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Seasonal Habitat Utilization by Juvenile Salmon in the Lower Taku River, Southeast Alaska

December 1988

ERRATA NOTICE

SEASONAL HABITAT UTILIZATION BY JUVENILE SALMON IN THE LOWER TAKU RIVER, SOUTHEAST ALASKA

by

J. F. Thedinga, M. L. Murphy, and K V. Koski

Auke Bay Laboratory
Northwest and Alaska Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
P. O. Box 210155
Auke Bay, Alaska 99821

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ABSTRACT

Seasonal habitat utilization of juvenile Pacific salmon (Oncorhynchus spp.) was determined in three habitat types (beaver ponds, side sloughs, and channel edges) in the Taku River, Alaska from May to November 1987 and in May 1988. Throughout the study, coho salmon (O. kisutch) were most abundant in beaver ponds (mean, 23/100 m^2), and sockeye (O. nerka) and chinook salmon (O. tshawytscha) were most abundant in channel edges (means, 29/100 m^2 and 47/100 m^2, respectively). Mean densities of age-0 coho, sockeye, and chinook salmon were much higher than densities of age-1 or age-2 fish in all months except May, when smolts dominated catches. Coho densities remained at a low level (mean, 1.6/100 m^2) throughout summer and early fall in side sloughs and channel edges, but steadily declined in beaver ponds after peaking in July. Sockeye densities were higher but more variable (mean, 10.8/100 m^2) in side sloughs and channel edges than in beaver ponds, where densities were consistently low (mean, 1.2/100 m^2). Chinook were absent in beaver ponds, and densities in side sloughs were low (6.2/100 m^2) except for an increase in November; Chinook densities in channel edges increased sharply from July (19.6/100 m^2) through October (69.9/100 m^2). Beaver ponds and side sloughs appeared to be important overwintering areas for juveniles and side sloughs important staging areas for migrating smolts in spring.

CONTENTS

INTRODUCTION

The Taku River is a major producer of five commercially important species of Pacific salmon (Oncorhynchus spp). The river originates in British Columbia, Canada and empties into Taku Inlet in Southeast Alaska. Taku River salmon are commercially harvested by the United States and Canada, therefore, partitioning of the salmon resource is a concern to both countries. To help secure optimal production and equitable division of the resource, information is needed on seasonal habitat utilization of juvenile salmon to ensure that rearing habitat in the U.S. portion of the Taku River (lower Taku River) is fully utilized.

Information is scarce on the life history of juvenile salmon in the Taku River. Two coded-wire tagging studies have been conducted: Kissner (1984) tagged juvenile chinook salmon in the Canadian portion and in the estuary of the Taku River, and Elliott and Kuntz (1988) recently began tagging juvenile coho salmon in Yehring Creek, a tributary entering the lower Taku River. One study to sample downstream-migrant juvenile salmon was conducted by Meehan and Siniff (1961) in the lower Taku River. Research completed by the National Marine Fisheries Service in 1986 (Heifetz et al. 1988) indicated that high densities of juvenile sockeye salmon rear in the lower Taku River in summer. Radio tagging studies of adult salmon showed that most sockeye and chinook salmon spawn in Canadian waters (Eiler et al. 1988). It was not evident, however, whether juveniles that migrated from the Canadian portion of the Taku River and reared in the lower river remained in specific habitats, or if certain areas harbored only transient fish and other areas supported stable populations throughout summer.

Objectives of this study were to determine seasonal changes in density, size, and age composition of three species of juvenile salmon in three habitat types in the lower Taku River.

STUDY AREA

The glacial Taku River is approximately 250 km long, of which over 200 km is in Canada, and drains an area of nearly 16,000 km^2 (Fig. 1). The lower river has many braids and numerous side channels, and tributaries that have beaver ponds. Channel width varies from approximately 400 m at the U. S./Canada border to nearly 3 km at the mouth. Discharge ranges from < 100 m^3/s in winter to nearly 2000 m^3/s in summer. Besides the seven species of Pacific salmon, dolly varden char (*Salvelinus malma*), whitefish (*Prosopium* spp.), long nose sucker (*Catastomus catastomus*), three-spine stickleback (*Gasterosteus aculeatus*), and cottids (*Cottus* spp.) rear in the lower Taku River.

METHODS

The habitat types selected for determining habitat utilization by juvenile salmon in the lower Taku River were based on the habitat classification systems of Sedell et al. (1983) and

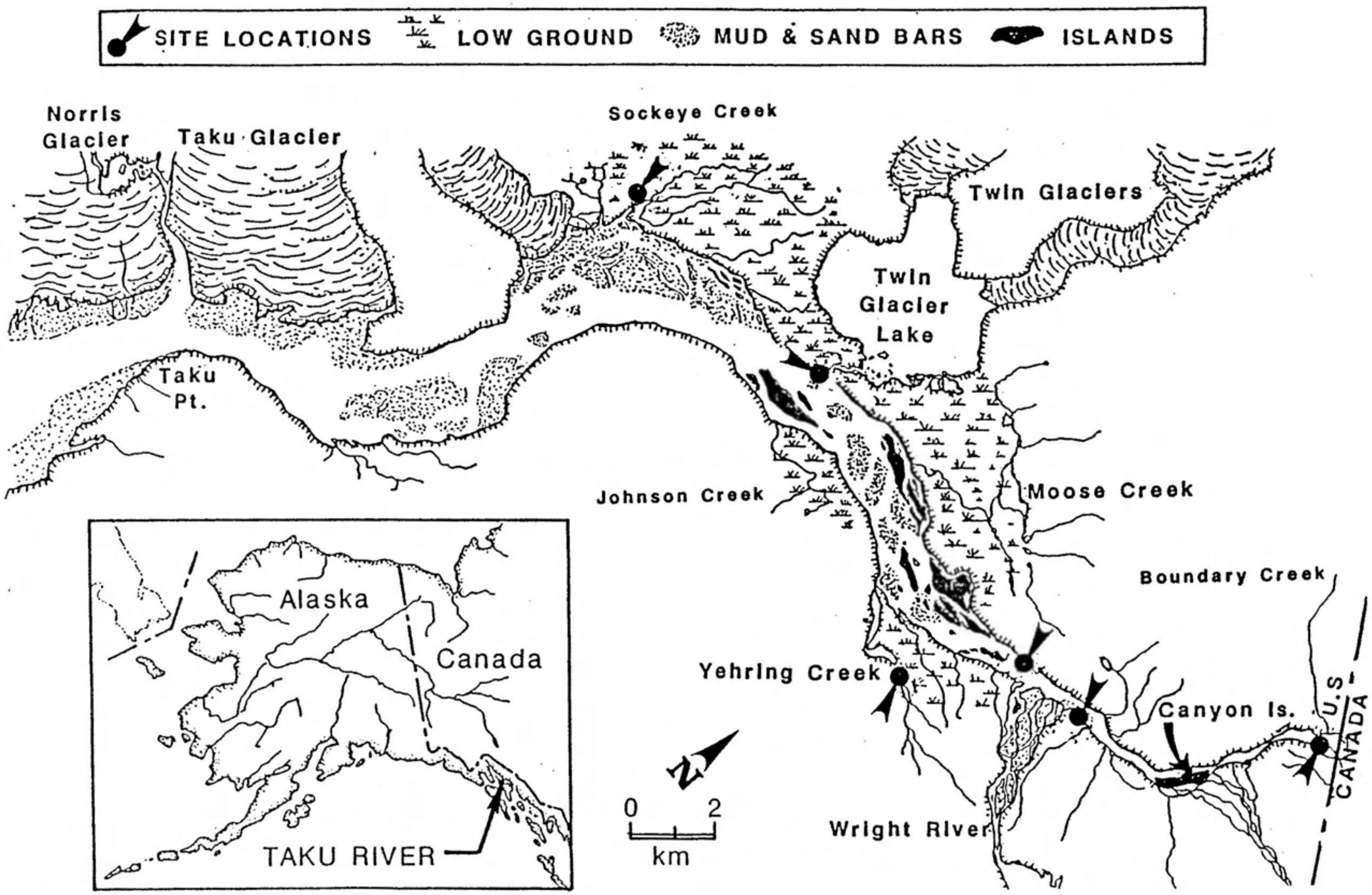

Figure 1. Study sites in the Taku River, Southeast Alaska.

Edgington and Lynch[1] (Table 1). Two habitats within the active river channel (side slough and channel edge) and one off-channel habitat (beaver pond) were selected because of the presence of at least 2 species of juvenile salmon in each site. Two sites in each habitat type were sampled from May to October 1987, three sites were sampled in November 1987 (one channel edge and two side sloughs), and all sites were sampled in May 1988 (Fig. 1).

Table 1.-- Definitions of habitat types in the lower Taku River, Alaska.

Habitat type	Definition
Side slough	Percolation-fed channels with slow (0-15 cm/s), sometimes clear water; formed when the head of a braid of side channel is blocked by sediment and organic debris.
Channel edge	Margins of main and side channels, extending about 3 m from shore; water velocity often moderate (<30 cm/s).
Beaver pond	Ponds impounded by beaver dams on terrace tributaries and upland sloughs.

Fish were captured with either a pole seine or a beach seine set from a canoe and retrieved from shore. At channel edges, three separate seining stations, spaced at least 50 m apart, were sampled with a small pole seine (netting was 5.4 m long and 1.5 m

[1]J. Edgington and J. Lynch, unpubl. data. Alaska Department of Fish and Game, Box 667, Petersburg, AK 99833.

deep with 6-mm mesh; poles were attached to both ends of the net). The seine was pulled parallel to shore for 20 m; the area seined was 74 m^2. At each station, at least 3 sets were made. At side sloughs, 3 seining stations were sampled for fish with either a pole seine or a beach seine. Depending on the beach seine used, the area sampled was 37 m^2 or 219 m^2, based on a semicircle of 15.2 m and 30.5 m perimeter, respectively. Fish were captured in beaver ponds with the same beach seines used for side sloughs.

Population sizes of all juveniles were estimated monthly. A single census mark-recapture method was used to estimate population size in beaver ponds, and in side sloughs when the water level was sufficiently low (Robson and Regier 1971). Fish were marked by clipping a tip of the caudal fin and released. After at least an hour, fish were recaptured in the same manner and examined for marks. In channel edges and side sloughs when the water level was high, the number of each species at each site was estimated by the removal method (Zippin 1958)

$$N = \frac{C}{1-(i-q)^n},$$

where $\underline{N}$ = number, $\underline{C}$ = total catch, $\underline{n}$ = number of passes, and $\underline{q}$ = probability of capture at each area. We estimated ($\underline{q}$) by successive approximation (Moran 1951). The probability of capture was assumed constant, and immigration and emigration were assumed negligible during sampling. The total catch of fish was

used in the analysis instead of t
probability of capture (q) was <
with a seine were made through each
Density at each separate area was
population estimate by the area s
site was computed as the mean of t

A subsample of fish of each
for fork length (FL) to the nearest
were taken for ageing. Age-0 fish
in the field by a predetermined cu
from 50-65 mm. Age composition wa
ages of the scales with the length
movement, all fish captured in sid
July were marked by removing one t

Habitat was measured monthly
beaver ponds and side sloughs was
width at 10-m intervals (transects)
habitat and applying the formula f

A = 1/2 (a +

Water depth was measured at 1/4, 1/
each transect of beaver ponds and a
slough and channel edge station. W
with a current meter at 1/4, 1/2, a
middle of each side slough and chan
of pool, riffle, and glide were visu

Water temperature was measured every 2 h with continuous recording ENDECO[2] thermographs at all sites except one channel edge and water turbidity was estimated with a nephelometer. Percentage of silt/sand in the substrate was visually estimated at each site.

RESULTS

Abundance and Distribution

Densities of juvenile coho, sockeye, and chinook salmon were high in spring, decreased sharply in summer, then increased in fall (Figs. 2, 3). Densities of all species were significantly different between habitat types ($\underline{P} < 0.05$, Friedman test). Coho were most abundant in beaver ponds (23/100 m^2) in all months except May 1987 when density was highest in side sloughs (Figs. 2, 3, 4). Sockeye were most abundant in side sloughs (22/100 m^2) and channel edges (29/100 m^2) (Fig. 4). Chinook were most abundant in channel edges (47/100 m^2) (Fig. 4) all months except November, when density was highest in side sloughs. Chinook were absent from beaver ponds all months.

Coho

Density of coho in the beaver ponds peaked in July (51.7/100 m^2), gradually declined through October, then increased slightly the following May (Figs. 2, 3). The peak in July was especially noticeable for age-0 fish where density increased from

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[2] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

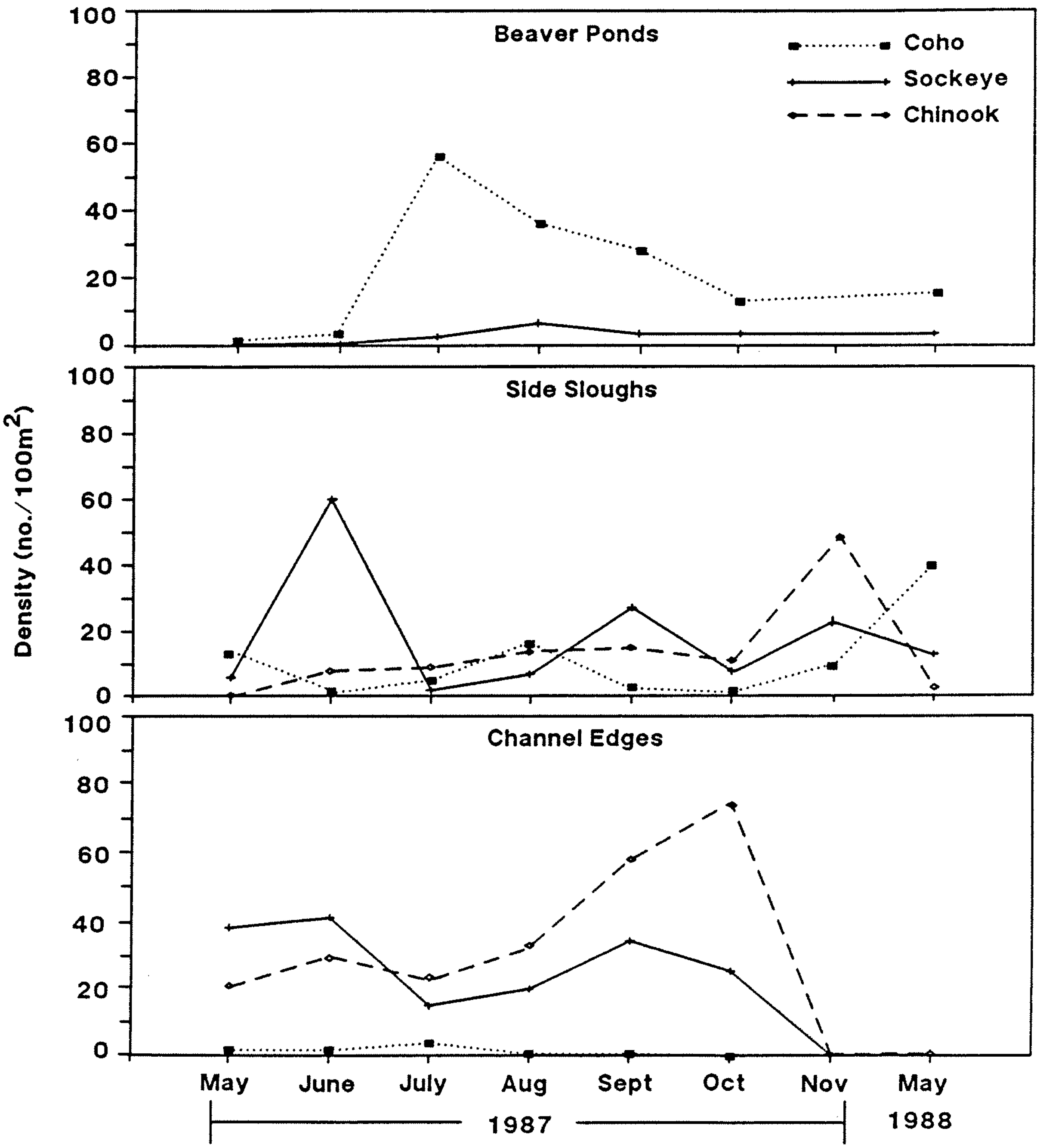

Figure 2. Mean monthly density (no./100 m^2) of age-0 fish in beaver ponds, side sloughs, and channel edges in the Taku River, Alaska May-November 1987 and May 1988.

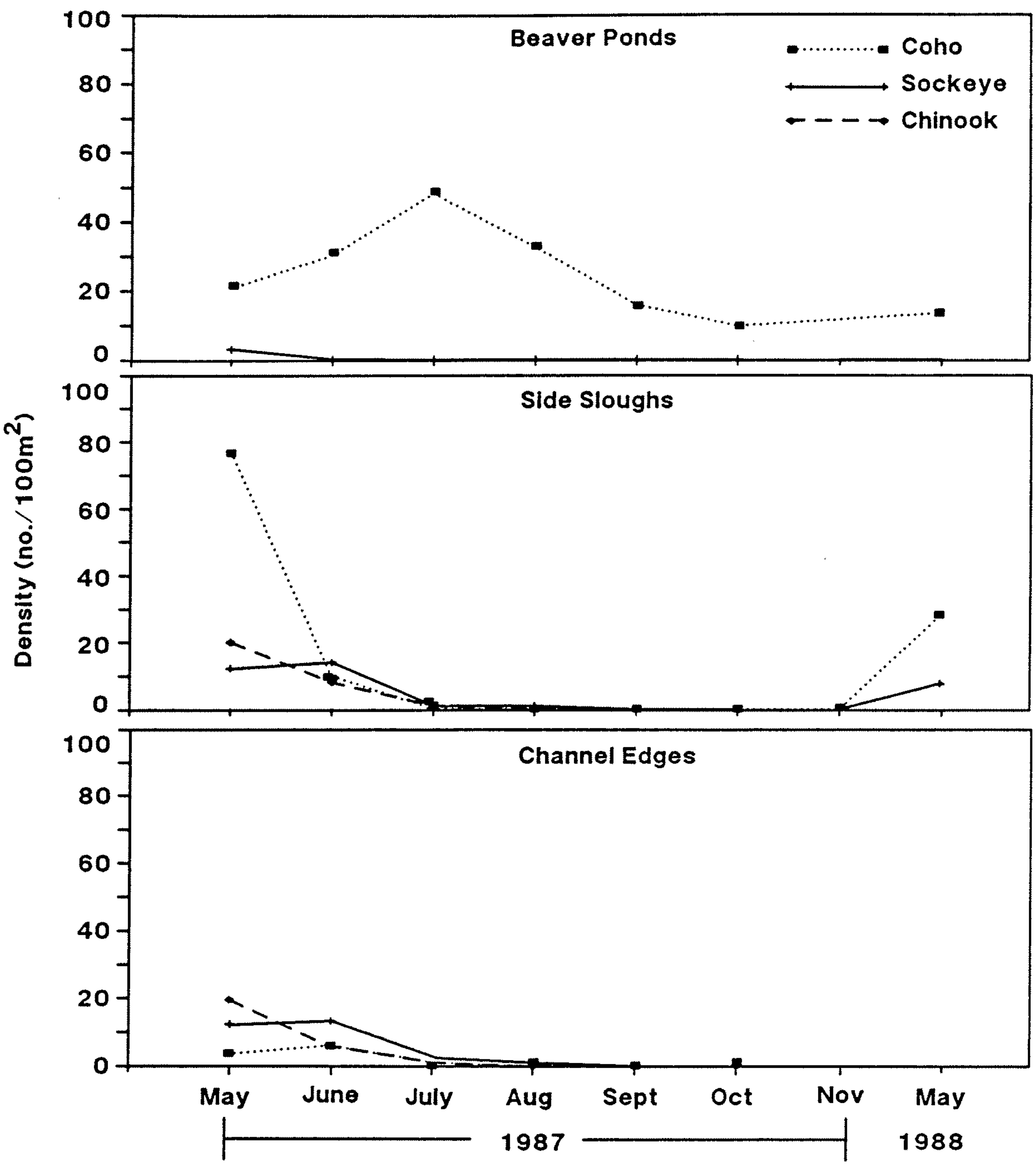

Figure 3. Mean monthly density (no./100 m^2 of age-1 and -2 fish in beaver ponds, side sloughs, and channel edges in the Taku River, Alaska, May-November 1987 and May 1988.

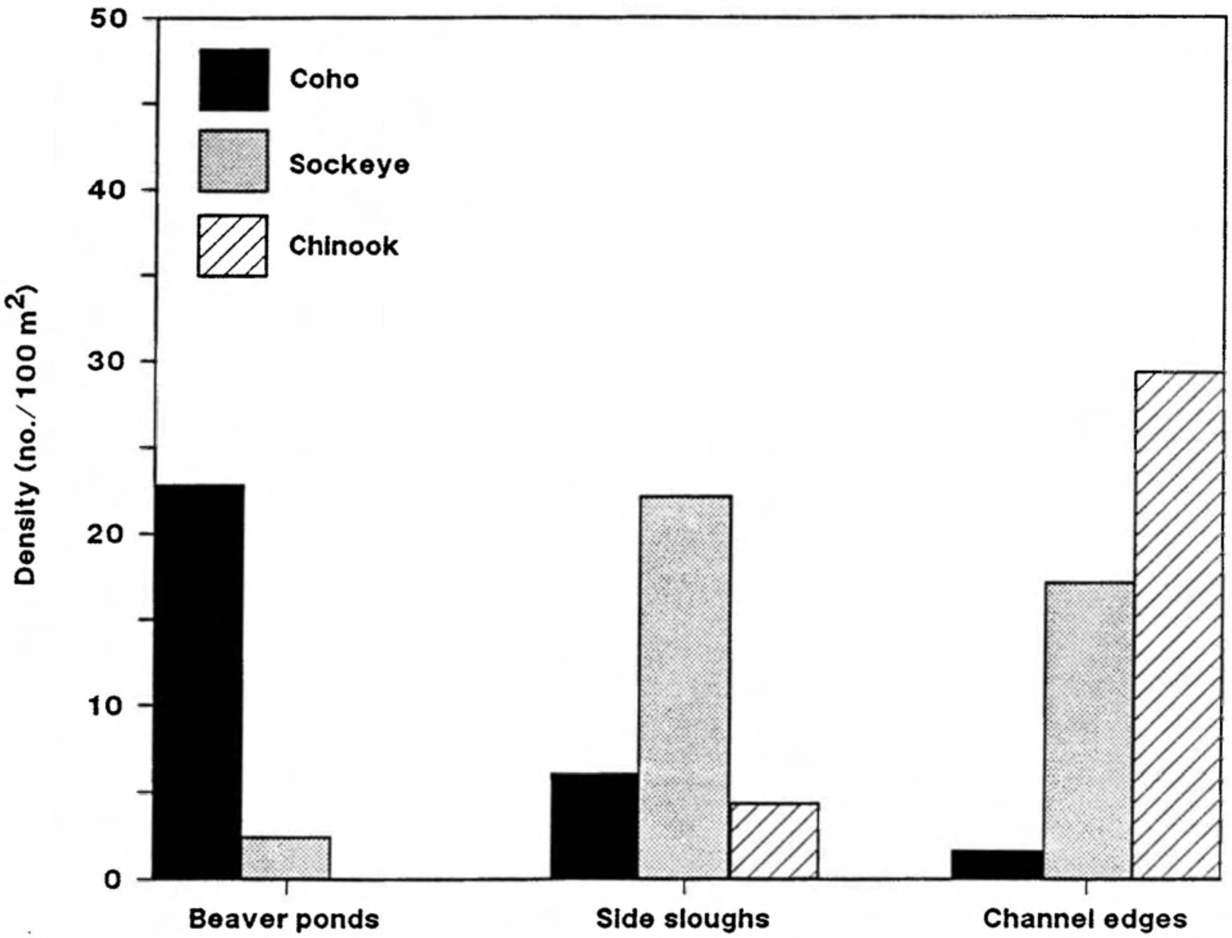

Figure 4. Mean density (no./100 m²) of age-0, -1, and -2 fish in beaver ponds, side sloughs, and channel edges in the Taku River, Alaska, May-November, 1987 and May 1988.

1/100 m^2 in June to 110.8/100 m^2 in July and probably was due to immigration of coho into the beaver ponds. After immigration ceased, densities declined through summer and fall, probably from mortality, to 10.5/100 m^2 in October. The increase in density during the following May was due to a 63% increase in coho density in Yehring pond from October to May and indicates that fish migrated into the pond after the pond was sampled in October. Unlike Yehring pond, coho density in Sockeye pond decreased from 25.3/100 m^2 in October to 3.7/100 m^2 in May.

Coho densities were low in channel edges all months (mean, 2.0 fish/100 m^2) and were generally low in side sloughs except in May (mean, July-November, 3.8 fish/100 m^2) (Figs. 2, 3). In May, coho density in side sloughs was 78.1/100 m^2 (predominately smolts) and in August density increased to 14.0/100 m^2. In November, coho density in Twin glacier slough increased to 10.1/100 m^2, probably a result of fish seeking over-winter habitat.

Sockeye

Sockeye densities in side sloughs and channel edges peaked 3 times during the study (Fig. 2). Sockeye densities peaked in June, decreased sharply in July after age-1 smolts left the river, rose in September, then declined in October. Density of age-0 sockeye increased in November in side sloughs, indicating that fish were probably using this habitat to overwinter, but were absent from channel edges. Sockeye densities were consistently low (3/100 m^2) in beaver ponds throughout the study.

Chinook

Chinook densities in channel edges and side sloughs decreased from May to June after age-1 smolts left the river and densities of age-0 chinook in channel edges increased steadily throughout the sampling period to nearly 70/100 m^2 in October (Figs. 2, 3). Density of age-0 chinook in side sloughs was low throughout the study except in November when density increased to nearly 50/100 m^2 probably indicating a movement of fish from channel edges to overwinter in side sloughs.

Size

Mean fork length (FL) of age-0 fish of all species increased in all habitats from May to November (Fig. 5). Coho FL was greater in beaver ponds than in channel edges and side sloughs until September, when FL was greater in side sloughs than in beaver ponds. In May, the mean FL of coho was nearly 10 mm greater in beaver ponds than in channel edges or sloughs. Coho fry FL in beaver ponds increased markedly (11 mm) from May to June then decreased sharply in July before steadily increasing through October. The decrease in FL in July probably can be attributed to rapid growth followed by an immigration of small age-0 fish. Although mean coho FL in channel edges surpassed that of coho in beaver ponds in September, densities were very low in channel edges (< 1/100 m^2), therefore, coho FL in mainstem areas is best characterized by fish from side sloughs.

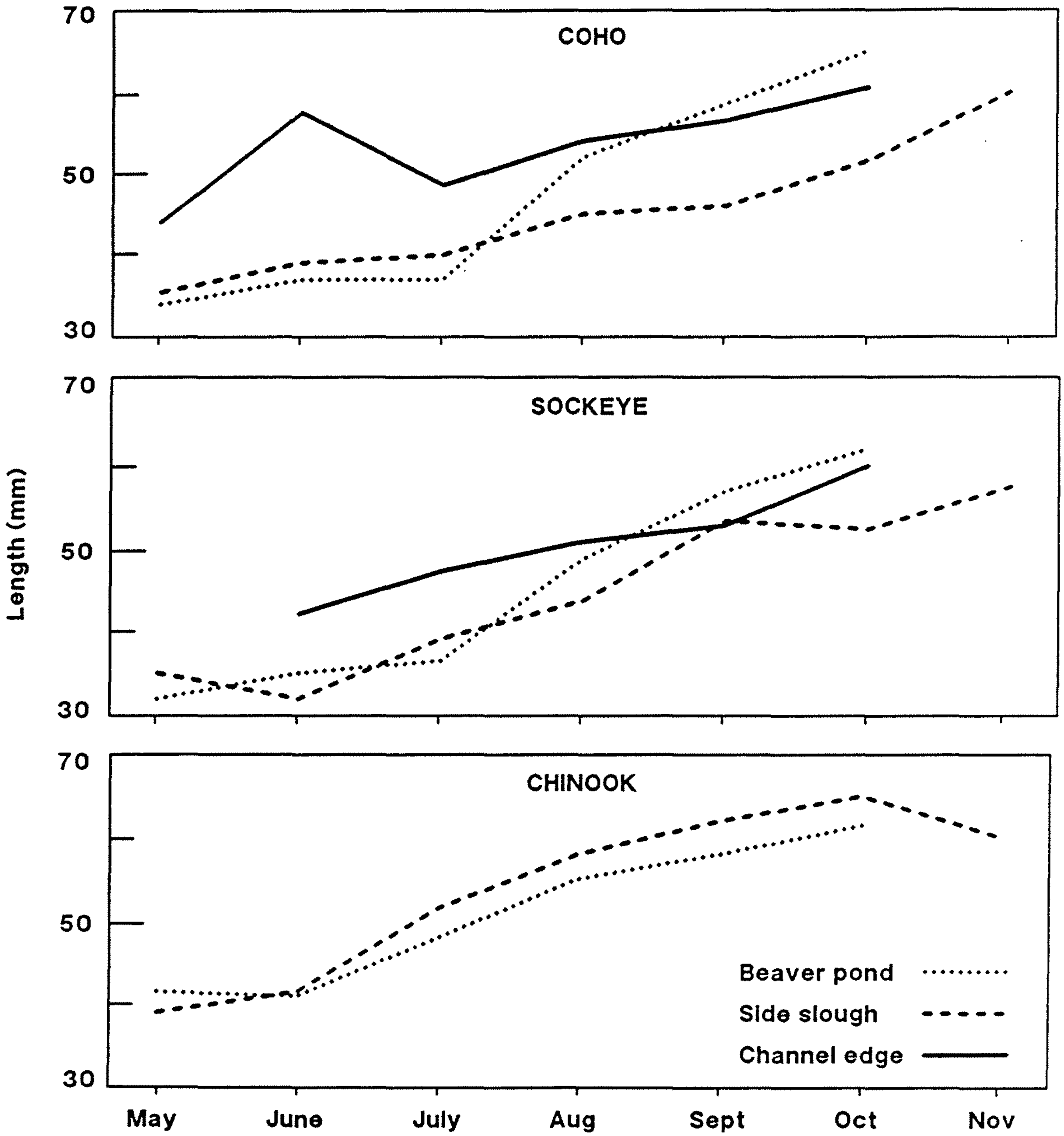

Figure 5. Mean length (mm) of age-0 fish in beaver ponds, side sloughs, and channel edges, Taku River, Alaska, May-November, 1987.

Mean FL of age-0 sockeye was greater in beaver ponds than in the other sites through August, but by September, FL was nearly the same in all habitat types (mean 51 mm) (Fig. 5). In October, mean length of age-0 sockeye from side sloughs was about 5 mm less than fry from beaver ponds or channel edges.

Length of age-0 chinook increased from about 40 mm in May to nearly 65 mm in October (Fig. 5). Age-0 fish were nearly the same size in side sloughs and channel edges in May and June, but were about 5 mm larger in sloughs than channel edges from July to October. In sloughs, mean FL decreased 7 mm from October to November; probably a result of immigration of smaller chinook.

Mark-recapture

Of the 238 fish fin-clipped in channel edges and side sloughs in July, four chinook, two coho, and one sockeye salmon were recaptured in the sites between August and November. The infrequency of recaptures indicates that populations of juveniles in these habitats were transient and that juveniles continuously migrated into and out of channel edges and side sloughs throughout summer and fall or that the number of fish marked was insufficient. Recapture rates of previously marked coho (fin clips used for population estimates) in the beaver ponds, however, were considerably higher (mean 26.1%, June-Oct.) than in channel edges and side sloughs, indicating more stable populations in the beaver ponds. Recapture rates in beaver ponds varied from 16% in July (after smolts had migrated) to 40% in September, and back to

16% in October during the fall migration to overwintering habitat.

Age composition

Age-1 and -2 fish (primarily smolts) dominated age composition in May and June and age-0 fish were most prevalent the remainder of the study (Fig. 6). From July through November, age composition consisted of about 92% age-0 fish in side sloughs and channel edges. In beaver ponds, however, age-0 fish comprised only 38% of the coho population from July through October. Age-0 sockeye were first caught in beaver ponds in June and comprised 80% of the sockeye population. From July through October, all sockeye salmon captured were age-0 fish.

Habitat

Habitat characteristics differed between habitat types (Table 2). Percentage of pool habitat ranged from 100% in beaver ponds to 16% in channel edges. Average depth was greatest in beaver ponds (1 m) and least in channel edges (0.32 m). Water velocity was greatest in channel edges (0.61 m/s) and least in beaver ponds (0 m/). Mean bi-monthly water temperature was significantly different ($\underline{P} < 0.05$; Friedman test) (Fig. 7) between habitat types. Seasonal trends in water temperature were similar between habitat types. The lowest temperatures from all sites occurred in September (mean, 7.1°) and the highest were in July (mean, 11.5°). The substrate in beaver ponds had the highest

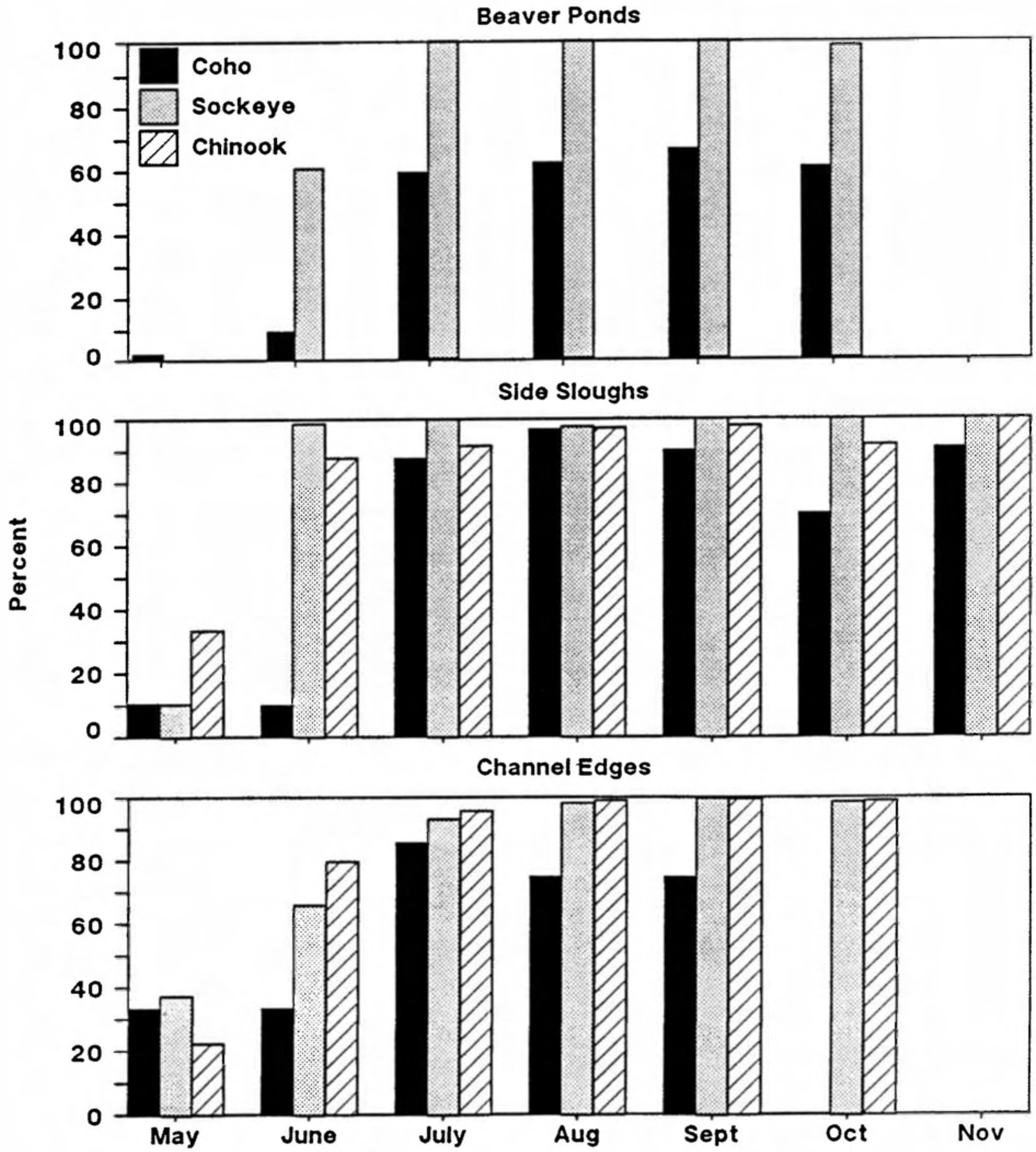

Figure 6. Percentage of age-0 fish in Beaver ponds, side sloughs, and channel edges in the Taku River.

Table 2.-- Habitat characteristics of each site sampled in beaver ponds, side sloughs, and channel edges in the lower Taku River. Data are monthly means, May-November 1987 and May 1988.

	Beaver ponds		Side sloughs		Channel edges	
	Yehring	Sockeye	Ward	Twin Glacier	Boundary	Martini
Habitat Area (m^2)	2929.00	377.00	4255.00	3263.00	162.00	162.00
% Pool	100.00	100.00	62.70	63.30	27.80	9.70
% Riffle	0.00	0.00	0.00	23.30	0.00	25.00
% Glide	0.00	0.00	37.30	13.40	72.20	65.30
Mean Depth (m)	0.96	1.10	0.78	0.51	0.35	0.29
Max. Depth (m)	1.50	1.70	2.45	0.00	1.10	0.68
Mean Width (m)	25.80	12.40	42.60	32.60	2.70	2.70
Water Velocity (m/s)	0.00	0.00	0.48	0.29	0.40	0.82
Water Temp (C°)	9.70	12.80	8.60	8.60	8.10*	8.10*
Substrate (%silt/sand)	100.00	100.00	100.00	90.40	61.30	36.60
Turbidity (NTU)	0.70	2.30	238.50	113.50	276.00	216.00

*Temperature recorded at a channel edge 2 km downstream of Martini channel edge.

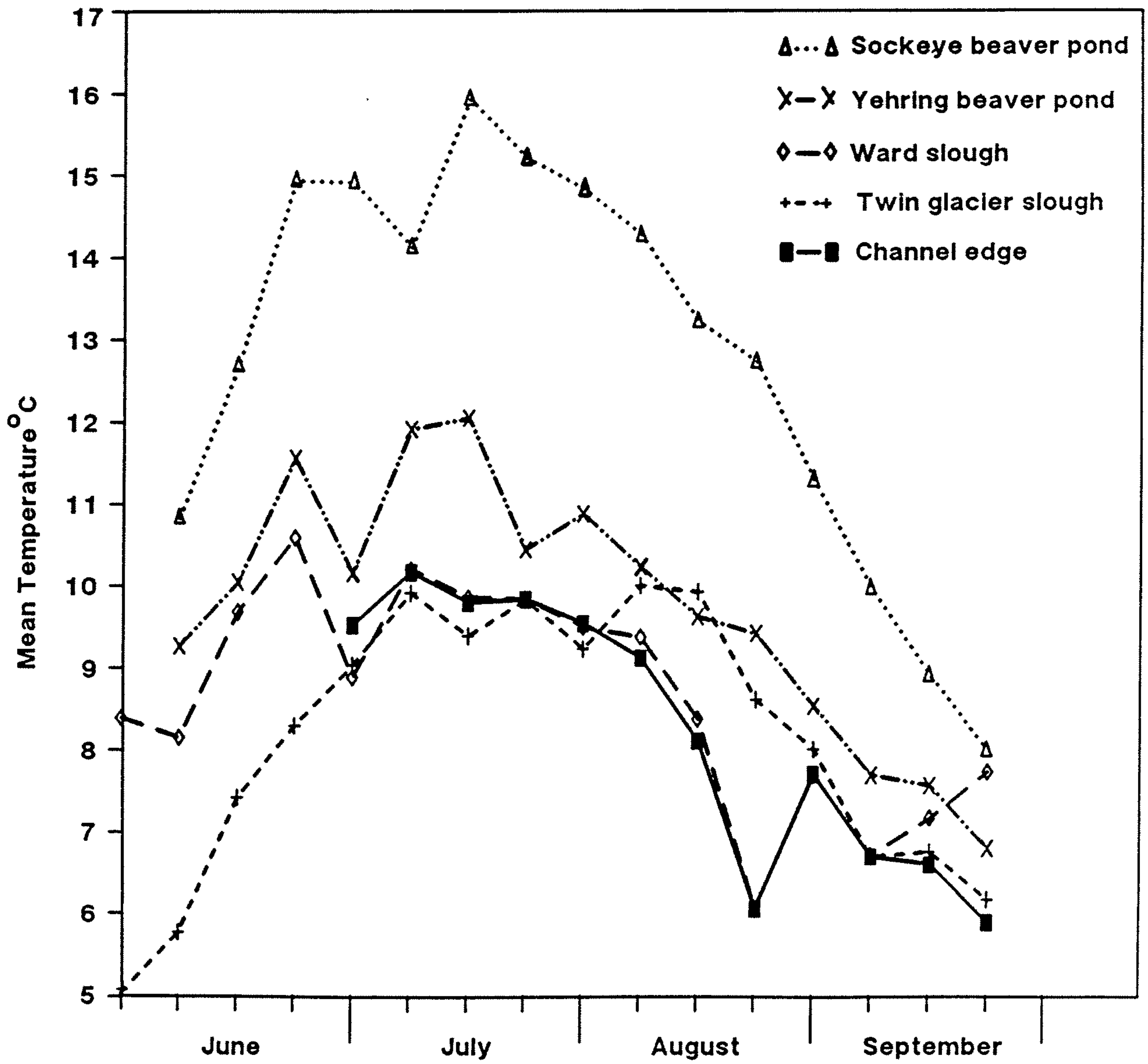

Figure 7. Mean weekly water temperature from 5 sites from the Taku River, Alaska 1987.

(100) and channel edges had the lowest (49) percentage of silt and sand. Turbidity averaged 1.5, 176, and 246 nephelometric turbidity units (NTU's) in beaver ponds, side sloughs, and channel edges, respectively, from May through November.

The area of side sloughs varied considerably with season, whereas the area of beaver ponds remained constant throughout the study. In November, area of the side sloughs was smallest, approximately 2000 m^2, and ranged from about 2500 to nearly 5000 m^2 between May and October. Although area of channel edges did not vary, relative distance from the center of the river channel to the channel edge sites changed greatly with fluctuations in river discharge. Thus, percentage of pool, riffle and glide habitat; water velocity; and substrate composition varied greatly between months in channel edge reaches.

Water velocity in channel edges and side sloughs varied with changes in river discharge and was significantly different between side sloughs and channel edges ($\underline{P} < 0.05$; Kruskall-Wallis test) (Fig. 8). For channel edges, the greatest water velocity occurred in July (0.93 m/s) and the lowest in May (0.53 m/s). For side sloughs, water velocity was 0 m/s in May and November and averaged 0.46 m/s from June to October.

Turbidity remained constant in beaver ponds but fluctuated greatly in channel edges and side sloughs (Fig. 9). The lowest turbidity measurements were recorded in November for both side sloughs and channel edges and coincided with the lowest recorded river discharge. From July to October, channel edges had the

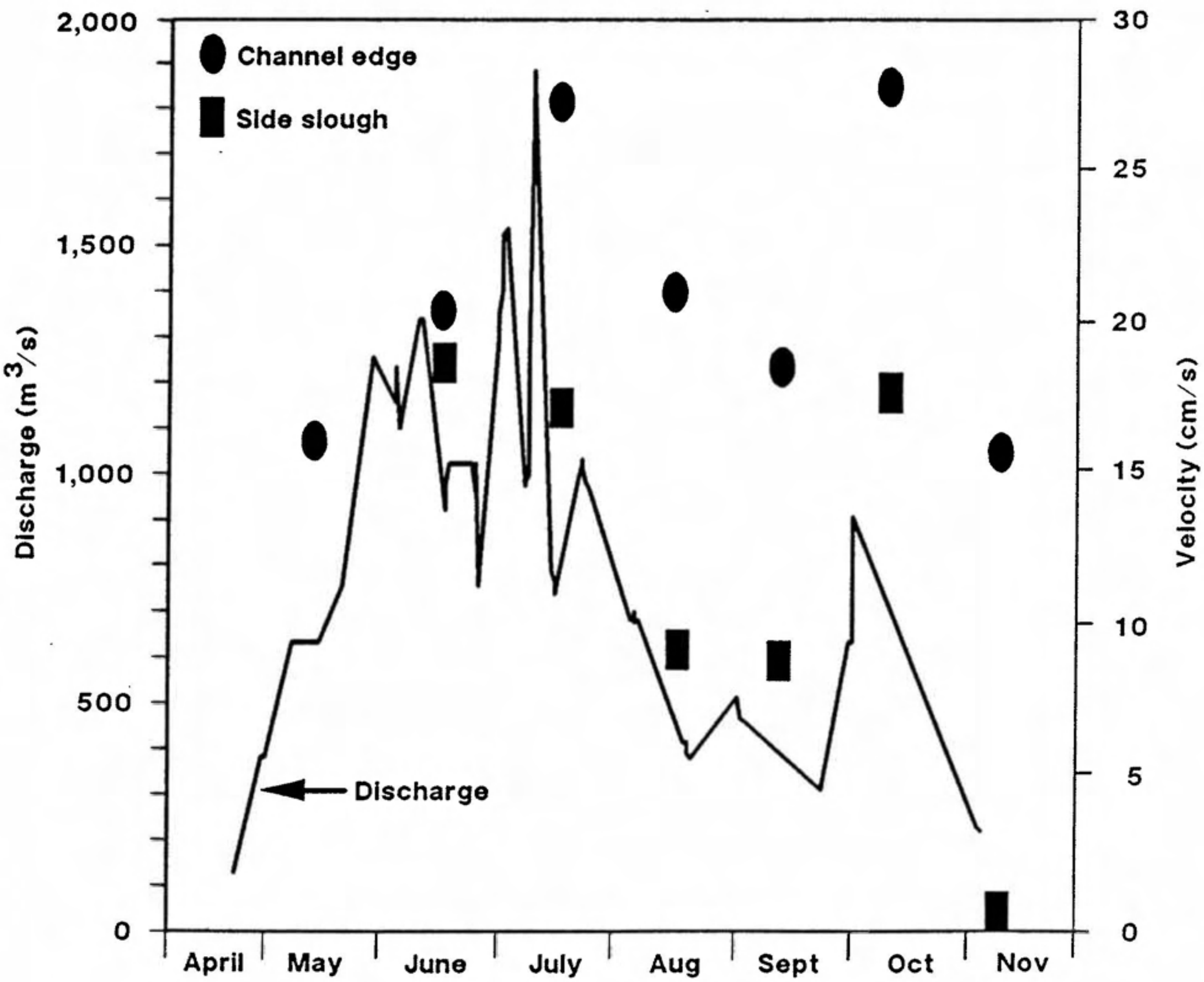

Figure 8. Water velocity in channel edges and side sloughs, and mainstem discharge in the Taku River, Alaska 1987.

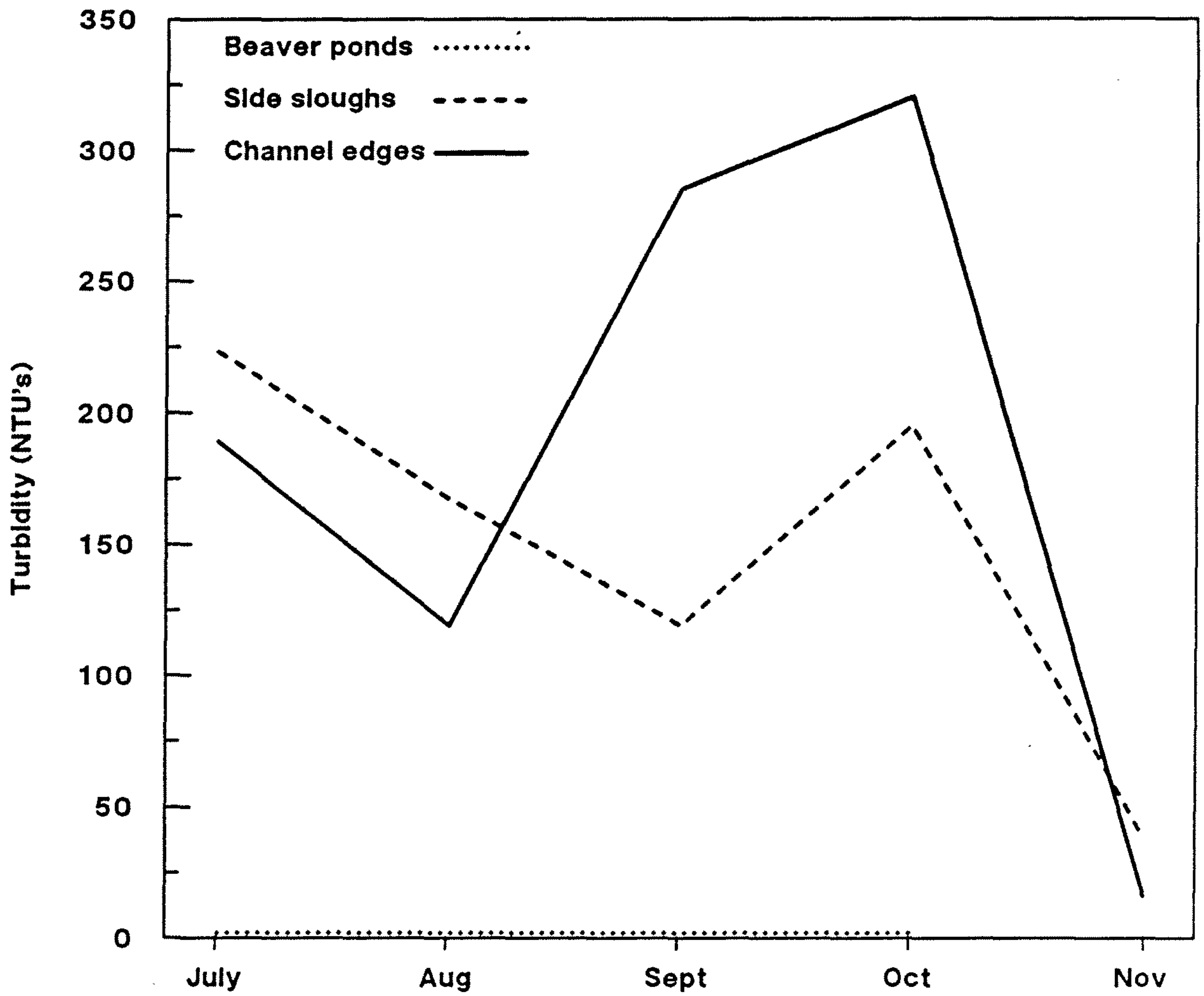

Figure 9. Monthly Turbidity (NTU's) in beaver ponds, side sloughs, and channel edges, Taku River, Alaska 1987.

highest turbidity levels and ranged from about 150 to 400 NTU's compared to a range of about 100 to 330 NTU's for side sloughs.

DISCUSSION

All habitats except channel edges harbored populations of a least two species of salmonids throughout the sampling period. Channel edges and side sloughs apparently are used primarily by transient fish from spring through fall, thus serving as important habitat for smolts migrating to sea and for age-0 fish dispersing downstream, however, because of harsh conditions, channel edges are not utilized in late fall. Side sloughs also appear to be important overwinter habitat for age-0 coho and sockeye. From fall through spring, side sloughs are predominately pool habitat with moderate amounts of large woody debris, and cobble and boulder substrate, all characteristics of good winter habitat for juvenile salmonids (Heifetz et al. 1986; Hillman and Griffith 1987; Tschaplinski and Hartman 1983). Beaver ponds are valuable year-round habitats for all ages of coho and for age-0 sockeye.

The increased densities of age-0 chinook salmon and variation in density of age-0 sockeye salmon from spring to fall in channel edges and side sloughs probably reflects immigration of chinook and "sea-type" sockeye (Wood et. al 1987) from upstream areas. The increase in sockeye densities corresponds to peak fyke net catches of sockeye in the Taku River (Murphy et al., in prep.) and indicates that these fish were migrating downstream, probably from Canadian waters.

The varied densities of sockeye may be caused by the change in location and characteristics of channel edges resulting from changes in river discharge. Changes in river discharge affected the physical characteristics of sites such as water depth and velocity, and therefore may have affected the suitability of these areas for rearing sockeye. Chinook, however were apparently less affected by changes in river discharge, probably because of their larger size and preference for channel edge habitats. As fish grow they tend to select faster, deeper water (Hillman and Griffith 1987, Lister and Genoe 1970), therefore, the larger age-0 chinook could rear in areas of increased water velocity. During low river discharge, water velocity decreases in side sloughs and available rearing habitat increases. When river discharge is high, water velocity in the center of the side sloughs is too fast for rearing salmon, therefore, available rearing habitat is limited to the slough margins.

Changes in density of age-0 coho in beaver ponds can be explained by immigration in early summer followed by a steady decline caused by mortality through fall. Our sampling, however, likely occurred prior to immigration by age-0 fish during the fall redistribution period (Bustard and Narver 1975; Cederholm and Scarlett 1981; Peterson 1982). The beaver ponds had higher densities in May 1988 then in October 1987, therefore, sampling in November likely would have detected an increase from October in coho density. The decrease in density in October may also result from coho migrating to upstream beaver ponds. The Sockeye beaver pond was devoid of fish in May 1987 and had a very low density of coho in May 1988, possibly because of low oxygen levels in winter.

Mean length of age-0 fish of all species increased steadily from May to October. The decrease in length of coho in July in beaver ponds can be attributed to an immigration of small age-0 fish from below the ponds. Access to beaver ponds is limited to periods of high water. Normally, the difference in water level between the ponds and below the ponds is approximately 1 m, prohibiting access by juvenile salmon. When the Tulsequea River floods the Taku River, as it did in July 1987, or when tributary streams flood, the water level of the ponds and below the ponds equalize, permitting access by juvenile salmon. Length of coho and sockeye salmon from May through July was greater in beaver ponds than in side sloughs and channel edges probably because of higher water temperature in the beaver ponds. By August, however, mean length of age-0 coho and sockeye was nearly the same, and by September, was greater in sloughs than in beaver ponds, probably a result of immigration.

Habitat preferences of coho salmon and life history characteristics of chinook and sockeye salmon may explain why densities of age-0 fish were higher than densities of age-1 and -2 fish in the mainstem Taku River. Coho generally prefer off-channel habitats (i. e. beaver ponds, tributary streams) (Thedinga et al. 1988), and chinook and non-lake rearing sockeye spend only one year or less in fresh water (Wood et al.1987; McPhearson 1986).

After age-1 and older smolts leave the river, usually by July, age-0 chinook and sockeye dominate mainstem habitats and coho are most prevalent in off-channel beaver ponds.

CONCLUSIONS

The lower Taku River is an important nursery area for juvenile coho, sockeye, and chinook salmon throughout the year. Apparently, because few sockeye or chinook salmon spawn in the lower river, a high proportion of the fish rearing in the lower river emigrated from Canadian waters. The channel edges harbored transient fish from May through October but probably were not utilized in winter. The side sloughs, however, were used by both transient fish and summer residents, and as over-winter habitat for all species. In all seasons, the beaver ponds were important rearing areas for coho, and to a lesser extent, sockeye. In 1986, the importance of the lower Taku River as summer rearing habitat was first realized (Murphy et al., in prep.), and now the River's value as important habitat in spring, fall, and winter has been demonstrated. Although side sloughs, channel edges, and beaver ponds appear to be important rearing areas for juvenile salmon, only two sites of each habitat type were sampled and other potentially important habitat types, especially those that could be utilized for over-winter habitat, such as upland sloughs and back waters, were not investigated and should be addressed in future research.

ACKNOWLEDGMENTS

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LITERATURE CITED

Bustard, D. R., and D. W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). J. Fish. Res. Board Can. 32:667-680.

Cederholm, C. J., and W. J. Scarlett. 1981. Seasonal immigrations into four small tributaries of the Clearwater River, Washington, 1977-1981. In E. L. Brannon and E. O. Salo (editors), Salmon and Trout Migratory Behavior Symposium, June 1981, University of Washington, Seattle, p. 98-110.

Edgington, J., and J. Lynch. 1986. Stikine River Studies. Unpubl. manuscr., Alaska Department of Fish & Game, Box 667, Petersburg, Alaska 99833.

Elliot, T. S., and K. J. Kuntz. 1988. A study of coho salmon in southeast Alaska: Chilkat Lake, Chilkoot Lake, Yehring Creek, and Vallenar Creek. Fishery Data Series No. 62, 55 p. Alaska Department of Fish and Game, Div. of Sport Fish, P. O. Box 20, Douglas, 99824-0020.

Heifetz, J., S. W. Johnson, K V. Koski, M. L. Murphy, and J. F. Thedinga. 1987. Abundance and distribution of juvenile sockeye salmon in the lower Taku River, Alaska. Southeast Alaska Inter-Divisional sockeye program review. April 1987 Juneau. Alaska Dep. Fish and Game, Comm. Fish. Div., P.O. Box 20, Douglas, AK 99824-0020.

Heifetz, J., M. L. Murphy, and K. V. Koski 1986. Effects of logging on winter habitat of juvenile salmonids in Alaskan streams. N. Am. J. Fish. Manage. 6:52-58.

Hillman, T. W., and J. S. Griffith. 1987. Summer and winter habitat selection by juvenile chinook salmon in a highly sedimented Idaho stream. Trans. Am. Fish. Soc. 116:185-195.

Kissner, P. D. 1984. A study of chinook salmon in southeast Alaska. Alaska Dep. of Fish & Game Project AFS 41-10, Vol. 25. P. O. Box 20, Douglas, AK 99824-0020. 53p.

Lister, D. B., and J. S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) salmon in the Big Qualicum River, British Columbia. J. Fish. Res. Board Can. 27:1215-1224.

Meehan, W. R., and D. B. Siniff. 1962. A study of the downstream migrations of anadromous fishes in the Taku River, Alaska. Trans. Am. Fish. Soc. 91: 399-407.

Moran, P. A. P. 1951. A mathematical theory of animal trapping. Biometrika 38:307-311.

Murphy, M. L., J. Heifetz, J. F. Thedinga, S. W. Johnson, and K V. Koski. In prep. Habitat utilization by juvenile salmon in the glacial Taku River, Southeast Alaska. Can. J. Fish. Aquat. Sci.

Murphy, M. L., K V. Koski, J. M. Lorenz, and J. F. Thedinga. In prep. Migrations of juvenile salmon in the Taku River, Southeast Alaska. U.S. Dep. Commerce, NOAA, NWAFC/NMFS Proc. Rep.

Peterson, N. P. 1982. Population characteristics of juvenile coho salmon (Oncorhynchus kisutch) overwintering in riverine ponds. Can. J. Fish. Aquat. Sci. 39:1303-1307.

Robson, D. S., and H. A. Reiger. 1971. Estimation of population number and mortality rates. In W. E. Ricker (editor), Methods for assessment of fish production in fresh waters, p. 131-165. Blackwell Science Publications, Oxford.

Sedell, J. R., J. Yuska, and R. Speaker. 1983. Study of westside fisheries in Olympic National Park, Washington. USDI, National Park Service, Contract Report No. CX-9000-0-E 081. Oregon State University, Corvallis 74 p.

Thedinga, J. F., K V. Koski, M. L. Murphy, J. Heifetz, S. W. Johnson, and C. R. Hawkes. 1988. Abundance and distribution of juvenile coho salmon (Oncorhynchus Kisutch) in the lower Taku River Alaska. In G. Gunstrom (editor), Southeast Alaska regional coho salmon program review. 23p. Regional Information Report No. 1J88-1. Alaska Dep. Fish & Game, Div. of Comm. and Sport Fish. Juneau, AK.

Tschaplinski, P. J., and G. F. Hartman. 1983. Winter distribution of juvenile coho salmon (Oncorhynchus kisutch) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Can. J. Fish. Aquat. Sci. 40:452-461.

Wood, C. C., B. E. Riddell, and D. T. Rutherford. 1987. Alternative juvenile life histories of sockeye salmon (Oncorhynchus nerka) and their contribution to production in the Stikine River, northern British Columbia. In H. D. Smith, L. Margolis, and C. C. Wood (editors) Sockeye salmon (Oncorhynchus nerka) population biology and future management, p. 12-24. Can. Spec. Publ. Aquat. Sci. 96.

Zippin, C. 1958. The removal method of population estimation. J. Wildl. Manage. 22:82-90.