six drainages (Table 1). Twenty-nine steelhead trout were captured in the Sandy River drainage and six steelhead trout were captured in the Russell Creek drainage. No steelhead trout were captured in the other four drainages.

Juvenile steelhead trout were relatively abundant in the Sandy River drainage. Fork lengths of the 23 juvenile steelhead trout captured in the Sandy River drainage ranged from 49-158 mm (Table 2). Weights ranged from 1-49 g and ages ranged from 0-2 years. One juvenile steelhead trout was captured in the Russell Creek drainage. It had a fork length of 68 mm, weighed 4 g, and was a young-of-the-year (age 0).

Six adult steelhead trout were captured in the Sandy River drainage. The mid-eye to fork lengths ranged from 328-635 mm and weights ranged from 350-3,600 g (Table 2). Readable scales were obtained from four of the six adult fish sampled; ages ranged from 2.3-2.4.

Table 1.-Number of fish captured by species in each drainage during 1992.

Species	Drainage and Sampling Period						Total
	Meshik (June 15-) (June 20)	King Salmon (June 21-) (June 28)	Sandy (July 22-) (July 30)	Chignik (July 31-) (Aug 10)	Sapsuk (Aug 10-) (Aug 15)	Russell (Sep 8-) (Oct 13)	
Steelhead (*Oncorhynchus mykiss*)			29			6	35
Chum Salmon (*O. keta*)		2				2	4
King Salmon (*O. tshawytscha*)	9	292	40				341
Sockeye Salmon (*O. nerka*)	221	1,169	626	34	113		2,163
Coho Salmon (*O. kisutch*)	820	936	2,880	1,050	1,901	1,117	8,704
Dolly Varden (*Salvelinus malma*)	128	54	219	1,896	92	585	2,974

Table 1.-continued.

Species	Meshik (June 15-) (June 20)	King Salmon (June 21-) (June 28)	Sandy (July 22-) (July 30)	Chignik (July 31-) (Aug 10)	Sapsuk (Aug 10-) (Aug 15)	Russell (Sep 8-) (Oct 13)	Total
	Drainage and Sampling Period						
Pygmy Whitefish (*Prosopium coulteri*)				68			68
Slimy Sculpin (*Cottus cognatus*)	6	155	62	32	16		271
Coastrange Sculpin (*C. aleuticus*)	4	48	10	124	107	21	314
Ninespine Stickleback (*Pungitius pungitius*)	8	45	55	14			122
Threespine Stickleback (*Gasterosteus aculeatus*)	12	403	1	303	47		766
Alaska Blackfish (*Dallia pectoralis*)	10	6	1	1	1		19

Table 1.-continued.

Species	Meshik (June 15-) (June 20)	King Salmon (June 21-) (June 28)	Sandy (July 22-) (July 30)	Chignik (July 31-) (Aug 10)	Sapsuk (Aug 10-) (Aug 15)	Russell (Sep 8-) (Oct 13)	Total
	Drainage and Sampling Period						
Starry Flounder (*Platichthys stellatus*)				1	10	3	14
Arctic Lamprey (*Lampetra japonica*)		6					6
Total	1,218	3,116	3,923	3,523	2,287	1,734	15,801

Table 2.-Sample size, mean length (mm) and weight (g) at age, standard deviation, and range for steelhead trout captured in the Sandy River and Russell Creek drainages, 1992. Juvenile steelhead trout were measured by fork length (mm) and adults by mid-eye to fork length (mm).

		Length			Weight		
Age	*N*	$\bar{X}$	*SD*	Range	$\bar{X}$	*SD*	Range
Sandy River							
0	1	49.0	-	-	1.0	-	-
1	18	86.8	10.5	70-107	7.9	2.4	4-12
2	4	154.5	3.0	150-158	41.5	4.8	35-49
2.3	1	328.0	-	-	350.0	-	-
2.4	3	446.3	14.4	430-465	1,133.3	102.7	1,000-1,250
UNK[a]	2	607.5	27.5	580-635	3,025.0	575.0	2,450-3,600
Russell Creek							
0	1	68.0	-	-	4.0	-	-
2.2	3	599.7	12.1	582-612	2,750.0	248.3	2,550-3,100
2.3	1	617.0	-	-	3,400.0	-	-
2.4	1	680.0	-	-	3,800.0	-	-

[a] Ages could not be determined.

Mid-eye to fork length of five adult steelhead trout captured in Russell Creek ranged from 582-680 mm. Weights ranged from 2,550-3,800 g. Adult ages of steelhead trout from the Russell Creek drainage ranged from 2.2-2.4.

The two largest steelhead trout from the Sandy River drainage were the only fish whose sex could be determined from secondary sex characteristics. Both fish were darkly colored males with well developed kypes, had firmly embedded scales, and appeared to have spawned earlier in the year.

Data were recovered from the Chignik River (Figure 2), Sapsuk River (Figure 3), and Russell Creek (Figure 4). The Maximum and minimum bi-hourly temperature recorded was 12.8 °C on 30 July and -0.4 °C on 31 January in Chignik River, 15.8 °C on 31 July and -0.2 °C on 4 January in Sapsuk River, and 15.2 °C on 9 August and -0.2 °C several times during November-April in Russell Creek. Thermographs could not be recovered from the Meshik River or Sandy River drainages.

DISCUSSION

As expected, no steelhead trout were captured in the Meshik River and the King Salmon River-Mother Goose Lake drainages. Wagner and Lanigan (1988) also did not capture steelhead trout during their study of the Meshik River during the summer of 1984. These systems are north of the documented range of steelhead trout on the Alaska Peninsula and will be used to document northward colonization of this species.

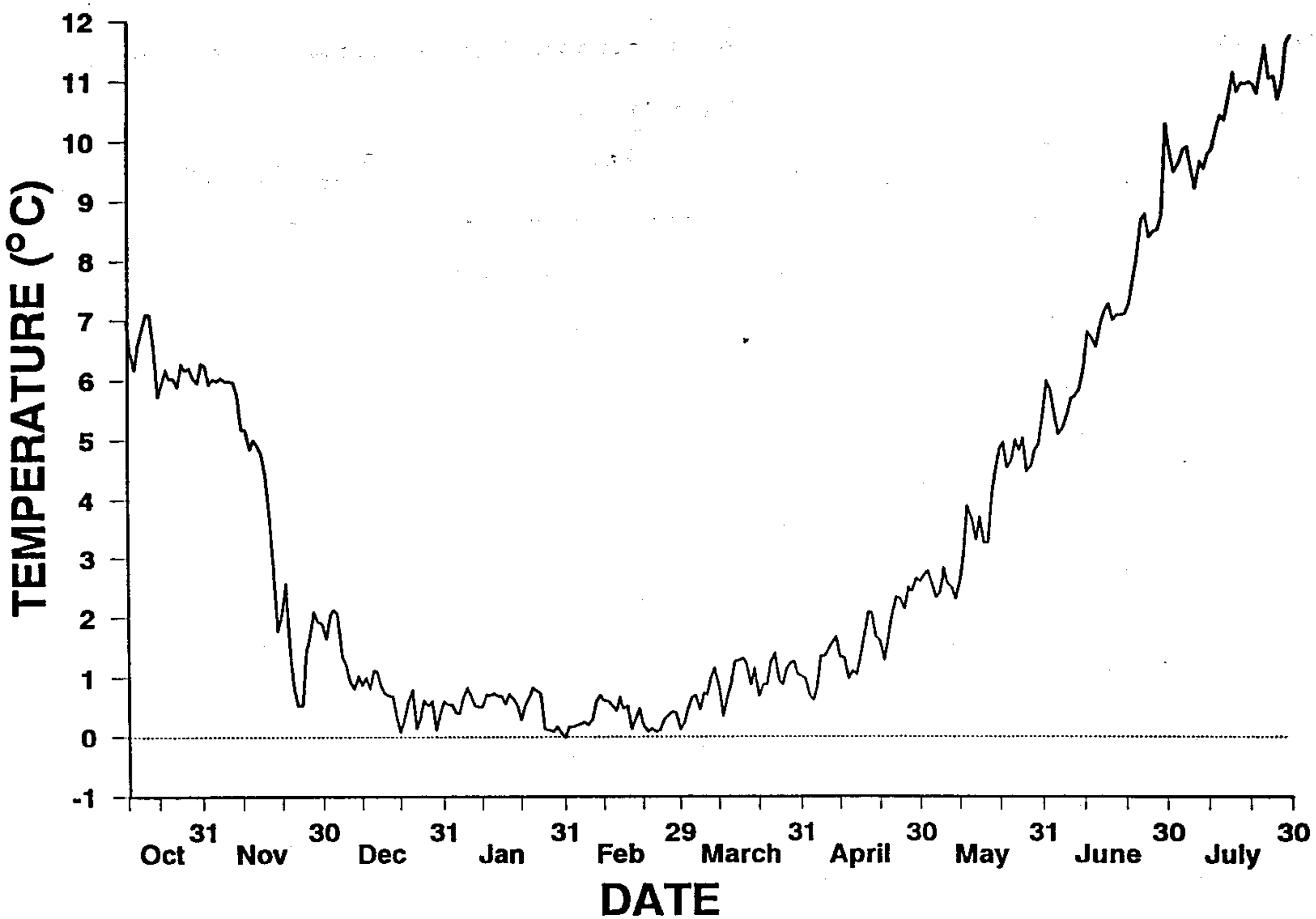

Figure 2.-Mean daily temperatures (°C) from the Chignik River drainage, October 12, 1991 to July 30, 1992.

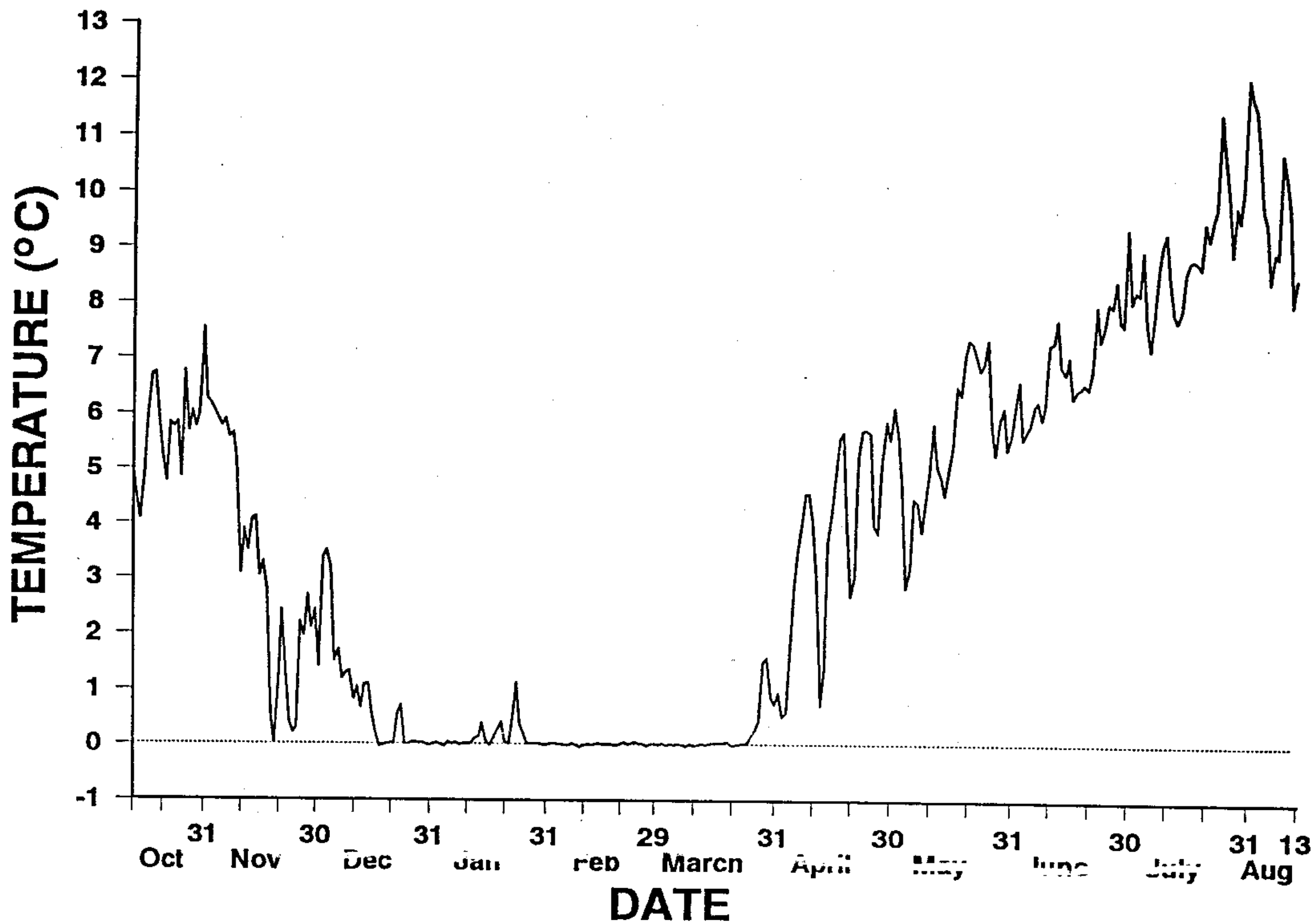

Figure 3.-Mean daily temperatures (°C) from the Sapsuk River drainage, October 12, 1991 to August 13, 1992.

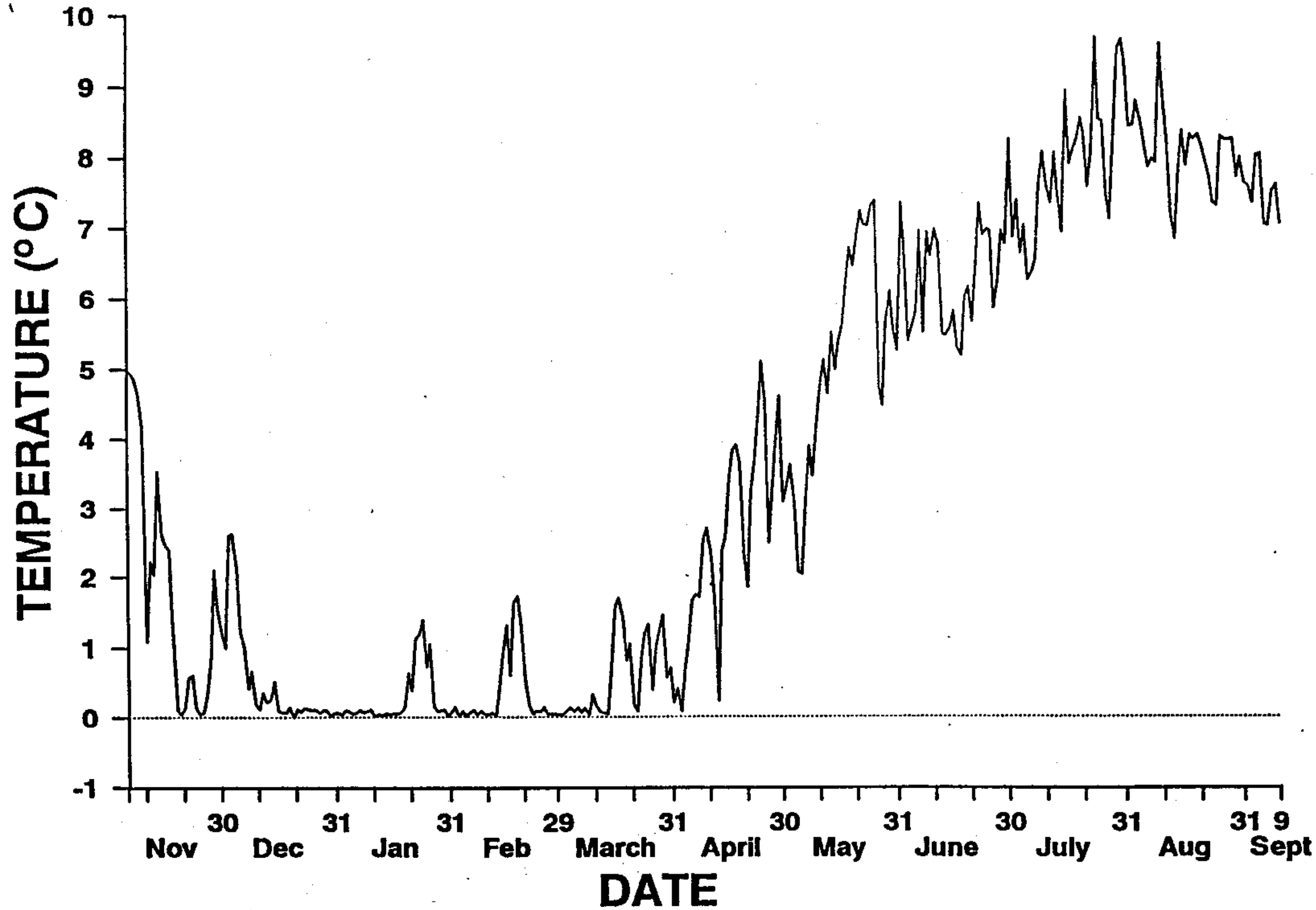

Figure 4.-Mean daily temperatures (°C) from the Russell Creek drainage, November 5, 1991 to September 9, 1992.

Steelhead trout were expected to be captured in the remaining drainages. However, no steelhead trout were captured in the Chignik River and Sapsuk River drainages. Steelhead trout exist in the Chignik River system, but their abundance appears to be low. Kelts (emigrating post spawners) have been observed during their out-migration at the Alaska Department of Fish and Game sockeye salmon weir on the Chignik River (Allen Quimby, Alaska Department of Fish and Game, personal communication). Kelts have also been captured in gill nets during the sockeye salmon subsistence fishery. During directed sampling in 1991, steelhead trout were not captured (Irving 1991). In addition, the Fishery Research Institute has been sampling sockeye salmon populations through out the drainage since 1955 without capturing any steelhead (Gregory Ruggerone, University of Washington, Seattle, personal communication). Anecdotal information suggests that the Alec (Scow) River may be the major spawning tributary for steelhead trout in the drainage, however, this tributary could not be accessed in 1992 due to low water levels.

Although steelhead trout were not captured during sampling in the Sapsuk River drainage, commercial fishermen have reported capturing kelts during the sockeye salmon fishery in the lower reaches of the drainage (Bob Berceli, Alaska Department of Fish and Game, personal communication). However, kelts have not been observed during their out-migration at the Alaska Department of Fish and Game sockeye salmon weir on the Sapsuk River mainstem. Anecdotal information suggests that the Caribou-David River system may provide the major spawning areas for steelhead trout in the drainage, but this system is difficult to access.

Juvenile steelhead trout were relatively abundant in the Sandy River drainage. One juvenile was captured in Sandy Lake while the remainder were captured in the river. The river is braided and appears to provide prime rearing habitat with clear, swift water, and an abundance of rootwads and side channels.

Overall very few steelhead trout were captured in 1991 and 1992. Possible reasons for the low catches were: (1) sampling during portions of the year when juvenile and adult steelhead trout were not available; (2) low numbers of juvenile steelhead trout compared to higher numbers of other species; (3) and a low amount of effort in each drainage.

With the time of sampling and the limited effort, the number of steelhead trout captured in the Sandy River drainage indicates that this stock is relatively healthy. The population supports a small recreational fishery that practices catch and release on this species (Mel Gillis, recreational fishing guide, personal communication). The remoteness of this drainage will probably assure that the short term health of this stock will not decline.

However, the population of steelhead trout in the Russell Creek drainage may be declining. Sampling in Russell creek occurred over a longer period than in Sandy River and occurred closer to the time adult steelhead are supposed to enter the stream. Seining in the Russell Creek drainage further increased the effort directed at steelhead. However, when compared to the catch in Sandy River, fewer juvenile and adult steelhead trout were captured. U.S. Fish and Wildlife coho sampling crews seined and conducted a creel survey in Russell Creek until early November. Only three steelhead were caught during seining and five steelhead were caught by anglers. This sampling suggests that the spawning population may be small. Anecdotal information from local fishermen suggests that steelhead catches have declined in recent years. Also, the drainage is readily accessible by road and fishing pressure has increased, primarily during the coho salmon run (Mark Chase, U.S. Fish and Wildlife Service, personal communication). The Russell Creek drainage is also subject to intense storms which cause frequent flooding. Flood scouring and natural environmental changes may have affected survival of some year classes and reduced the abundance of adult steelhead.

In freshwater, steelhead trout juveniles generally grow to approximately 100 mm after their first winter and 150 mm by the end of their second winter (Burgner et al. 1992). Juvenile steelhead trout from the Sandy River and Russell Creek drainages exhibited a similar growth pattern.

Steelhead trout in Alaska spend from one to four years in freshwater with most fish spending three years in freshwater before emigrating to the sea (Sanders 1985). However, all adult steelhead trout captured in the Sandy River and Russell Creek drainages had spent only two years in freshwater.

Spring and fall runs of steelhead trout occur throughout the state with fall runs predominating north and west of the Gulf of Alaska (Sanders 1985). The populations in the Sandy River and Russell Creek drainages appear to be fall run fish.

The spawning ages of steelhead trout in Alaska is highly variable (Sanders 1985). Steelhead may first spawn at age 2.1, however most fish spawn for the first time after two winters at sea. In Sandy River and Russell Creek, some steelhead first spawned at age 2.1, while the majority of fish spawned for the first time at age 2.2. Only one fish spawned for the first time at age 2.3 (Sandy River). The three fish that were repeat spawners appeared to have spawned annually.

The out migration of kelts in Alaska occurs anytime after spawning with the peak out migration occurring usually before mid-July (Sanders 1985). Two male steelhead trout captured on July 26 in the Sandy River drainage appeared to have spawned in the spring, but had not yet returned to sea.

The mean daily temperatures from the Chignik River, Sapsuk River and the Russell Creek drainages exhibited similar annual temperature fluctuations. However, the mean daily temperatures from the Sapsuk River and the Russell Creek drainages were more variable than temperatures from the Chignik River drainage. Both the Chignik River and Sapsuk River drainages contain large lakes which moderate diurnal temperature oscillations (Hynes 1970). However, the thermograph in the Chignik River system was located approximately one km downstream from the Chignik Lake outlet while the thermograph in the Sapsuk River system was located approximately 30 km downstream from the Sapsuk Lake outlet. The proximity of the Chignik River thermograph to the lake probably moderated temperature changes. The thermograph in the Sapsuk River system was located beyond the moderating influence of Sapsuk Lake and exhibited a pattern similar to Russell Creek.

The thermographs that could not be recovered apparently were detached from the substrate by ice. Although deep areas of the stream were chosen for anchoring the thermographs, these areas may be susceptible to ice scour as the stream freezes and the water level drops. Alternate methods of anchoring the thermographs will be developed.

Recommendations

Because the steelhead populations are small and sporadically distributed, overlooking a population is possible. Quantifying steelhead relative abundance within reasonable statistical bounds under the present sampling design is difficult. To overcome these sampling problems, a more efficient method to locate steelhead trout concentrations needs to be developed. Because steelhead trout spawn in the spring when water clarity is best, concentrations of adult spawners can be located using aircraft. Once adult spawning locations are found, then sampling for juvenile abundance could be concentrated in these areas.

The study design will be modified to include aerial surveys during the spring. The methods used in 1991 and 1992 to sample juveniles will not change. Aerial observations will aid identification of stream index reaches that can be consistently sampled for juvenile abundance and eliminate some sampling variability. Because the aerial survey will increase the project costs, juvenile sampling will need to be more focused. It will be assumed that the absence of adult steelhead indicates juvenile steelhead are not present or are in very low concentrations and these systems will not be sampled for the presence of juvenile steelhead trout. Information on presence and relative abundance (CPUE) of juvenile steelhead trout will be used to characterize distribution trends and indicate successful reproduction.

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