NOAA Technical Memorandum NMFS-AFSC-30

Distribution and Habitat of Adult Salmon in the Situk River, Alaska: Potential Impacts of Flooding from Russell Fiord

by
J. M. Lorenz

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

January 1994

NOAA Technical Memorandum NMFS

The National Marine Fisheries Service's Alaska Fisheries Science Center uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series reflect sound professional work and may be referenced in the formal scientific and technical literature.

The NMFS-AFSC Technical Memorandum series of the Alaska Fisheries Science Center continues the NMFS-F/NWC, series established in 1970 by the Northwest Fisheries Center. The new NMFS-NWFSC series will be used by the Northwest Fisher/es Science Center.

This document should be cited as follows:.

Lorenz, J. M. 1994. Distribution and habitat of adult salmon in the Situk River, Alaska: Potential impacts of flooding from Russell Fiord. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-30, 27 p.

GENERAL DISCLAIMER

This document may be affected by one or more of the following statements

- **This document has been reproduced from the best copy furnished by the sponsoring agency. It is being released in the interest of making available as much information as possible.**
- **This document may contain data which exceeds the sheet parameters. It was furnished in this condition by the sponsoring agency and is the best copy available.**
- **This document may contain tone-on-tone or color graphs, charts and/or pictures which have been reproduced in black and white.**
- **'This document is paginated as submitted by the original source.**
- **Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.**

NOAA Technical Memorandum NMFS-AFSC-30

Distribution and Habitat of Adult Salmon in the Situk River, Alaska: Potential Impacts of Flooding from Russell Fiord

by
J. M. Lorenz

Auke Bay Laboratory
Alaska Fisheries Science Center
11305 Glacier Highway
Juneau AK 99801-8626

U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary
National Oceanic and Atmospheric Administration
D. James Baker, Under Secretary and Administrator
National Marine Fisheries Service
Rolland A. Schmitten, Assistant Administrator for Fisheries

January 1994

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Distribution and habitat of adult sockeye *(Oncorhynchus nerka),* chinook (0. *tshawytscha),* and pink (0. *gorbuscha)* salmon in the Situk River, Alaska, were studied to determine the effects of predicted flooding from Russell Fiord. Over 4,500 sockeye and 122 chinook salmon were tagged at a weir in the lower Situk River between 14 June and 21 August 1988. Surveys were done periodically to estimate the number of adult. salmon in the survey area and to determine their habitat use and migration timing from late June to late September.% All three species used similar habitat while migrating upstream. Most tagged sockeye salmon (>90%) emigrated rapidly (median = 11.2 days in transit) and steadily from the flood corridor,,/" whereas most tagged chinook salmon (>90%) emigrated more slowly (median = 51.7 days) from the corridor, often holding for days in pools or deep glides. Visual estimates of the number of pink salmon indicated that only about 60% emigrated from the flood corridor. Salmon used a wide range of habitat conditions for spawning, --and spawning areas were nearly always segregated by species. Spawning habitat characteristics of sockeye salmon differed significantly from those of chinook salmon. Flooding from Russell Fiord would inundate salmon migration and spawning areas in the Situk River and probably cause a short-term decline in salmon production. Long-term impacts on salmon production are likely to depend on the quality and availability of habitat after the river channel has stabilized.

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

INTRODUCTION

Pacific salmon *(Oncorhynchus* spp.) from the Situk River near Yakutat, Alaska (Fig. l), support valuable commercial, recreational, and subsistence fisheries that may be in jeopardy because of an imminent and radical change in river hydrology: the Hubbard Glacier, about 30 km north of Yakutat, is predicted to dam Russell Fiord (Fig. 1) within a decade, causing water from the fiord to flood into the Situk River (Mayo 1988; Trabant et al. 1991). Clark and Paustian (1989) predict that overflow from Russell Fiord into the Situk River watershed will result in a colder, more turbid river with discharge 20 times that of the present Situk River (Mayo 1988).

To determine how the predicted flooding may affect adult salmon and their habitat in the Situk River, a baseline evaluation of their present distribution and habitat use was needed. This study describes migratory timing, spawning distribution, and habitat characteristics of adult sockeye *(0. nerka),* chinook (0. *tshawytscha),* and pink salmon *(0. gorbuscha)* in the Situk River in 1988; it also speculates on how predicted flooding may affect adult salmon distribution and abundance in the Situk River.

Background

Over the last 7,000 years, Russell Fiord has repeatedly been dammed by glaciers and has overflowed into the Situk River watershed (Mayo 1988; Trabant et al. 1991). The most recent overflow from the fiord was a result of damming by the Nunatak Glacier (Fig. 1) that ended 100-120 years ago (de Laguna et al. 1964; Clark and Paustian 1989). In 1986, water was impounded for 132 days(29 May-8 October) in Russell Fiord by an ice dam from Hubbard Glacier (Seitz et al. 1986); Water in the newly formed lake rose over 25 m above sea level (Seitz et al. 1986) and came within 14 vertical meters of overflowing into the Situk River watershed (Paul 1988). The ice dam eventually collapsed, but Hubbard Glacier continues to advance and is expected to form a larger, more stable dam that may persist for several hundred years (Trabant et al. 1991). Such a dam would cause glacial water to flow into the Situk River watershed (Mayo 1988; Trabant et al. 19.91).

Overflow from Russell Fiord into the Situk River watershed would create a river very different from the present one; now the Situk River channel is less than 30 m wide and has a discharge rate that averages 10-15 m^3/s, and has not exceeded 92 m^3/s since gaging began in 1988 (Lamke et al. 1991). The new river channel is expected to stay within the current Situk River watershed except near the mouth where it probably will spill over into watersheds now occupied by the

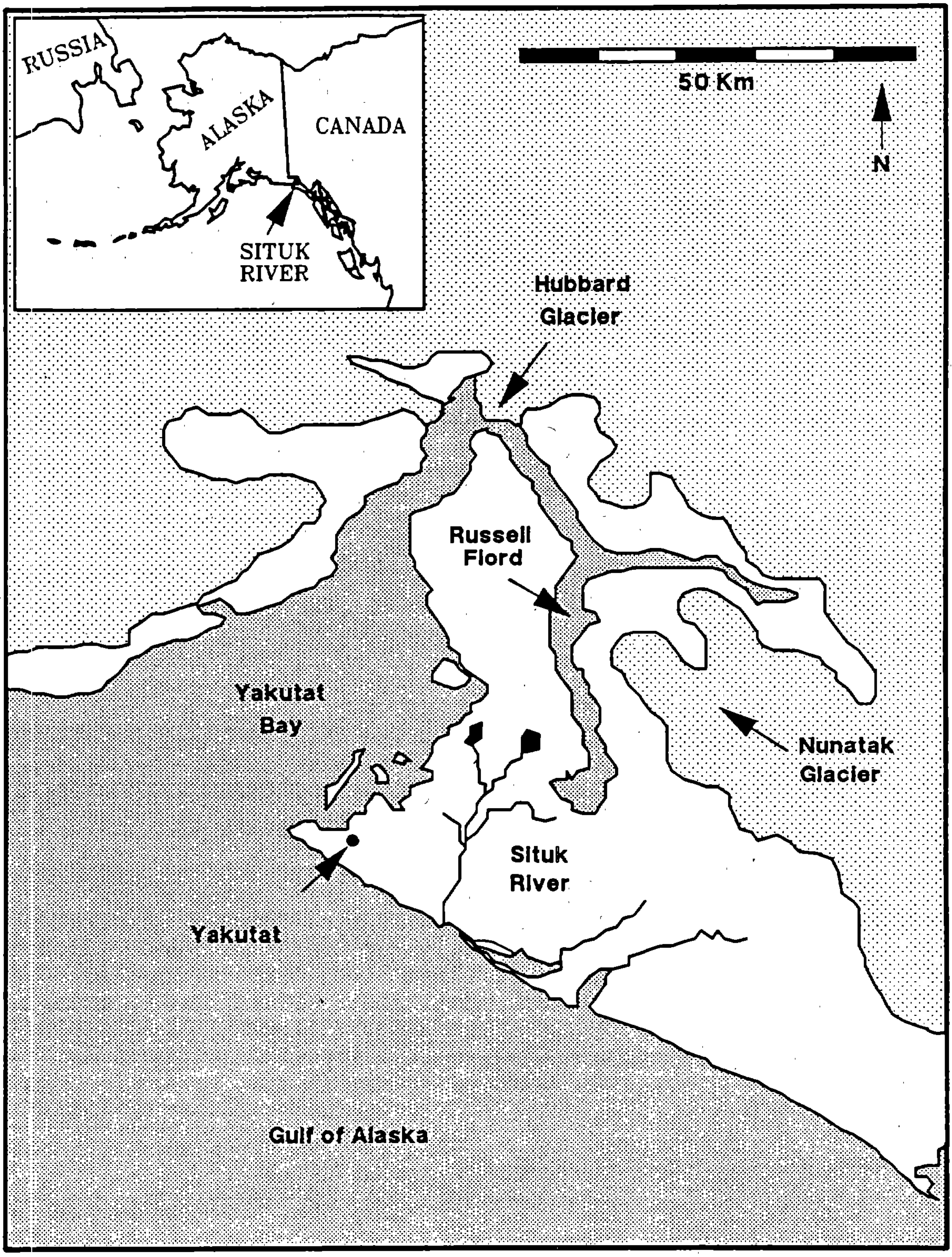

Figure 1.--Location map of the Situk River, Russell Fiord and several glaciers near Yakutat, Alaska.

Lost River and Kunayosh Creek (Fig. 2; Paul 1988). The new channel-probably will range from about 100 m wide near the Russell Fiord outflow to over 2,500 m wide near the river mouth (Paul 1988). Discharge from the newly formed lake is expected to average about 220 m^3/s, with peak discharge near 1,000 m^3/s (Mayo 1988). The river would also be colder and more turbid because of the predominately glacial origin of the discharge.

METHODS

Fish Tagging

Sockeye and chinook salmon were tagged at a weir in the lower Situk River between 14 June and 21 August 1988. Sockeye salmon were tagged with spaghetti tags and chinook salmon with Peterson disc tags (Table 1). Tags were deployed in three lots, each a different color designating a different period of the run (early, 7 June-7 July; middle, 8-25 July; and late, 26 July-22 August). Because few chinook salmon were available for tagging, Lotek[1] 30 MHz radio transmitters were orally inserted into the stomachs of 32 disc-tagged chinook (Table 2) to improve tracking and observation of that species.

Migration Studies

Twice every other week between 14 June and 8 August, channels in the predicted flood corridor between the Situk River bridge and the boat landing at the end of Lost River Road (Fig. 2) were surveyed by boat to observe fish and determine habitat use. Tagged fish were counted and pink salmon numbers were visually estimated during each survey (Tables 2-4).

Signals from radio-tagged chinook salmon were located during surveys by scanning the transmitter frequencies with Advanced Telemetry Systems receivers; maximum range with a directional loop antenna was about 0.5 km. By using the directional antenna while attenuating the receiver's gain, the receiver also functioned as a directional indicator until it was within a few meters of a transmitter. The locations of most radio-tagged fish were established visually by approaching the signal until the fish were observed. Some radio-tagged fish in cover or deep water, however, could not be seen, and their positions were estimated by triangulation.

---

[1]Reference to trade namesdoes not imply endorsement by the National Marine Fisheries Service, NOAA.

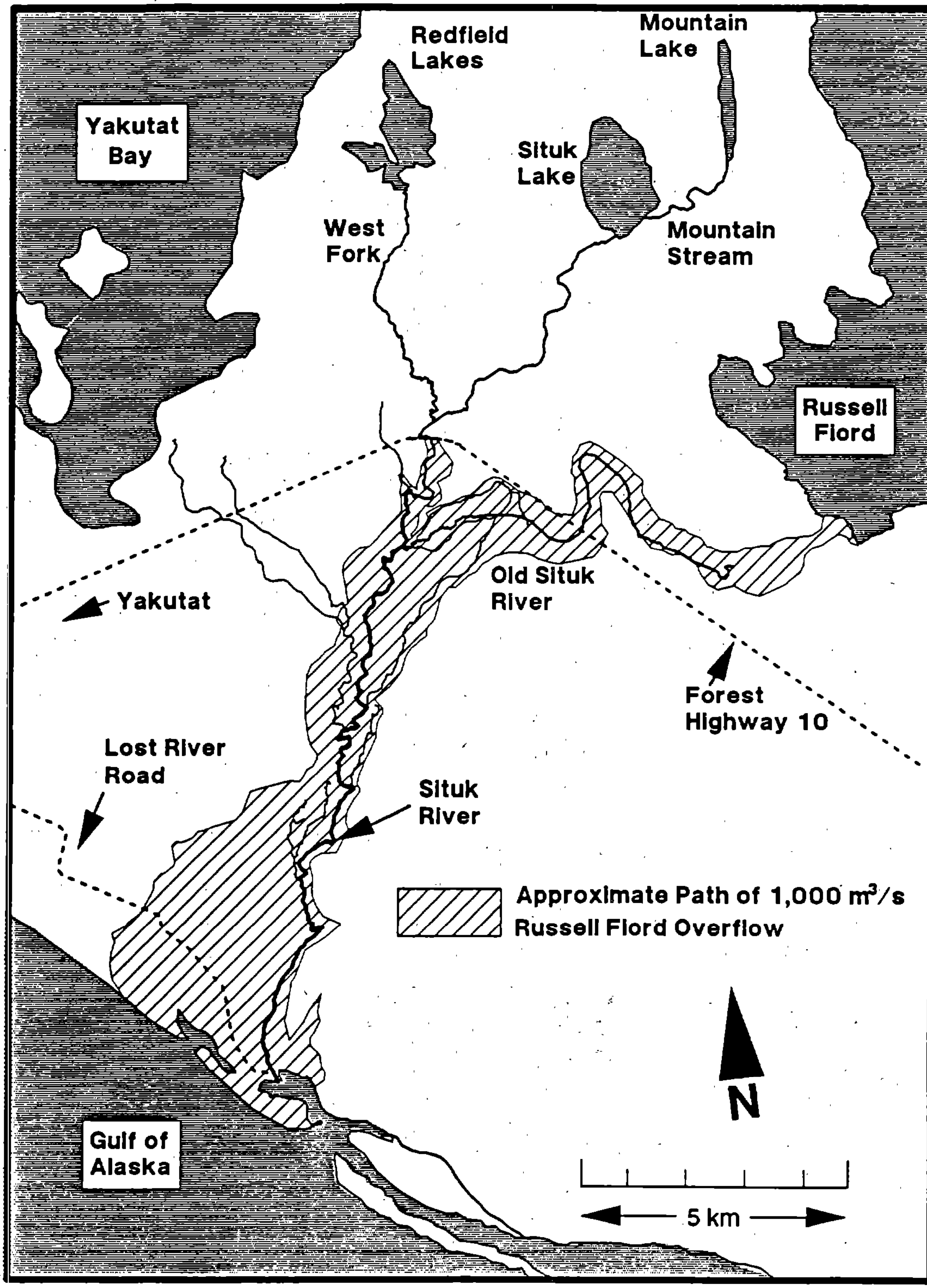

Figure 2. --Estimated course of 1,000 m^3/s of water flow from Russell Fiord through the Situk River watershed (adapted from Paul 1988).

Table 1.--Numbers of sockeye and chinook salmon tagged, and escapement through the Situk River weir in three periods between 14 June and 21 August 1988.

Species	Period	Number tagged	Escapement	% Tagged
Sockeye	1	1,053	20,981	5.0
Sockeye	2	1,642	17,907	9.2
Sockeye	3	1,850	8,118	22.8
	Total	4,545	47,006	9.7
Chinook	1	43	280	15.4
Chinook	2	41	618	6.6
Chinook	3	38	180	21.1
	Total	122	1,078	11.3

Table 2.--Date, cumulative number of radio-tagged chinook, and number of radio-tagged chinook located in adult salmon migration surveys of the main-stem Situk River, 1988. Numbers of radio-tagged fish that were subtracted (pre-spawn mortality or tag loss) from the cumulative counts are in parentheses.

	Fish tagged			Tags located		
Date	Early	Middle	Late	'Early	Middle	Late
Jun 17	1			1		
Jun 29	3			3		
Jun 30	6			6		
Jul 12	6	3		6	3	
Jul 14	6	5		5	5	
Jul 25	6	6 (1)		5	5	
Jul 26	6	6 (1)	2	5	5	2
Jul 29	6	6 (1)	8 (1)	5	5	8
Aug 9	6	6 (1)	10 (1)	5	5	10
Aug 10	6	6 (1)	9 (3)	5	5	9
Aug 17	6	6 (1)	11 (3)	5	5	11
Aug 18	6	6 (1)	12 (3)	5	4	12
Aug 22	6	6 (1)	16 (3)	5	4	10
Aug 25	6	6 (1)	16 (3)	3	0	0
Sep 2	6	6 (1)	16 (3)	1	0	0
Sep 14	6	6 (1)	16 (3)	0	0	0
Sep 30	6	6 (1)	16 (3)	0	0	0

Table 3.--Survey dates, cumulative numbers of tagged sockeye salmon (Xi), numbers of tagged sockeye observed (n_i), and sockeye observation efficiencies **($\hat{a}$)** during adult salmon migration surveys of the main-stem Situk River, 1988. Data used to determine observation efficiencies are in italics. Numbers of radio-tagged chinook salmon in each category are in parentheses.

	Fish tagged (X_i)			Tags observed (n_i)			
Date,	Early	Middle	Late	Early	Middle	Late	$\hat{a}$
				Sockeye			
Jun 17	*15*			*6*			0.40
Jun 29	1053			381			0.40
Jun 30	1053			322			0.40
Jul 12	1053	*560*		186	*221*		0.39
Jul 14	1053	992		118	287		0.39
Jul 25	1053	1642	*481*	52	141	*286*	0.59
Jul 26	1053	1642	690	33	106	301	0.59
Jul 29	1053	1642	1850	27	136	347	0.59
Aug 9	1053	1642	1850	11	17	290	0.59
Aug 10	1053	1642	1850	15	32	187	0.59
Aug 17	1053	1642	1850	5	16	14	0.59
Aug 18	1053	1642	1850	3	17	6	0.59
Aug 22	1053	1642	1850	1	3	2	0.59
Sep 2	1053	1642	1850	0	0	0	0.59
Sep 14	1053	1642	1850	0	0	0	0.59
				Chinook			
Jun 17	2 (1)			2 (1)			0.29
Jun 29	*17 (3)*			*7 (3)*			0.29
Jun 30	30 (6)			14 (6)			0.29
Jul 12	43 (6)	3 (3)		17 (6)	3 (3)		0.22
Jul 14	43 (6)	*28 (5)*		18 (6)	*10 (5)*	0.22	0.22
Jul 25	43 (6)	41 (6)	*6 (0)*	19 (5)	22 (5)	*3 (0)*	0.50
Jul 26	43 (6)	41 (6)	8 (2)	17 (5)	21 (5)	6 (2)	0.50
Jul 29	43 (6)	41 (6)	13 (8)	16 (5)	15 (5)	10 (8)	0.50
Aug 9	43 (6)	41 (6)	16 (10)	20 (5)	17 (5)	12 (10)	0.50
Aug 10	43 (6)	41 (6)	15 (9)	17 (5)	16 (5)	10 (9)	0.50
Aug 17	43 (6)	41 (6)	31 (11)	16 (5)	17 (5)	15 (11)	0.50
Aug 18	43 (6)	41 (6)	32 (12)	9 (5)	9 (5)	20 (12)	0.50
Aug 22	43 (6)	41 (6)	36 (16)	6 (5)	5 (4)	18 (10)	0.50
Sep 2	43 (6)	41 (6)	36 (16)	3 (3)	0 (0)	1 (0)	0.50
Sep 14	43 (6)	41 (6)	36 (16)	1 (1)	0 (0)	1 (0)	0.50

Table 4.--Date and estimated number of pink salmon observed during surveys of the main-stem Situk River, 1988.

Date	Fish observed
Jun 17	0
Jun 29	0
Jun 30	0
Jul 12	2
Jul 14	17
Jul 25	45
Jul 26	65
Jul 29	35
Aug 9	25
Aug 10	140
Aug 17	270
Aug 18	625
Aug 22	1750
Aug 25	3050
Sep 2	1975
Sep 14	1460

Where chinook salmon were observed or located by telemetry, or where groups of sockeye (>lO -fish) or pink salmon (>20 fish) were observed, these environmental data were recorded: habitat type (pool,. riffle, or glide), average' depth (mean of three or more measurements), and amount (absent, common, or abundant) of cover (i.e., overhanging or submerged riparian vegetation and large woody debris [LWD]).

Not all tagged fish in the survey area were observed during each survey (Tables 2-3); therefore, the number of tagged fish in the survey area was estimated as the number of tagged fish observed times observation efficiency (a; Tables 2-3): Observation efficiency was calculated from one survey in each tagging period by the equation

$$\hat{a} = \frac{n}{x}, \qquad (1)$$

where $\hat{a}$ is observation efficiency, n is the number. of tagged fish observed during the survey that had been tagged since the tagging period began, and x is the cumulative number of fish tagged since the tagging period began. I assumed that 1) all fish tagged since the start of a tagging period remained in the survey area until the data for observation efficiencies in that period were compiled, 2) observation efficiency was constant during a tagging period, and

3) (observation efficiency of radio-tagged. fish was 1. The number of fish, in the survey area was estimated for each tag group by the equation

$$\hat{n}_i = \frac{n_i}{\hat{a}} , \qquad (2)$$

where $\hat{n}_i$ is the estimated number of tagged fish in the survey area at survey i, and n_i is the number of tagged fish. observed during survey i.

The proportion of tagged fish from each group remaining in the 'survey area was calculated with the equation

$$\hat{P}_i = \frac{\hat{n}_i}{x_i} , \qquad (3)$$

where $\hat{P}_i$ is the proportion of tagged fish remaining in the survey area at survey i, and x_i is the cumulative number of fish tagged up to survey i.

Regression of $\hat{P}$ on survey date provided an empirical model of emigration from-the boat survey area for each group of tagged fish. Logarithmic transformation, (Sokal and Rohlf '1969) of sockeye emigration data provided the best regression fit, probably due to both the proportional data and the fact that fish bound for 'spawning areas in Old Situk River (Fig. 3) stayed in the survey area for long periods, thus positively skewing the P distribution. Angular transformation (Sokal and Rohlf 1969) of chinook emigration data provided the best regression fit, probably because the data is proportional. The nonnormal distributions of $\hat{P}$ also indicate that medians are the best measures of central tendency for this data: An F test was used to compare the slopes of the regression lines, thereby determining whether emigration rates varied significantly between tagged groups.. When significant differences were found, Scheffe's test (Snedecor and Cochran 1967) was applied to determine which. emigration rates were unlike the others. Regressions of data for disc-tagged and radio-tagged chinook salmon did not differ significantly ($P > 0.5$; t test) within any tagging period, and the data for the two tag groups were pooled by tagging period.

Equations were derived from the regressions to 1) es&-mate P within a tag group for any date (d, where d was 1 on 1 January and 366 on 31 December) after tagging of that group began; and 2) estimate the number of days of residency (D)in the main-stem flood corridor for any proportion (p) of a tag group. The equations for chinook are

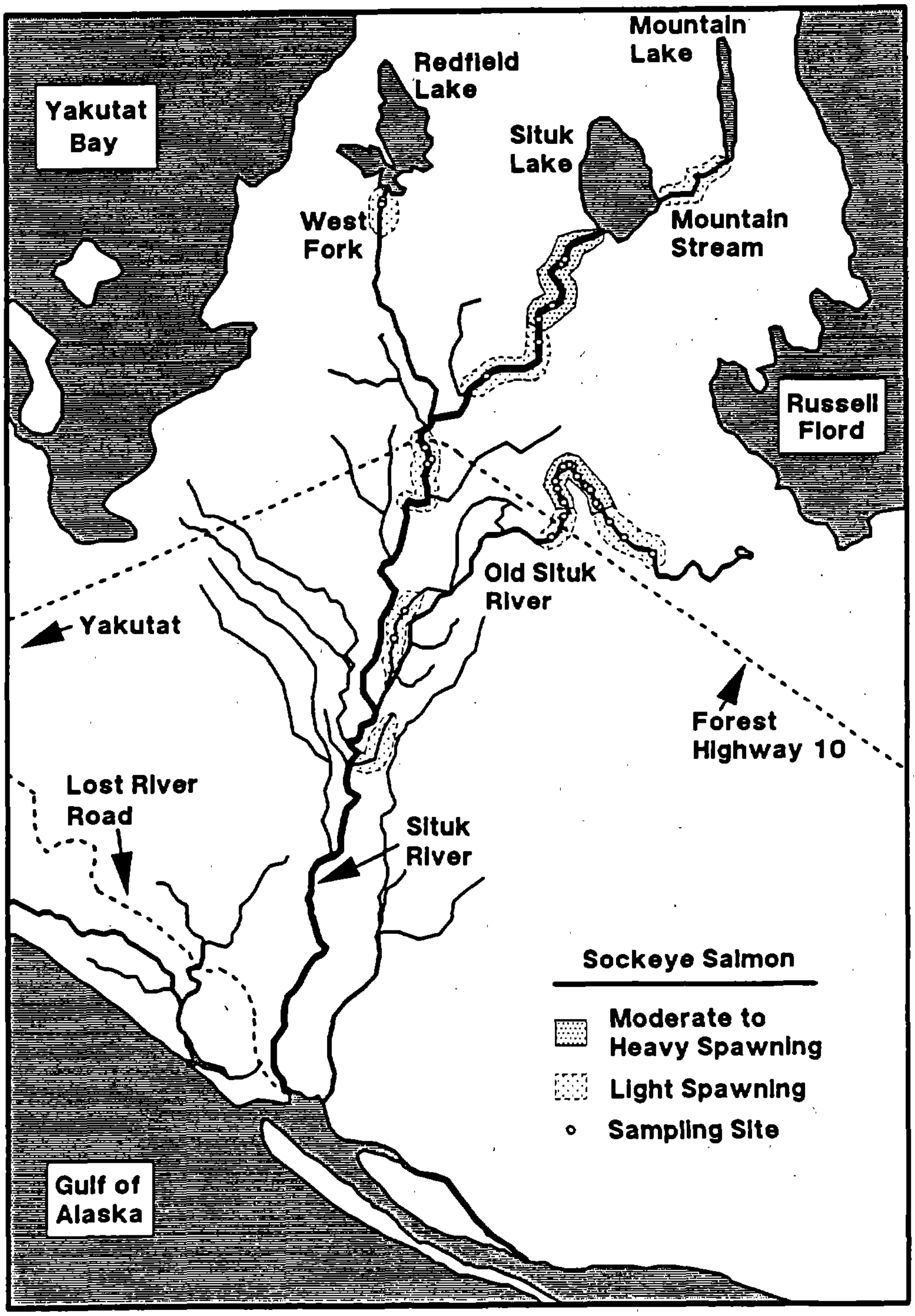

Figure 3. --Distribution of stream-spawning sockeye salmon and sites sampled for spawning habitat characteristics in the Situk River watershed, 1988.

$$1)\quad \hat{P} = \sin(Sd + C)^2 \tag{4}$$

and

$$2)\quad \hat{D} = \frac{\arcsin\sqrt{p} - C}{S}\ . \tag{5}$$

The equations for sockeye are

$$1)\quad \hat{P} = e^{(Sd+C)} \tag{6}$$

and

$$2)\quad \hat{D} = \frac{(\ln p) - C}{S}\ , \tag{7}$$

where S is the slope of the regression line, C is a constant, and e is the base of the natural logarithm. Factors used in equations 4-7 and indices of variability are summarized in Table 5. Relationships between emigration rate and date were illustrated by plotting *P* values (expressed as percentages) versus survey dates,.

Table 5. --Data to estimate $\hat{P}$ and $\hat{D}$ (equations 4-7) for groups of tagged fish in the main-stem flood corridor of the Situk River, 1988. R^2 values and standard errors of the regression slopes and estimates also are provided.

Period	Slope	Constant	First day of tagging.	R^2,	Standard error Slope	Standard error Estimate
			Sockeye			
Early	**-0.100**	**18.09**	**181**	**0.96**	**0.006**	**0.474**
Middle	**-0.122**	**23.45**	**194**	**0.95**	**0.010**	**0.438**
Late	**-0.203**	**42.20**	**208**	**0.87**	**0.032**	**0.940**
			Chinook			
Early	**-0.021**	**5.32**	**181**	**0.76**	**0.003**	**0.244**
Middle	**-0.032**	**7.92**	**194**	**0.90**	**0.003**	**0.186**
Late	**-0.030**	**8.05**	**208**	**0.79**	**0.005**	**0.333**

Spawning Studies.

Several areas of the watershed (Situk River, West Fork Situk, Old Situk River, and Mountain Stream; Fig. 2) were surveyed by boat, foot, and fixed-wing aircraft to locate spawning salmon. Surveys took place 27 July-30 September: ground surveys were discontinued on 15 September, but an aircraft survey was done on 30 September.

During surveys, tagged fish were counted and approximate numbers and locations of untagged salmon were recorded on 1:42,240 scale maps. Observed salmon spawning range also was recorded on maps during all surveys. Spawning-habitat characteristics of sockeye and chinook salmon were measured during ground surveys. Spawning by sockeye and chinook salmon was observed in 19 reaches (i.e. isolated groups of spawning sites), and spawning-habitat characteristics were measured at 63 spawning sites (31 and 32 sites, respectively; Figs. 3 and 4) in those reaches.' Water depth was measured to the nearest centimeter at the surface of the undisturbed substrate adjacent to each spawning site. At the site of each depth measurement,. water velocity (cm/s) was averaged from measurements with an electronic current meter at 0.2 and 0.8 of the depth, and surface and intragravel (15 cm into the substrate) temperatures were measured with an electronic thermometer. Where individual redds could be discerned (26 sockeye and 19 chinook salmon redds), maximum length and width were measured and substrate composition in the area disturbed by redd construction was visually estimated. Redd length and width were measured to the nearest centimeter and substrate composition was recorded in percentages of three size classes: fine (<2 mm), gravel (2-100 mm), and coarse (>lO cm).

RESULTS

About 10% of all sockeye and chinook salmon-were tagged, but the number of tagsdeployed and the percentage of the escapement tagged varied by period (Table, 1).

Upstream migrant salmon of all three species usually shared habitat. Migrating fish in the flood corridor were most frequently observed in pools or -in deep (>l m) glides along banks with cover from overhanging or submerged riparian vegetation.

'Estimated numbers of tagged fish between the weir and the bridge on the Situk River declined significantly ($P < 0.001$; F test) over time for all tag groups, as fish emigrated from the flood corridor. Migration rates, however, differed significantly ($P < 0.05$; F test) among groups of tagged fish both within and between species, Most (95% of sockeye and 97% of chinook) tagged fish left the flood corridor, but tagged sockeye salmon emigrated from the survey area (median = 11.2 days) significantly faster ($P < 0.01$; F test) than tagged chinook salmon (median = 51.7 days).

About 43,000 salmon were seen in spawning areas (11,500 sockeye, 438 chinook, and 31,000 pink). Each species usually

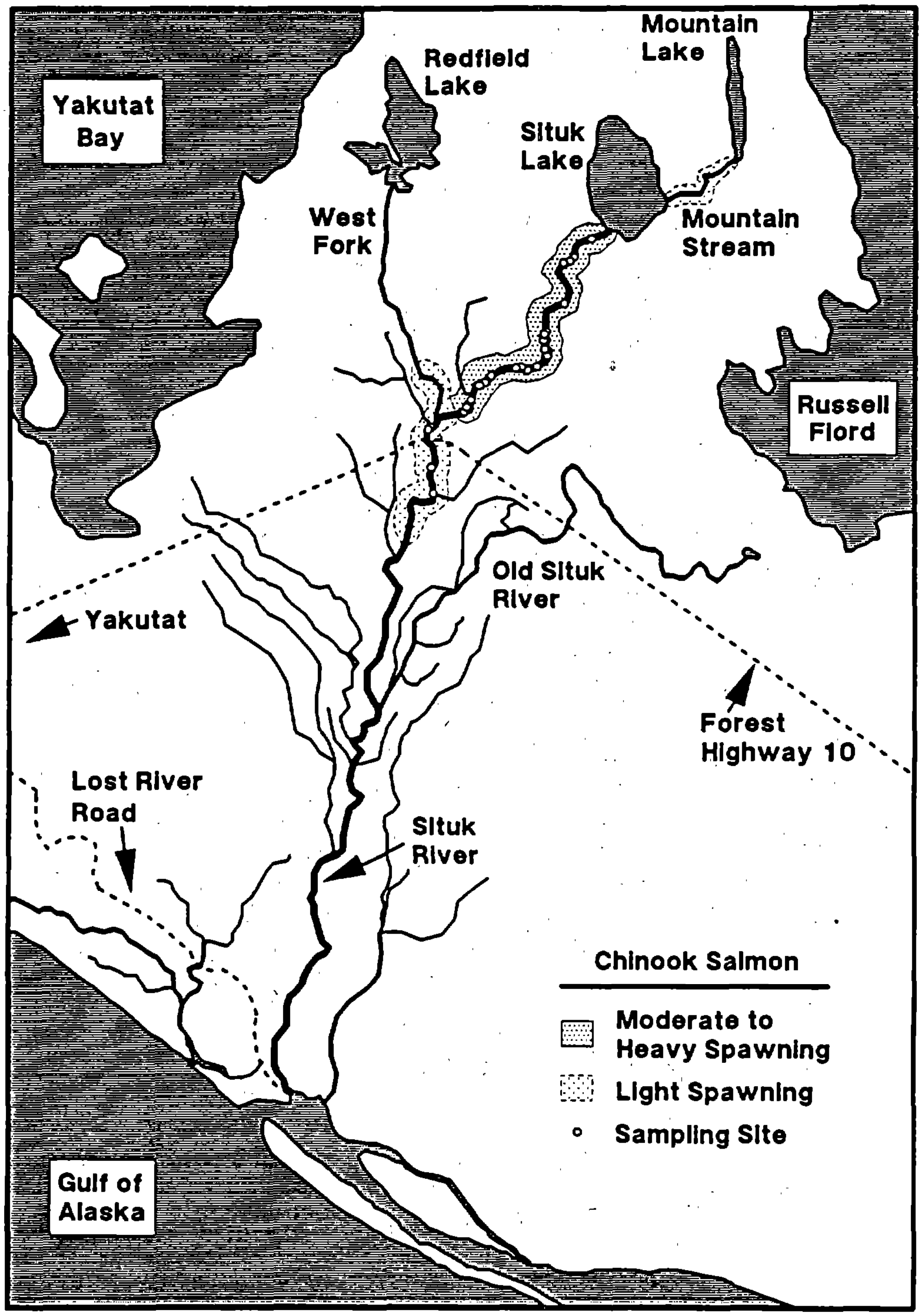

Figure 4.--Distribution of spawning chinook salmon and sites sampled for spawning habitat characteristics in the Situk River watershed, 1988.

spawned in a separate area, although pink salmon occasionally spawned where chinook or sockeye salmon were spawning. Few (<5% of the escapement; Table 1) sockeye and chinook salmon were observed spawning in the flood corridor (Figs. 3 and 4),. whereas about 40% of observed pink salmon spawning was in the flood corridor (Fig. 5). Spawning salmon were observed. in all habitat types (pools, riffles, and glides) and used diverse hydraulic and substrate conditions (Table 6).

Sockeye Salmon

Most sockeye salmon emigrated steadily from the migration survey area in the flood corridor (Table 3). Models of emigration by groups of tagged sockeye salmon (Fig. 6) fit the observed data (R = 0.96, 0.95, and 0.87 for early, middle, and -late tagging periods, respectively). Sockeye salmon tagged late in the run left the migrationsurvey area at a significantly ($P < 0.05$; Scheffe's test) faster rate than sockeye salmon tagged in the early or middle periods. Most (95%) sockeye salmon tagged early in the run had migrated out of the survey area by 10 August, whereas most (95%) sockeye salmon tagged in the middle and late parts of the run left the survey area by 17 August (Table 3). Migrating sockeye salmon frequently concentrated where deep (>l m) glides intersected quiet pools (often formed behind large woody debris) or in glides along channel margins with overhanging or submerged riparian vegetation.

Sockeye salmon were observed to spawn over a 2-month period. Spawning sockeye salmon were first seen about 5 km upstream of the Situk River bridge on 27 July, during the first ground survey in that area; they were most abundant the second or third weeks of August, and rare on 30 September. About 90% of the sockeye salmon in the survey area spawned near lakes (Fig. 3); spawning density was greatest within 3 km downstream of Situk Lake. Large groups of sockeye salmon also spawned in other areas: directly upstream of Situk Lake in Mountain Stream, in the area immediately upstream of the road crossing of the Old Situk River, and downstream of Mountain Lake (Mountain Stream). Spawning of sockeye salmon also was observed elsewhere (Fig. 3) in the Situk River, Old Situk River, and near Redfield Lakes (West Fork of the Situk River).

Most (65%) sockeye salmon that were observed during spawning surveys spawned in glides, but some (30%) spawned in pools and a few (5%) in riffles. Sockeye salmon used an average of 3.7 m of stream bed to construct a redd. Spawning sites averaged 49.6-cm water depth and 26.5-cm/s water velocity. Substrate composition at redd sites averaged 23% fine sediment, 72% gravel, and 5% coarse sediment.

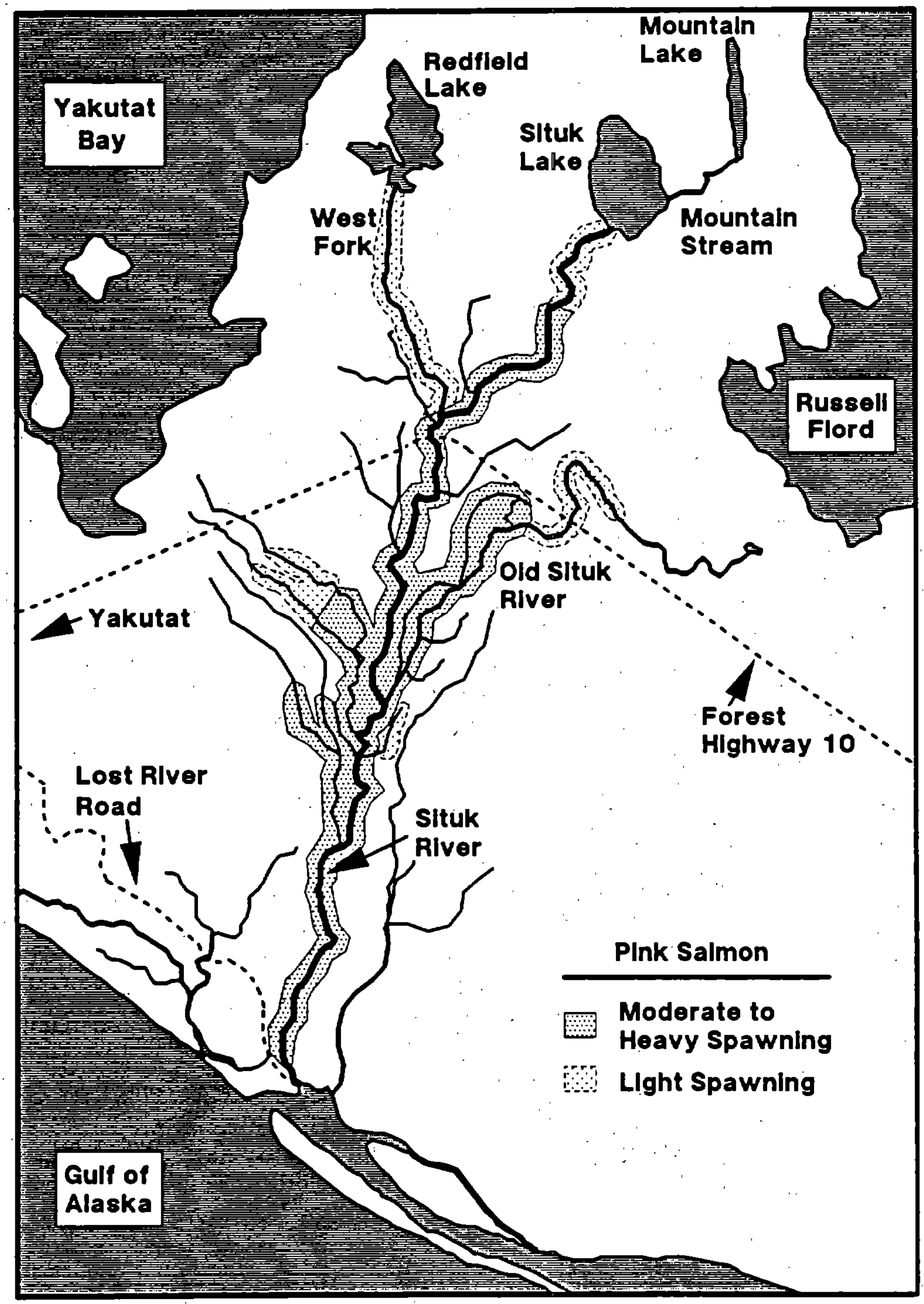

Figure 5. --Distribution of stream spawning pink salmon in the Situk River watershed, 1988.

Table 6.--Characteristics of sockeye and chinook salmon spawning habitat in the Situk River, 1988. Mean values are presented with standard errors in brackets.

	Sockeye	Chinook
Redd dimensions		
Length (m)	2.4 [0.1]	5.6 [0.2]
Width (m)	1.6 [0.1]	3.3 [0.2]
Area (m^2)	3.7 [0.4]	19.0 [1.5]
Water		
Depth (cm)	49.6 [3.4]	79.6 [5.4]
Velocity (cm/s)	26.6 [6.5]	73.0 [5.1]
Substrate composition		
Fine (%)	23.4 [2.8]	5.3 [1.4]
Gravel (%)	72.0 [3.5]	76.1 [4.2]
Coarse (%)	5.0 [2.5]	18.7 [4.2]
Temperature		
Water column (°C)	9.1 [0.4]	12.2 [0.2]
Intra-gravel (°C)	6.2 [0.4]	11.9 [0.2]

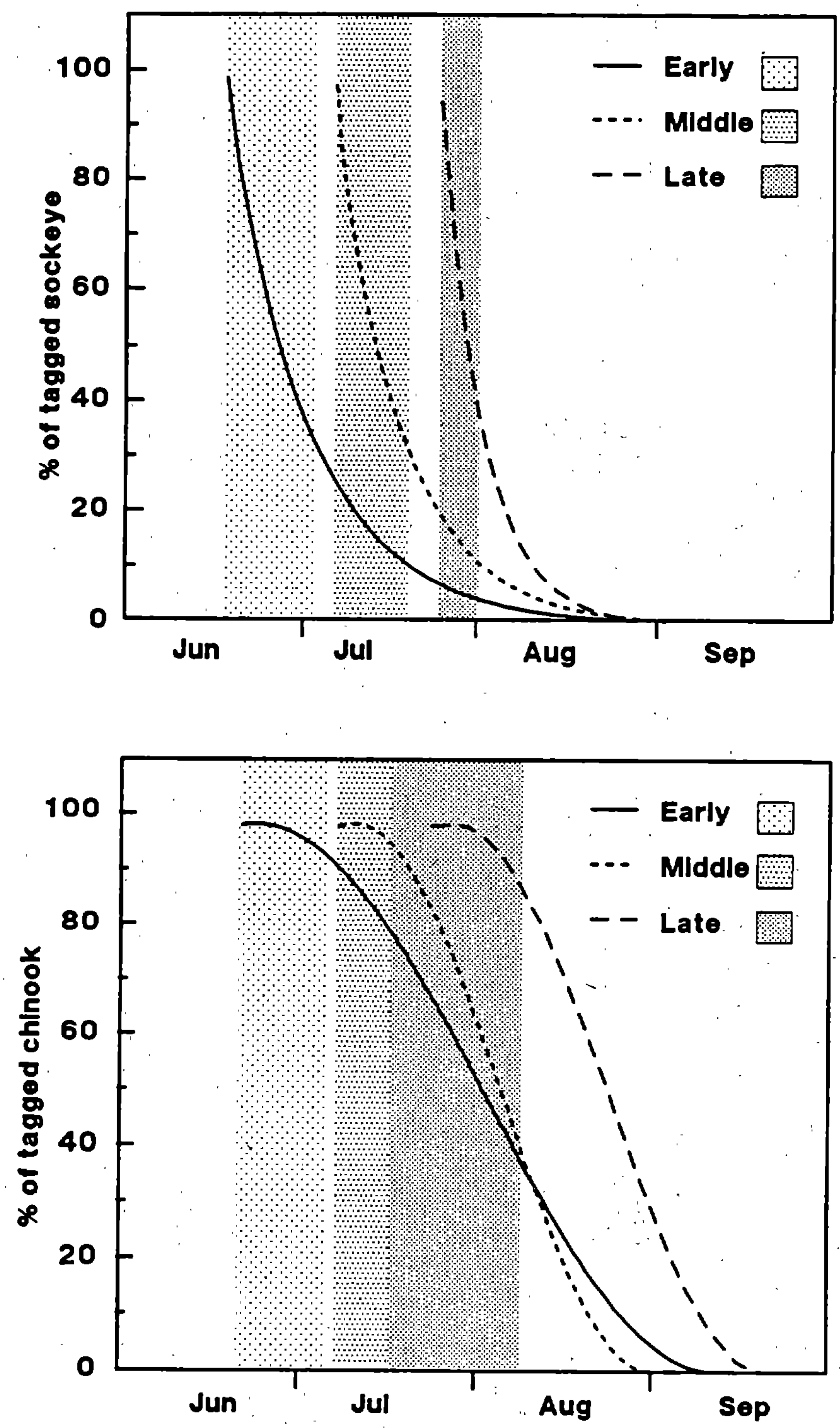

Figure 6.--Curves illustrating estimated percentages of three respective groups of tagged sockeye and chinook salmon between the weir and the bridge on the Situk River, Alaska, from June through September 1988. Shaded areas encompasS tagging dates.

Differences between surface water and intragravel temperature (averaging 9.1°C and 6.2°C, respectively) indicate that upwelling groundwater often was present in sockeye salmon spawning areas. All measured characteristics of habitat (Table 5) used by stream-spawning sockeye salmon differed significantly ($P < 0.05$; t test) from those used by chinook salmon; sockeye salmon spawning areas had shallower and slower water, smaller substrate, and more evidence of groundwater influence than chinook salmon spawning areas.

Chinook Salmon

Tagged chinook salmon emigrated more slowly ($P < 0.01$; F test) from the migration survey area in the flood corridor than did sockeye salmon, but most (99%) left the flood corridor by 1 September (Table 3). Models of emigration by groups of tagged chinook salmon (Fig. 6) fit the observed data (R = 0.76, 0.90, and 0.79 for early, middle, and late tagging periods, respectively). Emigration rates differed significantly ($P < 0.001$; F test) among groups, of tagged-chinook salmon; chinook salmon tagged in the late period emigrated from the survey area significantly more quickly ($P < 0.05$; Scheffe's test) than those tagged in the early or middle periods. Migrating chinook salmon were found primarily in deep (>2 m), open pools or deep (>l m) glides along banks with overhanging or submerged riparian vegetation. Radio-tagged chinook salmon often held in the same pool for nearly the entire time they were monitored in the flood corridor, and then moved quickly (within 1 or 2 days) to spawning areas. Radio-tagged chinook salmon using deep glides usually moved upstream more steadily than chinook salmon using deep pools.

Chinook salmon spawning was observed between 30 July and 14 September. Spawning chinook salmon were first observed about 1.5 km upstream of the Situk River bridge on 30 July; they were most abundant about the first, week of September, and spawning ceased before 30 September; no spawning chinook salmon were observed during the aerial survey on 30 September, and radio telemetry indicated that most (>90%) radio-tagged fish were well downstream of, their spawning sites and presumably were dead.

All chinook salmon spawned in either riffles or glides. Chinook salmon used an average of 19.0 m^2 of stream bed to construct a redd. Spawning sites had a mean water depth of 79.6 cm and mean water velocity of 73.0 cm/s. Substrate composition at redd sites averaged 5.3% fine sediment, 76.0% gravel, and 18.7% coarse sediment. Mean water temperature in chinook salmon spawning areas was 12.2°C and mean intragravel temperature was 11.9°C (Table 6).

Radio-tagged chinook salmon were closely tracked throughout the survey and provided detailed data on migration patterns and habitat use. Of 30 radio-tagged chinook salmon, 26 were tracked to spawning areas. Only four radio-tagged fish were not tracked to spawning areas: one migrated well upstream but died of unknown causes before spawning, one was caught at an undisclosed location by a sport fisherman, and two regurgitated their radio tags 'near the Situk River weir soon after tagging. Twenty-four (92%) of the remaining radio-tagged chinook salmon spawned between the Situk River bridge and Situk Lake (Fig. 4), the area with the highest density of chinook salmon spawning. One radio-tagged chinook salmon spawned within 1 km downstream of the Situk River bridge,, and one also spawned in the lower 1 km of the West Fork. A few chinook salmon (about 10-15) without tags also were observed spawning in other areas (Fig. 4): within 3 km downstream of the Situk River- bridge and in Mountain Stream upstream of Situk Lake.

Pink Salmon

Migrating pink salmonwere observed primarily in glides with overhanging vegetation or in transitional areas between pools and riffles. Spawning pink salmon were first observed on 10 August about 10 km upstream of the Situk River landing, and 'were last observed on 8 September near the boat landing. Many pink salmon spawned in one of three-areas: from 7 km upstream of the landing to 4 km downstream of Situk Lake, in the Old Situk River from its mouth to 1 km downstream of Forest Highway 10, and sporadically in the West Fork from its mouth to Redfield Lakes (Fig. 5). Pink salmon spawned in shallow (<40 cm), open glides or in transitional areas between pools and riffles.

DISCUSSION

Habitat Utilization

Migratory behavior and habitat use by sockeye, chinook, and pink salmon in the Situk River in 1988 were similar to those reported for the species in other rivers. Adult sockeye salmon in the Situk and other river systems migrate rapidly from salt water to lacustrine areas (Bevan 1962; Ricker 1966) and remain there until they spawn either in lakes or in streams connected to lakes (Foerster 1968). Sockeye salmon that spawned in the Situk River used habitat similar to that used by sockeye salmon in other streams (Foerster 1968; Leman 1989): relatively shallow, low-velocity water and variable substrate that was often infused with upwelling groundwater.

Adult chinook salmon in the Situk River often held in large pools or deep runs until mature, as they do 'in other river systems (Hamilton and Buell 1976; Burger et al. 1985). Chinook salmon in the Situk River spawned in relatively deep, fast water and used large substrate, as they do in other parts of their range (Smith 1973; Reiser and Bjornn 1979).

Pink salmon in the Situk River apparently migrated directly to spawning areas, consistent with their migratory behavior in other coastal streams (Ishida 1966; Heard 1978). Spawning pink salmon in the Situk River used habitat with characteristics similar to spawning habitat used by other pink salmon populations (Neave 1966; Reiser and Bjornn 1979).

Effects of Flooding on Fish and Habitat

Flooding from Russell Fiord would impact habitat in the Situk River used by migrating and spawning salmon. Discharge from the fiord is predicted to be more than 20 times the volume of the present Situk River (Paul 1988), which would inundate or erode all existing channels downstream of the Situk River bridge (Seitz et al. 1986; Paul 1988). Overflow from Russell Fiord could persist for decades, possibly centuries (Mayo 1988; Trabant et al. 1991), providing both a larger body of water to serve as fish habitat than the present Situk River and access to new fish habitat in the Russell Fiord watershed.

Duration and timing of the potential flooding will determine the magnitude of effects on fish habitat; in any case, several years will probably pass before inundated areas become stable. A persistent ice dam that would cause a relatively constant flow from Russell Fiord is predicted; however, a number of ice dams may initially form and fail, causing intermittent flooding, of, the Situk River watershed (Trabant et al. 1991). Fish habitat within the new floodplain, however, would begin to stabilize only when a relatively constant flow regime is established. A stable channel and, thus, stable fish habitat should be established after 3-5 years of relatively constant flow (Clark and Paustian 1989).

Migration corridors of all anadromous fish would be affected by flooding from Russell Fiord, although fish may still use the same corridors and maintain the same run timing. The new river would be large and turbid, and would offer good cover for holding and migrating fish; however, fish in the flood corridor when. flooding begins may be injured and displaced or cut off from spawning areas, as coho salmon and steelhead were in the Toutle and Cowlitz Rivers (Washington) after the 1980 eruption of Mount St. Helen's (Stober et al. 1981). Some fish also may attempt to avoid the turbid water. Pink salmon in the Bella Coola River, British Columbia, for example, delay spawning migrations and select alternate spawning areas to avoid glacial turbidity (Wickett 1958). The glacial runoff from Russell Fiord would certalinly decrease water temperature in the flood corridor and may cause fish to migrate more sluggishly. Changes in river temperature should not affect maturation rates because salmon gonad maturation is not greatly affected by changing water temperature (Billard 1985) within the range likely in the Situk River.

Location of the main spawning areas is a factor in determining the initial impacts of flooding on Situk River salmon populations; most sockeye and chinook salmon now spawn outside the predicted flood corridor, whereas many pink salmon spawn inside the flood corridor. Spawning areas outside the flood corridor would not be directly impacted by flooding; however, spawning areas in the flood corridor would be affected by channel morphology changes, increased fine sediment, and lowered temperature. Spawning areas in the flood corridor may be eroded or buried as a new channel develops under the influence of the new flow regime. Fine sediment mobilized by erosion and sediment from glacial turbidity also could clog or cement spawning gravel (Cooper 1965), and thus impede the intragravel water flow necessary for egg incubation (Wickett 1958; Reiser and Bjornn 1979). Cooler water temperature would slow egg and alevin development (Leitritz and Lewis 1980), thereby delaying hatching, emergrence, and seaward migration.

Timing and duration of the flood event, or events, also could: contribute to the initial impacts of flooding on Situk River salmon populations; closure of Russell Fiord is most likely to occur during spring, with overflow occurring 7-14 months later (Trabant et al. 1991). Thus, a flood would probably begin between December and August, thereby affecting, either eggs and alevins in the gravel or migrating salmon. A flood beginning in winter would probably destroy a large proportion of the pink salmon year class. My observations indiciate that 40% of the adults spawned within the flood corridor in 1988. In 1990 an estimated 84% of downstream migrant pink salmon fry came from within the flood corridor[2]. A flood beginning in spring or summer could affect migrations of juvenile or adult salmon; juvenile salmon may be washed out to sea before they are ready and adult fish may avoid flooded areas, thereby escalating competition in other spawning areas. In any case, flooding could decrease salmon production initially.

---

[2]J. Thedinga, Fishery Biologist,, Auke Bay ,Laboratory, 11305 Glacier Hwy., Juneau, AK 99801-8626. Pers. commin., March 1990.

A series of ephemeral dams that cause intermittent flooding could also cause cumulative effects, including those outlined above and additional effects caused by dewatering of river channels; river flow would decrease by more than 90% following the collapse of a Russell Fiord ice dam and many channels would dry up, stranding and killing fish and possibly dewatering redds. Thus, a single overflow event of long durationy-although potentially destructive--would probably be less detrimental to salmon populations than intermittent flooding.

A persistent ice dam could eventually form in Russell Fiord, and river channels and salmon habitat could stabilize. Side channels and some parts of main channels probably would provide rearing and spawning areas, as they do in other large' glacial rivers (Lake 1984; Lorenz and Eiler 1989; Murphy et al. 1989). Impoundment of Russell Fiord would increase the hydraulic gradient between the Situk River watershed and Russell Fiord, potentially creating new groundwater outflows that could provide salmon spawning and rearing habitat (Clark and Paustian 1989). Groundwater outflow channels are important to spawning populations of sockeye, chum (0. *keta),* and, coho salmon (0. *kisutcb)* in other watersheds, such as the Kamchatka River basin, U.S.S.R. (Leman 1989). Fish also. could have access to new habitat in Russell Lake and its watershed. All streams flowing into Russell Fiord are steep, high-energy streams that probably have little potential as spawning habitat; however,. the lake is a potential rearing area for juvenile sockeye and coho salmon.

After the river channels stabilize, species composition and size of salmon populations in the Situk River may continue to change as fish populations adapt to available habitat. Some species, or population cohorts within a species (stocks), may adapt more readily to the new conditions than others. Many chum and sockeye salmon, for example, spawn in some glacial rivers (Bishop 1981; Lorenz and Eiler 1989), whereas most other salmon do not. Sockeye and chinook salmon also rear at moderate densities in some glacial river habitats (Wood et al. 1987; Murphy et al. 1989).

Some Situk River salmon seem to exhibit spawning and rearing strategies that could enable them to adapt to the predicted habitat conditions after flooding begins,. The last overflow from the fiord was relatively recent (<120 years), and these fish may be remnants of populations adapted to previous episodes of- overflow from Russell Fiord. Some aspects of the habitat-utilization patterns and life history of sockeye salmon that spawn in Old Situk River; for example, indicate that they may be a remnant population. Many sockeye salmon in Old Situk River (and also the main channel of the' Situk River) use riverine spawning areas permeated by groundwater, a habitat component that should become more available in the Situk River watershed should Russell Fiord become impounded (Clark and Paustian 1989). Most (>90%[3]) sockeye salmon that spawn in Old Situk River use areas with little access to lake rearing habitat for their offspring and, therefore, go to sea before overwintering; most sockeye salmon in Alaska spawn in areas with access to lakes (Foerster 1968) because their offspring rear in lakes for at least a year before going to sea; however, sockeye salmon that go to sea before overwintering are common in glacial rivers and groundwater-fed streams in Alaska (McPherson 1987). Chinook salmon in the Situk River also may be a remnant population from previous overflow events because populations of chinook salmon in Alaska usually are found in large river systems rather than small coastal streams like the Situk River, (Kissner 1986).

The short duration of this study prohibited collection of data on some species, such as coho salmon and steelhead *(0. mykiss);* that contribute significantly to Situk River fisheries. This study, therefore, probably did not reveal all the potential impacts of flooding. The study may also., underestimate the area and range of conditions used by sockeye, chinook, and pink salmon, because their escapements to the Situk -River in 1988 were below average (Table 7).

In conclusion, this study confirms that habitat used by adult salmon exists in the corridor where flooding from Russell Fiord into the Situk River is predicted. If flooding of the predicted magnitude occurs, some salmon habitat would be altered or destroyed and salmon migration and distribution patterns may change. Flooding would directly affect migration habitat of all salmon species and large areas of pink salmon spawning habitat. Flooding also, may affect other spawning areas by displacing, large numbers of spawning fish (primarily pink salmon) into those areas. Timing of the initial flood event or events could determine the immediate effects of flooding on Situk River fish populations. Regardless of initial population changes, however, long-term production of salmon from the Situk River could be limited by' the innate abilities of endemic fish stocks to use post-flood habitat.

---

[3]Alaska Department of Fish and Game, Commercial Fisheries Division Scale Laboratory, 802 Third Street, Douglas, AK 99824, unpublished data, 1990.

Table 7.--Escapement of sockeye, chinook, and pink salmon to the Situk River in 1988 compared to the mean and range of escapements between 1979 and 1988. Escapement in 1988 as a percentage of the 10-year average is in parenthesis.

Escapement years		Sockeye[a]	Chinook[b]	Pink[a]
1988		**47,006**	**1,078**	**78,753**
		(60.3%)	**(75.8%)**	**(93.5%)**
1979-1987	**Mean**	**77,930**	**1,422**	**84,242[c]**
	Range	**46,701-128,879**	**611-2,572**	**40,211-126,346**

[a]Unpublished data provided by Gordon F. Woods, Alaska Dep. Fish and Game, Commercial Fisheries Div.; P.O. Box 68, Yakutat, AK 99689, August 1990.

[b]Compiled from Hubartt and Kissner (1987) and Bethers and Ingledue (1989).

[c]Mean and range for even year pink salmon escapements between 1980 and 1988

ACKNOWLEDGMENTS

I thank S. Feldhausen, F. Ryman, -A. Yanotti, B. Kirkpatrick, and J. Turley for their assistance in fish tagging and data collection for this project. I also thank the Commercial Fisheries Division of the Alaska Department of Fish and Game, Yakutat, for making this project possible through use of the tagging facility at the Situk River weir.

CITATIONS

Bethers, M., and D. Ingledue. 1989. Management of Situk River king and sockeye salmon fisheries. Report to the Alaska Board of Fisheries, 11 p. Alaska Dep. Fish and Game, 802 Third Street, Douglas, AK 99824.

Bevan; D. E. 1962. Estimation by tagging of the size of migrating salmon populations in coastal waters. In T. S. Y. Koo (editor), Studies of, Alaska Red Salmon, p. 375-449. Univ. Washington Press, Seattle.-

Billard, R. 1985: Environmental factors in salmonid culture and the control of reproduction. In R. N. Iwamoto and S. Sower (editors), Salmonid Reproduction: An International Symposium. Review papers,. p. 70-87. Washington Sea Grant Program, WSG-WO 85-2. Univ. Washington, Seattle.

Bishop, D. M. 1981. Hydrologic studies on the Tsirku-Chilkat River confluence: A major salmon spawning habitat.' A report to the Alaska Department of Natural Resources, 15 p. Environaid, 12175 Mendenhall Loop Road, Juneau, AK 99801.

Burger, C. V., R. L. Wilmot, and D. B. Wangaard. 1985. Comparison of spawning areas and times for two runs of chinook salmon (Oncorhynchus tshawytscha) in the Kenai 'River, Alaska. Can. J. Fish. Aquat. Sci. 42:693-700.

Clark, M. D., and S.J. Paustian. 1989: Hydrology of the Russell Lake-Old Situk River watershed. In E. B. Alexander (editor), Proceedings of Watershed '89, a conference on the stewardship of soil, air, and water resources, March 21-23, 1989, Juneau, Alaska, p. 103-111. U.S. Dep. Agric., Forest Serv., Alaska Region, Juneau, AK 99802-1628.

Cooper, A. C. 1965. The effect of transported stream sediment on the survival of sockeye and pink salmon -eggs and alevins. Int. Pac. Salmon Fish. Comm. Bull. 18, 71 p.

de Laguna, F., F. A. Riddell, D. F. McGeein, K. S. Lane, and J. A. Freed. 1964'. Archaeology of the Yakutat Bay area, Alaska. Smithsonian Inst., Bur. Am. Ethnology Bull. 192, 218 p.

Foerster, R. E. 1968. The sockeye salmon, *Oncorhynchus nerka.* Fish. Res. Board Can. Bull. 162, 422 p.

Hamilton, R., and J. W. Buell. 1976. Effects of modified hydrology on Campbell River salmonids. Tech. Rep. Series No. PAC/T-76-20, 127 p. Dep. Environ., Fish. and Mar. Serv., Habitat Protection Directorate,, Vancouver, BC.

Heard, W.R. 1978. Probable case of streambed overseeding-1967 pink salmon,. *Oncorhynchus gorbuscba,* spawners and survival of their progeny in Sashin Creek, southeastern Alaska. Fish. Bull., U.S. 76:569-582.

Hubartt, D. J., and P. D. Kissner. 1987. A study of chinook salmon in southeast Alaska. Fish. Data Ser. No. 32, 25 p. Alaska Dep. Fish and Game, 'Div. Sport Fish, Juneau, AK 99802.

Ishida, T. 1966. Pink salmon in the far east. Int. N. Pac. Fish. Comm. Bull. 18:29-39.

Kissner, P. D. 1986. Status of important native chinook salmon stocksin southeast Alaska. *In* Chinook salmon in southeast and harvest estimates, of selected sport fisheries. Study AFS-41-12(A), vol. 26:1-57. Alaska Dep. Fish and Game, Div. Sport Fish, Juneau, AK 99802.

Lake, M. R. 1984. 'Field studies of juvenile salmon in the Stikine River. Unpubl. manuscr. Environmental Assessments Div., Alaska Regional Office, Natl. Mar. Fish. Serv., NOAA, 709 W. Ninth St., Juneau, AK 99801.

Lamke, R. D., B. B. Bigelow, J. L. Van Maanen, R. T. Kemnitz, and K.M. Novcasky. 1991. Water resources data Alaska water year 1990. U.S. Geological Survey Water-Data Report AK-90-1, '252 p. U.S. Geological. Survey, Water Resources Div., 4230 University Drive - Suite 201, Anchorage, AK 9508-4664.

Leitritz, E., and R. C. Lewis. 1980. Trout and salmon culture: (Hatchery methods). Calif. Fish Bull. No..-164, 197 p. Univ. California,' Berkeley.

Leman, V. M. 1989. Classification of salmon (genus *Oncorhynchus)* redds in the Kamchatka River basin. J. Ichthyol. 28(5):148-158. [English transl. by Scripta Technica, Inc., of the Russian in Vopr. Ikhtiol. 1988(5) :754-763.1

Lorenz, J. M., and J. H. Eiler. 1989. Spawning habitat and redd characteristics of sockeye salmon in the glacial Taku River, British Columbia and Alaska. Trans. Am. Fish. Soc. 118:495-502.

Mayo, L. R. 1988. Advance of Hubbard Glacier and closure of Russell Fiord, Alaska--Environmental effects and hazards in the Yakutat area. *In* J. P. Galloway and T. D. Hamilton (editors), Geologic studies in Alaska by the U.S. Geological Survey during 1987; p. 4-16. USGS Circular 1016. U.S. Geological Survey, Federal Center, Box 25425, Denver, CO 80225.

McPherson, S. 1987. Prevalence of zero-check sockeye salmon in southeast Alaska. *In* G. Gundstrom (editor), Southeast Alaska Inter-Divisional Sockeye Salmon Program Review, April 16 & 17, 1987, Juneau, AK, np. Southeast Region, Commer. Fish. Div., Alaska Dep. Fish and Game, 802 Third St., Douglas, AK 99824.

Murphy, M. L., J. Heifetz, J. F. Thedinga, S. W. Johnson, and K V. Koski. 1989. Habitat utilization by juvenile Pacific salmon *(Onchorynchus)* [sic]. in the glacial Taku River, southeast Alaska. Can. J. Fish; Aquat. Sci. 46:1677-1685.

Neave, F. 1966. -Pink salmon in British Columbia. Int. N. Pac. Fish. Comm. Bull. 18:71-78.

Paul, L. 1988. Situk River flood plain analysis. Publ. R10-MB-30, 42 p. U.S. Dep. Agric., Forest Serv., Alaska Region, 709 W. 9th St., Juneau, AK 99801.

Reiser, D. W., and T. C. Bjornn. 1979. "Habitat requirements of anadromous salmonids. *In* W. R. Meehan (editor), Influence of forest and rangeland management on anadromousfish habitat in the western United States and Canada. Gen. Tech. Rep. PNW-96, p. 1-54. U.S. Dep. Agric., Forest Serv., Pacific Northwest Forest and Range Experiment Sta., 809 NE 6th Ave., Portland, OR 97232.

Ricker, W. E. 1966. Sockeye salmon in British Columbia. Int. N. Pac. Fish. Comm. Bull. 18:59-70;

Seitz, H. R., D. S. Thomas, and B. Tomlinson. 1986. -The storage and release of water from a large glacier-dammed lake: Russell Lake near Yakutat, Alaska, 1986. U.S. Dep., Interior, Geological Survey Open-File Rep. 86-545, 10 p. Juneau, AK 99801.

Smith, A. K. 1973. Development and application of spawning, velocity and depth criteria for Oregon salmonids. Trans. Am. Fish. Soc. 102:312-316.

Snedecor, G. W., and W. G. Cochran. 1967.' Statistical methods, 6th ed. Iowa State Univ. Press, Ames, 593 p.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co., San Francisco, 776 p.

Stober, Q. J., B. D. Ross, C. L. Melby, P. A. Dinnel, T. H. Jagielo, and E. O. Salo. 1981. Effects of suspended volcanic sediment on coho and chinook salmon in the Toutle and Cowlitz Rivers. Rep. FRI-UW-8124, 147 p. Univ. Washington, Seattle.

Trabant, D. C., R. M. Krimmel, and A. Post. 1991. A preliminary forecast of the advance of Hubbard Glacier and its influence on Russell Fiord, Alaska. U.S. Geological Survey, Water Resources Investigations Rep. 90-4172, 34 p.

Wickett, W. P. 1958. Review of certain environmental factors affecting the production of pink and chum salmon. J. Fish. Res. Board Can. 15:1103-1126.

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. Fish. Aquat. Sci. 96.

RECENT TECHNICAL MEMORANDUMS

Copies of this and other NOAA Technical Memorandums are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22167. Paper copies vary in price. Microfiche copies cost $3.50.

AFSC-

29 IGNELL, S. E., L. J. SIMON, and M. L. DAHLBERG. 1994. Estimation of salmonid bycatch in the 1989 Japanese squid driftnet fishery, 45 p. NTIS number pending.

28 MORTENSEN, D. G., and H. SAVIKKO. 1993. Effects of water temperature on growth of juvenile pink salmon (Oncorhynchus gorbuscha), 12 p. NTIS number pending.

27 LOW, L-L. (compiler). 1993. Status of living marine resources off Alaska, 1993, 110 p. NTIS number pending.

26 LOW, L-L. (compiler). 1993. Status of living marine resources off the Pacific coast of the United States for 1993, 90 p. NTIS number pending.

25 KINOSHITA, R. K., A. GREIG, J. D. HASTIE, and J. M. TERRY. 1993. Economic status of the groundfish fisheries off Alaska, 1992, 102 p. NTIS number pending.

24 SINCLAIR, E. H. (editor) 1993. Fur seal investigations, 1991, 142 p. NTIS No. PB94-118171.

23 PARKS, N. B., F. R. SHAW, and R. L HENRY. 1993. Results of a 1988 trawl survey of groundfish resources of the upper continental slope off Oregon, 164 p. NTIS No. PB94-118163.

22 YANG, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 150 p. NTIS No. PB94-112463.

21 KINOSHITA, R. K., and J. M. TERRY. 1993. Oregon, Washington, and Alaska exports of edible fishery products, 1992, 52 p. NTIS No. PB93-226652.

20 REEVES, J. E. 1993. Use of lower minimum size limits to reduce discards in the. Bristol Bay red king crab (Paralithodes camtschaticus) fishery, 16 p. NTIS No. PB93-228187.

19 SYRJALA, S. E. 1993. Species-specific stratification and the estimate of groundfish biomass in the Eastern Bering Sea, 20 p. NTIS number pending.

18 PELLA, J., M. HOFFMAN, S. HOFFMAN, M. MASUDA, S. NELSON, and L. TALLEY. 1993. Adult sockeye and pink salmon tagging experiments for separating stocks in northern British Columbia and southern Southeast Alaska, 1982-1985, 134 p. NTIS No. PB93-226660.

17 SEASE, J. L., J. P. LEWIS, D. C. MCALLISTER, R. L. MERRICK, and S. M. MELLO. 1993. Aerial and ship-based surveys of Steller sea lions (Eumetopias iubatus) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands during June and July 1992, 57 p. NTIS No. PB93-226025.

16 FISCUS, C. F. 1993. Catalogue of cephalopods at the National Marine Mammal Laboratory, 183 p. NTIS No. PB93-226678.

15 KINOSHITA, R. K., A. GREIG, L. E. QUEIROLO, and J. M. TERRY. 1993. Economic status of the groundfish fisheries off Alaska, 1991, 94 p. NTIS No. PB93-197861.