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Susitna River Instream Flow

ALASKA POWER AUTHORITY
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DRAFT INSTREAM FLOW RELATIONSHIPS REPORT

VOLUME NO. 2

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HARZA-EBASCO SUSITNA JOINT VENTURE

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I. INTRODUCTION

This document comprises Volume II of the Instream Flow Relationships Report (IFRR), a two-volume series on instream flow processes in the middle Susitna River. The report is the result of work funded by the Alaska Power Authority as part of its informational needs for the proposed Susitna Hydroelectric Project. The objectives of the IFRR are twofold: 1) to identify the relative importances of salient physical processes to fish resources, and 2) to evaluate and, where possible, quantify the influences of incremental changes in important physical variables on fish habitat. Volume I addressed the first objective. It also introduced concepts which are the basis for the more refined analytical techniques described here in Volume II. Volume II presents the basic framework of an analytical methodology designed to describe the magnitudes of change in fish habitat associated with alterations in instream flow processes.

This volume is presented in five sections. The remainder of the introduction briefly describes the project and its setting, the project's influence on salient physical processes, fish resources in the middle Susitna River, and the scope of the IFRR studies. This is followed by a three-part analysis of the influence of important physical parameters on fish resources. Section II quantitatively describes the response of juvenile chinook salmon habitat to mainstem discharge using velocity, depth, and cover criteria. Other variables which may influence fish habitat, but which were not modeled quantitatively, are discussed. The relative importance of each and how they might be incorporated into the response curves are discussed. Section III is an analysis of chum salmon spawning and incubation habitat presented in the same format as Section II, and Section IV focuses on other fish species in the middle Susitna River. Finally, a summary section will present conclusions and discuss the approach needed to ascertain magnitudes of response for an effective negotiated settlement.

Project Setting and Description

The Susitna River is an unregulated glacial river in southcentral Alaska with a drainage area of 19,600 square miles (Fig. I-1). It flows 320 miles

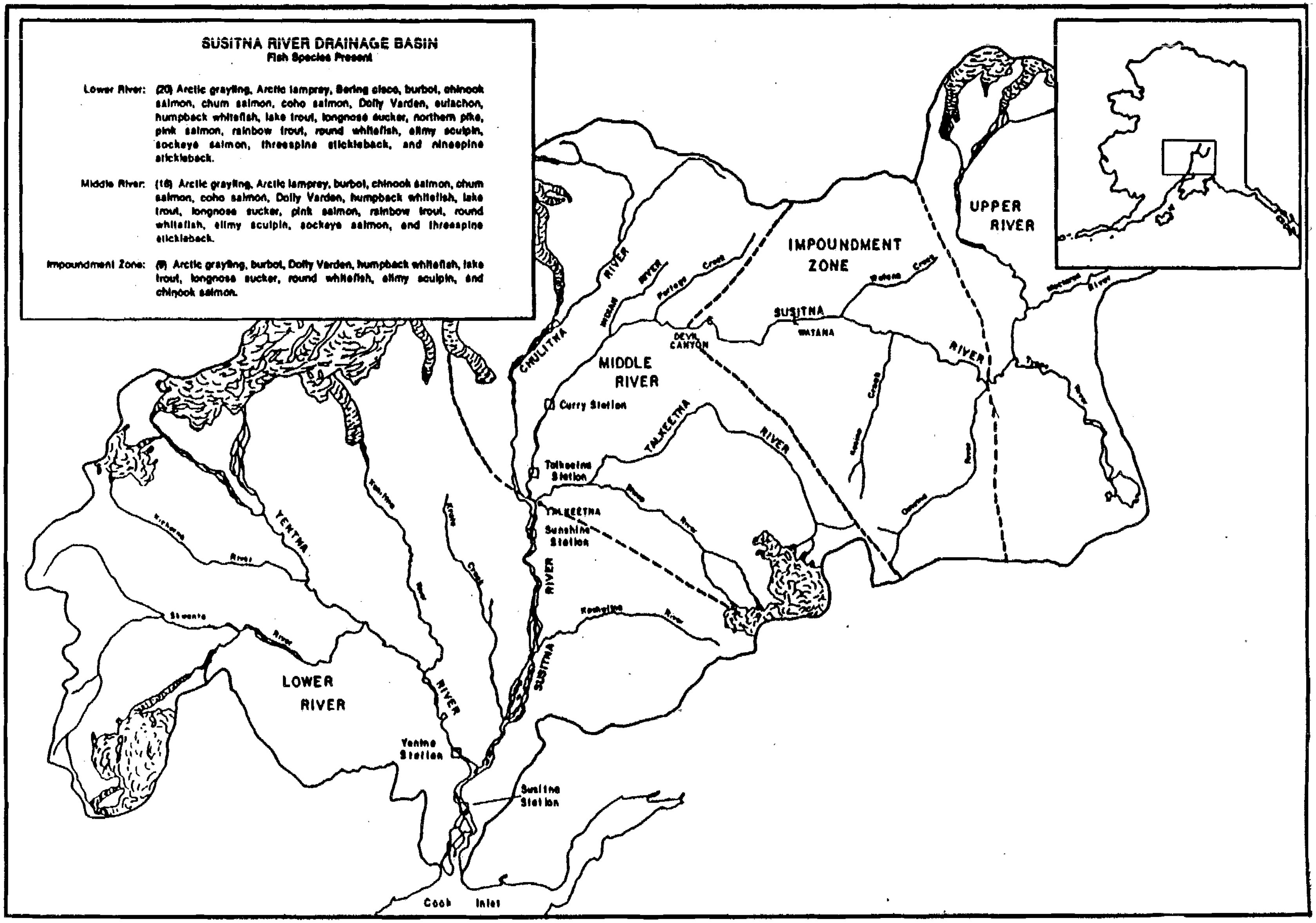

Figure I-1. Susitna River drainage basin and fish species by study zone (from University of Alaska 1985).

southwest into Cook Inlet from its headwaters in the Alaska Range. It is bordered on the north and west by the Alaska Range and on the south and east by the Talkeetna Mountains.

The river exhibits wide variations in flow in response to changes in weather patterns and climatic conditions. Seasonal fluctuation is most pronounced with typical summer flows ranging from 16,000 to 30,000 cubic feet per second (cfs) and winter flows averaging between 1,000 and 2,000 cfs. Climatic conditions and weather patterns influence flow regimes in the Susitna River through surface runoff and glacial melt, which are mediated by precipitation and temperatures. Concomitantly, glacier melt contributes large inputs of suspended solids to the system. Consequently, high concentration of total suspended solids (TSS) and turbidities are characteristic of the Susitna at those times of the year, particularly during the summer when glacier melt, along with snow melt and other surface runoff, is also contributing to high flows. Thus, changes in temperature, streamflow, TSS, and turbidity are correlated. Furthermore, as discussed in Volume I, these are the physical variables that most influence fish habitat in the Susitna River.

The Susitna Hydroelectric Project, as proposed, will consist of two dams constructed on the Susitna River to serve energy demands in the Railbelt region. Construction would occur in three stages: 1) Stage I will create an electrical generating capacity of 440 MW by the construction of Watana Dam, a 700-foot-high rockfill structure. The projected completion date is 1999. 2) Stage II will be completed in 2005 by the construction of a concrete-arch dam at Devil Canyon. Electrical generating capacity at the Devil Canyon site will be 680 MW. 3) Stage III would complete construction of the Watana Dam by raising its height to 885 feet with a concomitant increase in electrical generating capacity to 1110 MW. At the completion of Stage III in 2012, the total capacity of the project would be 1709 MW.

As originally conceived, the project was to be built in only two stages. The Alaska Power Authority submitted a license application to the Federal Energy Regulatory Commission (FERC) in February, 1983 to construct and operate the project. Subsequent cost-benefit analysis, however, resulted in the formulation of the three-stage proposal as the preferred alternative.

The three-stage project presents no net change in final design and capacity from that envisioned under the original two-stage plan. However, the modification in scheduling does require the preparation of an amendment to the license application. Thus, an amendment will be filed with the FERC in early 1986. A draft of this amendment (APA 1985) has been prepared and is presently circulating for public comment. Descriptions of all aspects of the project are available in that document, and the reader is referred to it for discussions that are most detailed than those presented here.

The major tributaries to the Susitna are the Chulitna, Talkeetna, and Yentna Rivers. The Chulitna, a glacial river which originates in the Alaska Range, joins the Susitna at river mile (RM) 99. The Talkeetna River, which drains from the Talkeetna Mountains, enters the Susitna at RM 97. The Chulitna and Talkeetna Rivers, then, join the Susitna at about the same place and, together, contribute about 59% of the total flow at the Parks Highway Bridge. For this reason and because of geomorphologic considerations, the confluence of these three rivers (the three rivers confluence) serves as a boundary between the lower and middle segments of the Susitna River. The lower segment extends from the confluence to Cook Inlet. The Yentna River enters the lower segment at RM 28. The middle Susitna River extends upstream about 50 miles from the three rivers confluence to Devil Canyon (RM 150). The upper Susitna River exists above Devil Canyon.

Project-related impacts will be dampened in the lower Susitna River because of the relatively large influences of the Chulitna and Talkeetna rivers, and, further downstream, the Yentna River. Downstream impacts will be most pronounced in the middle Susitna River and, thus, this segment is the focus of the majority of environmental assessment work and is the subject of this report.

Project Influence on Salient Physical Processes

As discussed previously, the important riverine physical variables, relative to the project, are flow, TSS, turbidity and temperature. Each varies under natural conditions, with predictable trends occurring seasonally. These natural variations will be altered in the middle Susitna River by operation of the project. The changes which occur will depend upon the stage of the project and the operational flow regime chosen for that stage. It is important to understand the physical processes that occur naturally and the potential changes that are likely to result from the project before assessments on fisheries can be made. Therefore, each of the aforementioned physical variables are described along with anticipated alterations which will result from project operations.

Flow

Typical summer flows in the middle Susitna River range from 16,000 to 30,000 cfs while winter flows are much less, ranging from around 1,000 to 3,000 cfs. In addition to seasonal trends, shorter-term variation occurs in response to precipitation and temperature. Figure I-2 shows mean monthly flows at Gold Creek averaged over the years 1951 to 1983. The peak mean monthly flow occurred in June at 28,000 cfs, while the minimum flow was slightly higher than 1,000 cfs in March. Anticipated with-project flows are also shown in Figure I-2. The project will dampen the seasonal fluctuations in flow. The magnitude of seasonal oscillation will be increasingly reduced as development of the project proceeds until, by the completion of Stage III, minimum and maximum flows are about 8,000 cfs and 11,000 cfs, respectively. Mean annual flows will be about 10,000 cfs.

It must be understood that the anticipated flows in Figure I-2 are based on only one of the flow cases (E-VI) described in the application amendment. This case is the alternative preferred by the applicant because it is thought to satisfy operational flow requirements while, at the same time, providing an opportunity to meet fisheries objectives. However, adjustments are possible and may be warranted after the completion of environmental analyses. The following discussions of TSS, turbidity, and temperature include descriptions of predicted differences between natural conditions and the E-VI flow case.

Total Suspended Solids

Total suspended solids in the middle Susitna River are generally positively correlated with flow. That is, concentrations of TSS increase as flow increases in response to glacier melt and surface runoff. By far the most

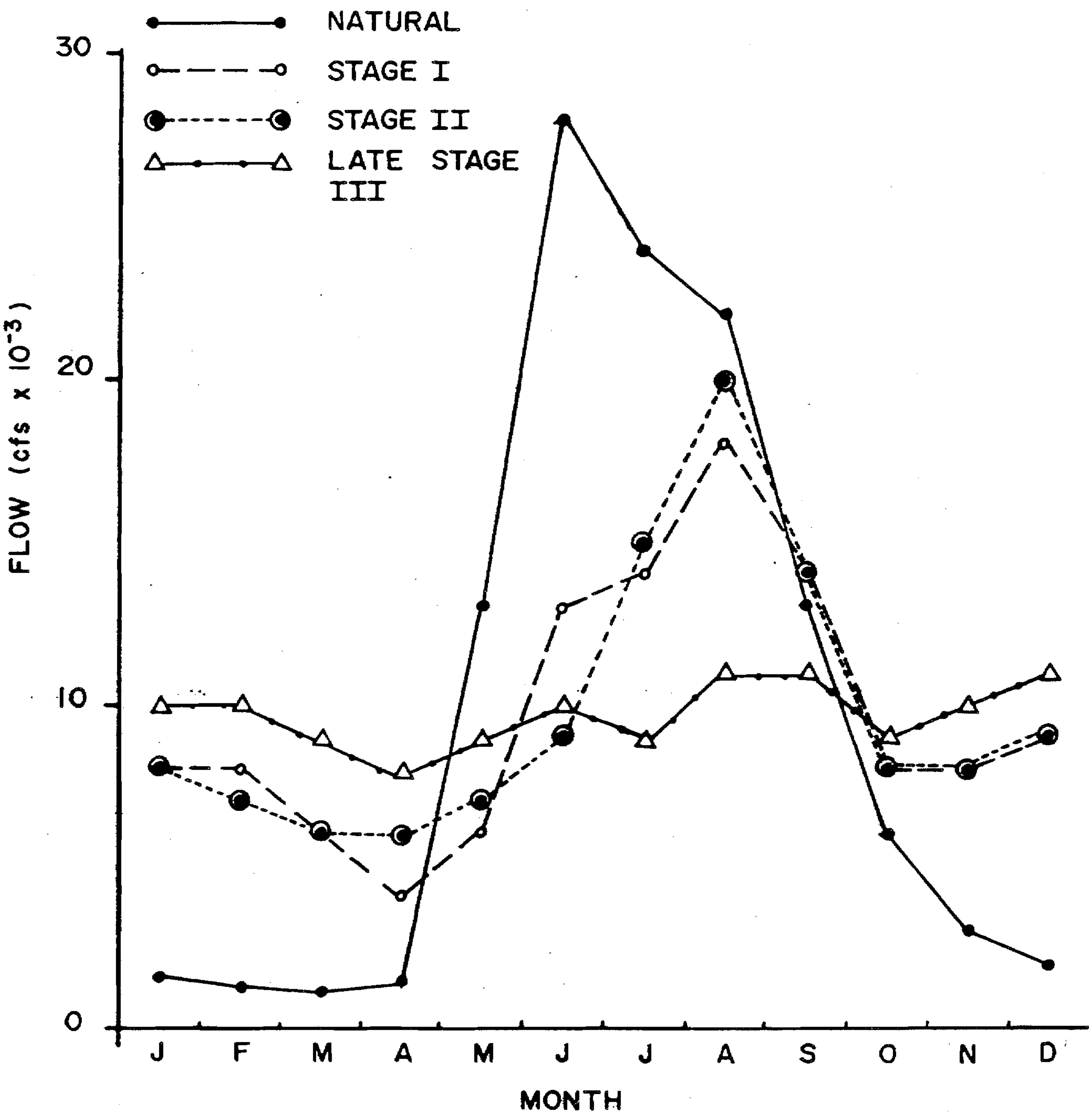

Figure I-2. Estimated with-project mean monthly flows at Gold Creek compared to natural flows (data from APA 1985).

important contribution to TSS is glacier flour, released during periods of elevated temperature. Thus, the seasonal pattern of TSS closely follows that of flow, namely, high in the warmer summer months and low during the winter. Figure I-3 illustrates the differences between concentrations in TSS under natural conditions and those anticipated during the three stages of the project. Seasonal variations in TSS are expected to decline when the project becomes operational because the impoundment will release relatively constant concentrations of TSS throughout the year. However, even though TSS concentrations will remain relatively constant at approximately 100-150 mg/l, they will be higher than natural conditions during the fall and winter, and lower during the spring and summer.

Turbidity

Turbidity is a measure of the scattering of light in water from suspended sediment. Thus, TSS and turbidity are positively correlated, although the exact relationship is situation-specific and difficult to quantify. Part of the problem in relating turbidity to TSS is because of differences in particle size. Generally, turbidity is imparted to a body of water by particles less than three microns in size, whereas TSS can consist of a much wider range of particle sizes. The larger of these are apt to quickly settle from suspension in quiescent water. Although these larger particles contribute very little to turbidity readings while they are in suspension, they do add considerable mass to concentration values of TSS. Thus, the relationship between turbidity and TSS can be very different between lotic and lentic systems. Another source of inaccuracy in establishing a relationship between TSS and turbidity is that significant differences in turbidity readings can exist between samples with similar concentrations of TSS because of differences in particle geometry.

Nevertheless, with-project turbidity estimates were established by applying a conversion factor to predicted TSS values. Although the use of this conversion factor is somewhat questionable and more work is probably required to elucidate a valid relationship between the two variables, the general seasonal trends in TSS and turbidity should theoretically be similar. Figure I-4 shows natural turbidity values in the middle Susitna River and predicted with-project values calculated using a turbidity to TSS conversion ratio of 2

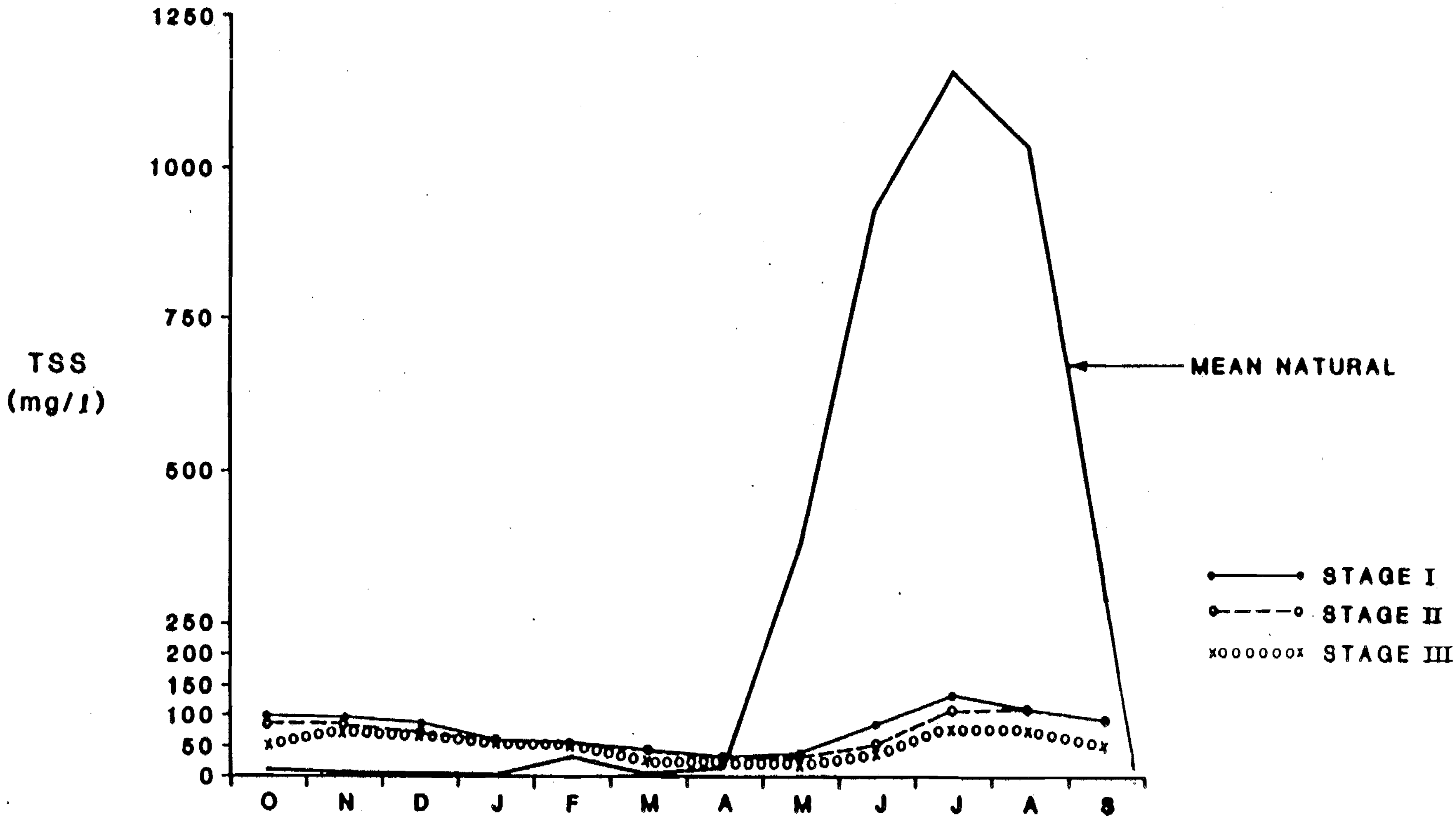

Figure I-3. Estimated with project mean monthly suspended sediment concentrations in the middle Susitna River compared with natural values (from Harza-Ebasco Susitna Joint Venture 1985).

Months >100 NTU Jan, Feb, June, July, Aug, Sept, Oct, Nov, Dec
>150 NTU June, July, Aug, Sept, Oct, Nov, Dec

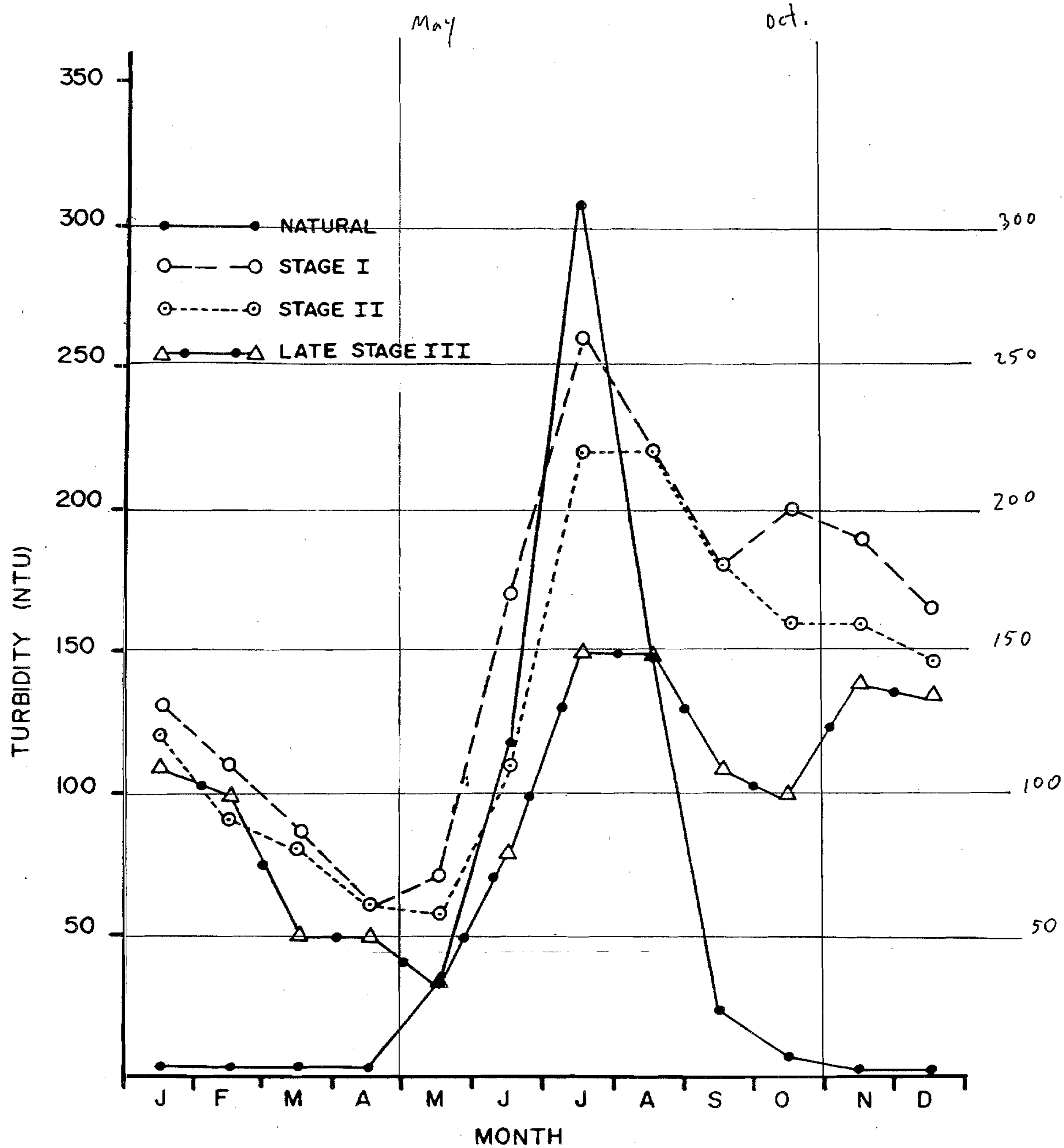

Figure I-4. Estimated with-project mean monthly turbidity values at Gold Creek compared to natural values (with-project values from APA 1985, natural values from ADF&G 1983g).

(Harza-Ebasco 1985). As in the case of TSS, turbidity is positively correlated with flow and is seasonally variable. Turbidities will not fluctuate over the course of the year during operation of the project as much as under natural conditions. On the other hand, with-project turbidities, like TSS concentrations, will be higher than those under natural conditions during the fall and winter but lower during the spring and summer.

Temperature

Temperature is interrelated with flow, TSS, and turbidity. Actually, changes in the latter three are largely dependent upon climatic temperature which, in turn, is the main variable affecting water temperature. Thus, it is logical that all four variables exhibit the same seasonal trends. Temperatures in the middle Susitna River range from 0°C during winter to 12-13°C in the summer. The project, however, will store large volumes of water and then release it at relatively constant discharge rates resulting in increased temperatures during the winter and lowered temperatures during the summer. The effect will become more pronounced as subsequent stages are completed. However, changes in temperature profiles unlike those of flow, TSS and turbidity, will not occur along the whole length of the river below the site location. The further downstream water travels the more it will be influenced by ambient air temperatures until project-related influences are negligible. Figure I-5 shows the impacts of the project on temperature regimes. Greater differences between natural and with-project temperatures occur in the upper and middle reaches (RM130) than at the lower end (RM 100) of the middle Susitna River. Furthermore, the later stages of the project cause greater deviations from natural water temperatures because of the greater volumes of water stored.

The discussion to this point has centered on mainstem temperatures. However, temperatures in peripheral fish habitats, such as sloughs and side channels, can differ from those in the mainstem depending upon the amount and temperatures of upwelling, climatic conditions, and the volume and temperatures of mainstem water entering these habitats when berms are overtopped. Tributary temperatures, on the other hand, will not be affected by the project. Generally, temperatures of sloughs and side channels that are not overtopped will be lower in summer than mainstem temperatures (APA 1985). This is a

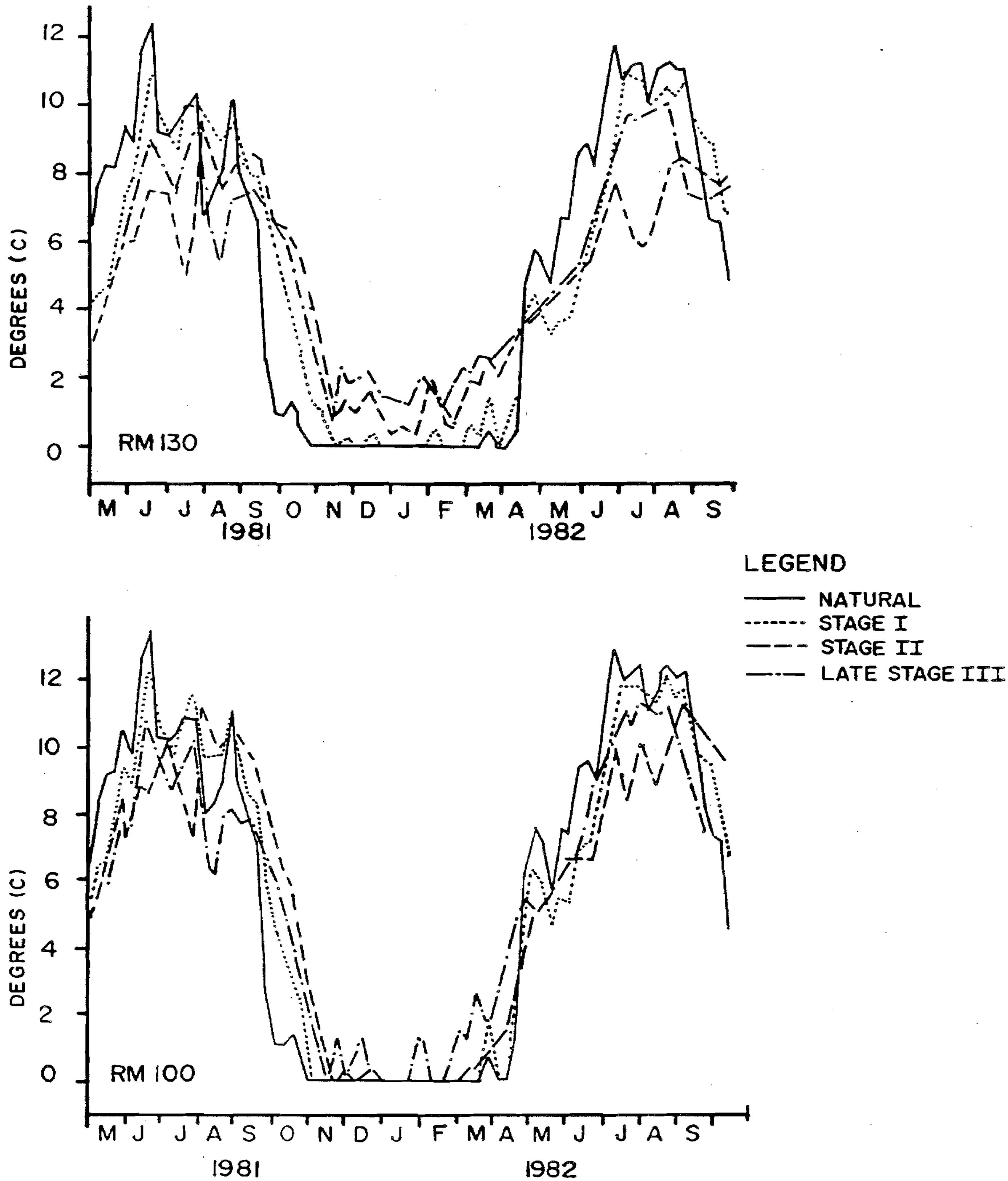

Figure I-5. Estimated with-project temperatures at two river miles (RM) at three stages of development compared with natural temperatures (modified from APA 1985).

result of upwelling in these habitats and tributary input, the temperatures of which are usually colder than mainstem temperatures. On the other hand, higher than normal flows in winter caused by the project may contribute to the freezing of some leads that are normally open as a result of relatively warm winter upwelling.

As discussed in Volume I, ice processes may contribute to other impacts on peripheral habitat. Thus, ice processes are important influences on fish habitat in the Susitna River. Because of the effects of the project on temperature regimes, ice cover will change both spatially and temporally as illustrated in Figure I-6. Whereas ice forms naturally over the entire middle river in winter, the release of relatively warm water from the project will result in open water below the dam site all year long. The distance downstream that open water will exist, however, will vary according to the stage of development. At the completion of Stage I, the middle Susitna River will be ice free from the Watana Dam downstream to RM 139. On the other hand, the section of ice-free river will extend from the Devil Canyon Dam (RM 150) to RM 114 with the completion of Stage III. Furthermore, the length of time that ice exists on the middle river will be altered by the project. Figure I-6 shows that ice normally begins forming at Talkeetna (RM 100) in mid-November. Melt-off is complete toward the end of May. However, the period that ice exists on the middle river will be markedly shortened until the completion of Stage III when ice cover will exist only from early January to the middle of March.

Fish Resources in the Middle Susitna River

Existing fish resources are described in detail in numerous reports (see, for example, APA 1985). Volume I of the IFRR summarizes these resources and describes important physical variables that influence them. We briefly reiterate here what those resources are. The approach taken in developing a methodology which establishes the relationships between these resources and instream flow processes is described in the next section.

Approximately 20 species of fish inhabit the Susitna River at one time or another during their life histories (see Fig. I-1). These species include

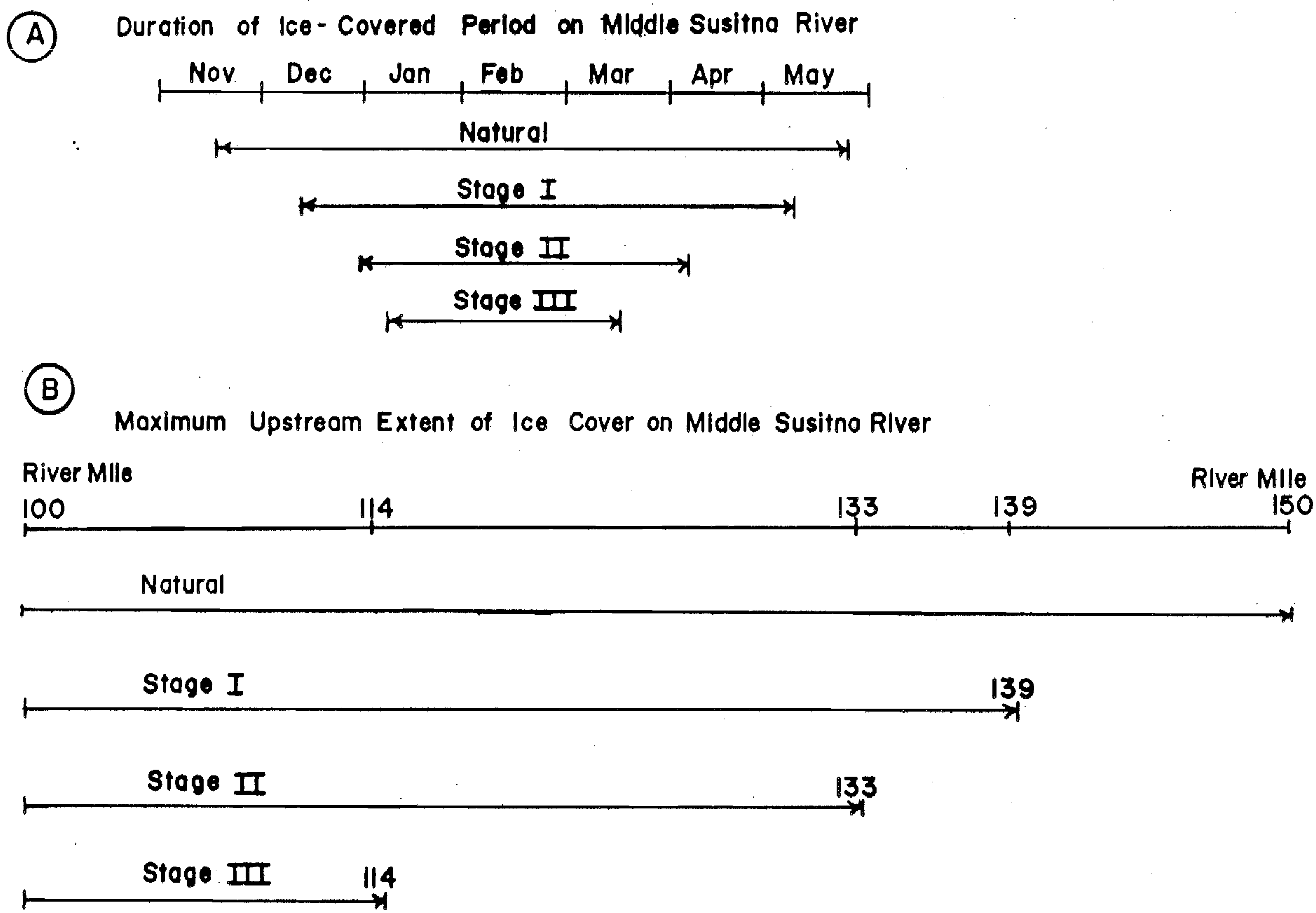

Figure I-6. Extent and time of ice cover on the middle Susitna River under natural and with-project conditions.

commercial, sport, subsistence and non-game fish. The most important in terms of recreational and commercial interests are five species of Pacific salmon, rainbow trout, Dolly Varden, Arctic grayling, and burbot.

The goal of the Alaska Power Authority in identifying environmentally acceptable flow regimes for the proposed project is to maintain existing fish resources and levels of production. It is possible that this can be accomplished by the selection of appropriate operational flow and/or temperature regimes. To do this, it is necessary to quantify the response of fish in the Susitna River to incremental changes in mainstem discharge, temperature, and water quality.

Scope of the IFR Studies

The IFR studies were undertaken to establish the relationships between physical variables, fluvial processes and fish resources in the middle Susitna River. This represents an extremely complex problem because of the number of environmental variables involved and the number of species of fish which inhabit the middle Susitna River. It is necessary, therefore, to reduce the scope of work by focusing only on the most important physical variables, and by carefully identifying the important fish resources which are most sensitive to project-related changes in those variables.

Whereas physical parameters can be quantified relatively easily, quantifying the response of fish to changes in these parameters requires the selection of an appropriate response variable(s). To avoid many of the uncertainties associated with correlating fish populations with environmental parameters, habitat is often used as a response variable (Stalnaker and Arnette 1976, Olsen 1979, Trihey 1979). Accordingly, habitat analysis is used in the IFR studies as an indicator of how fish populations respond to changes in fluvial processes. When using fish habitat as the response variable, the direction and magnitude of change in habitat availability or habitat quality is used to indicate the response of the population. Although the relationship between habitat and population is not necessarily linear, it has been found to be positively correlated (Binns and Eiserman 1979, Wesche 1980, Loar 1985).

Six habitat types were identified within the middle Susitna River (ADF&G 1983b, Klinger and Trihey 1984). These are: 1) mainstem, 2) side channels, 3) side sloughs, 4) upland sloughs, 5) tributaries, and 6) tributary mouths. Furthermore, depending upon mainstem stage, some of these habitats may be transformed from one type to another (Klinger and Trihey 1984). The importance of each habitat type varies with species and life stage. This necessitated the selection of evaluation species/life stages, based on their importance and sensitivity. In this way, the species and habitats analyzed were reduced to a manageable number. Each evaluation species/life stage was carefully selected so that if concerns for each were addressed, then concerns for other species would be implicitly incorporated into the analysis. Therefore, the analysis was simplified but, at the same time, remained comprehensive.

Evaluation species/stages were selected by determining the species that are most sensitive or important to commercial, subsistence, and recreational interests, and by determining the life stages that are most vulnerable to predicted environmental perturbations associated with the project. This sensitivity analysis proceeded according to the species/life stages likely to be present in affected habitats. Of the six habitat types, only three will be significantly affected by alterations in physical variables. These are mainstem, side channels, and side sloughs. These habitats are used mostly by anadromous species; resident species are present in relatively low densities. Therefore, modeling the use of mainstem, side channels, and side sloughs by salmon was considered to be of primary importance.

Only two species of salmon, chinook salmon and chum salmon, were used as evaluation species. The rationale for this decision was that the three habitat types most susceptable to project-induced effects are used by salmon for migration, spawning/incubation, and rearing/overwintering. Of these three life stages, only migrating adults are not critically sensitive to the kinds of physical changes that will likely be associated with the project. On the other hand, chinook salmon rearing/overwintering is one of the most important uses of side channel and side slough habitats. Thus, chinook rearing/overwintering was included as an evaluation species/stage. These same two habitats are also used intensively by chum and sockeye spawning/incubation, but because chum salmon are far more abundant in the middle Susitna River than sockeye salmon, chum spawning/incubation was chosen as another evaluation species/stage.

Other species are important in the middle river but their use of and sensitivity in the habitats affected by the project do not warrant detailed analytical analyses. If habitats used by chum and chinook salmon are incorporated into the quantitative methodologies, then concerns about other species can be addressed subjectively. Consequently, this report is presented in sections that quantitatively analyze, where possible, chinook rearing/overwintering and chum spawning/incubation, and subjectively address concerns for other species.

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The analytical methodology used for chinook and chum salmon is based on the premise that available habitat can be quantified and then standardized to an equivalent amount of optimal habitat known as weighted usable area (WUA). This technique allows ~~for~~ differences in habitat quality by incorporating habitat suitability criteria into the analysis. The analysis is performed using the instream flow incremental methodologies (IFIM) as discussed by Milhous et al. (1984). Because instream flow is a driving variable which either directly or indirectly affects water temperature and water quality, the response of WUA to incremental changes in mainstem discharge is the focal point of the quantitative relationships analysis.

Volume I of the IFRR identified the physical parameters, habitat types, and evaluation species/life stages discussed above. It also presented rankings of the relative importances of each, introduced the methodology for quantifying available habitat (WUA) as it responds to changes in mainstem discharge, and discussed other variables which, although not quantifiable at that time, nevertheless may be important criteria in determining the response of fish populations in the middle Susitna River to fluvial processes.

Volume II provides a logical sequel to Volume I. It provides a refined analysis of that which was presented in Volume I. Whereas Volume I identified key processes and established the approach for quantifying the response of fish habitat to changes in streamflow, Volume II provides the basic framework of a useable methodology for application in the middle Susitna River.

One important procedure used in Volume II is the extrapolation of model output to the entire middle river. To extrapolate results obtained at individual sites to a system-wide response, the concept of representative groups of study sites was introduced in Volume I. The entire middle river was divided into 172 specific areas, each of which was characterized structurally and hydraulically. These areas were then categorized into 10 representative groups, based on morphologic, hydraulic, and hydrologic similarities. Thus, the entire length of the middle river has been divided into representative groups of study sites. This replaces the longitudinal, representative reach approach commonly used in homogeneous, single-channel systems, a change from traditional methodology necessitated by the existence of split- and multi-thread channels in the middle Susitna River. Included in the analysis was the phenomenon of habitat types transforming from one type to another according to breaching flows. Within each representative group there exists both modeled and non-modeled sites. Modeled sites are those that have been extensively surveyed. In Volume II results of habitat response analyses are extrapolated from modeled sites to their respective representative groups using areal proportionality. System-wide responses are then estimated by integrating the individual responses of all 10 representative groups.

Volume II also defines limits and boundaries for the model and describes how other non-modeled parameters could be incorporated. The main objective of Volume II is the refinement of principles elucidated in Volume I into an integrated procedure for use during the settlement process. It is hoped that the IFRR will be useful in arriving at a negotiated settlement which incorporates a comprehensive understanding of the effects of various project design and operation scenarios on fish habitat.

II. RESPONSE OF JUVENILE CHINOOK HABITAT TO MAINSTEM DISCHARGE

This section evaluates the weighted usable area (WUA) group curves for portions of the river, described by Steward et al. (1985), and discusses how they may be used to estimate the system-wide response of juvenile chinook habitat in the middle Susitna River to variations in mainstem discharge. This procedure requires an interpretation of the information obtained by the modeling techniques and of the suitability criteria on which the curves are based. The significance of other factors not included in the model is examined and suggestions on how they may be incorporated are presented. Juvenile chinook abundance and distribution data are evaluated to ascertain if they suitably reflect the WUA forecasts for portions of the river.

Chinook Salmon Biology in the Middle Susitna River

Distribution and Abundance

APA (1985) and Jennings (1985) summarized the species biology and habitat utilization of salmonids in the Susitna River drainage. However, a brief outline of the biology of chinook salmon in the middle Susitna River is given to highlight life stages and periods during the year that chinook may be influenced by altered with-project flow, temperature and water quality regimes.

Chinook spawning in the middle Susitna River generally accounts for less than 5 percent of the total Susitna River basin escapement and occurs entirely in clearwater tributaries. Of those fish that do migrate into the middle Susitna River, more than 90 percent spawn in Indian River (RM 138.5) and Portage Creek (RM 140) (Barrett et al. 1984). Spawning generally peaks between the last week of July and the first week of August. However, the passage of spawning chinook into these two principal tributaries is not likely to be impeded at low mainstem discharges (Trihey 1983). Consequently, chinook spawning and egg incubation is not critically sensitive to alteration in mainstem discharge and is not included in the analysis.

Chinook fry emerge from the tributary spawning gravels in late March to mid-April and remain near their natal areas for one to two months. Possibly as a result of territorial behavior and limited carrying capacity of the natal areas, some juveniles then initiate a downstream movement and population densities begin to increase in mainstem-associated habitats in late July. Some 0+ juveniles move downstream and leave the middle Susitna River entirely, rearing in the lower river or entering Cook Inlet. Large numbers of 0+ chinook appear to outmigrate from the middle Susitna River during high mainstem discharges (Hale 1985). In the lower Susitna River the highest densities of 0+ juveniles were collected in the deep, low velocity, clearwater of tributary mouths (Suchanek et al. 1985). It is unclear whether those 0+ outmigrants that do enter Cook Inlet survive. However, age 0+ outmigrants may form a transition check or other similar tightening of the circuli on their scales which may be interpreted as a freshwater annulus thereby underestimating the importance of this age class (Roth and Stratton 1985). Richards (1979) showed that 72% of the adult scales analyzed from the Deshka River during 1978 were 0+ ocean outmigrants, whereas creel census scale samples had classed them primarily as 1+.

Of the habitats associated with the mainstem of the middle Susitna River, 0+ chinook densities are highest in the side channels, particularly during July and August. Side sloughs and upland sloughs become more important in September through November as juvenile chinook seek out suitable overwintering habitats. Population estimates for chinook fry at sloughs and side channels during 1984 are given in Table II-1. From May through November approximately 60 percent of the juvenile chinook in the middle Susitna River utilize the tributary habitats and 40 percent use the mainstem-associated habitats (Figure II-1).

The majority of juvenile chinook in the Susitna River go to sea after spending one winter in freshwater. This is typical of juvenile chinook in other Alaskan rivers (Burger et al. 1983, Kissner 1976, Meehan and Snift 1962, Waite 1979). Age 1+ juveniles outmigrate from the middle Susitna River from early

Table II-1. Chinook salmon fry, population estimates by site for sloughs and side channels surveyed in the Susitna River above the Chulitna River confluence, 1984 (from Roth and Stratton 1985).

Sampling Site	Branding Dates	Recapture Dates	Estimate Method	Population Estimate
Upper Side Channel 11	7/19 - 8/1	7/30 - 8/2	Schaefer	3,420
Side Channel 10	7/16 - 7/19	7/17 - 7/20	Schaefer	7,630
Moose Slough	8/8 - 8/11	8/9 - 8/12	Schaefer	4,990
Slough 22	9/8 - 9/13	10/8	Petersen	47,050
Slough 19	8/28	9/26	Petersen	4,500
Side Channel 21	9/24 - 9/26		CPUE Index	3,700
Slough 20	10/8 - 10/12		CPUE Index	13,800

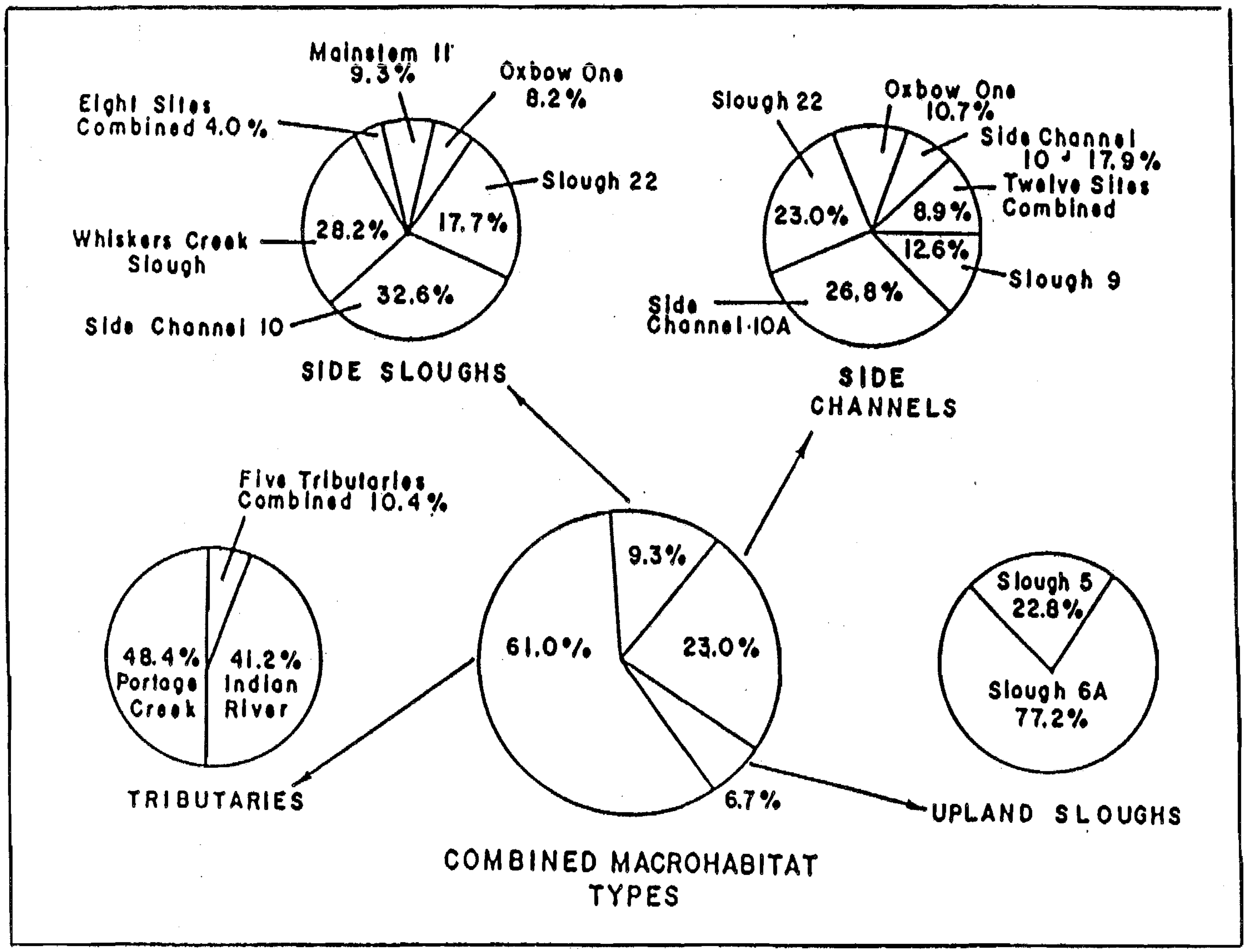


Figure II-1. Density distribution of juvenile chinook salmon by macrohabitat type on the Susitna River between Chulitna River confluence and Devil Canyon, May through November 1983. Percentages are based on mean catch per cell (from Dugan, Sterritt and Stratton 1984).

May to mid-July. Outmigration from the lower river peaks in mid-June and is completed by early August (Suchanek et al. 1985).

Growth of Juvenile Chinook

In the middle Susitna River, chinook fry emerge from the gravel in their natal tributaries at about 37 mm long. By the beginning of June they have grown to 44 mm and by early October have a mean length of 64 mm. Chinook fry collected in the lower Susitna River are on average from 2 to 10 mm larger during the same time period (Figure II-2). Growth in the tributaries was greater than growth in the side channel and side sloughs during 1984 (Table II-2). Growth of 0+ chinook in the Deshka and Talkeetna Rivers during the same time period was significantly higher than the middle Susitna River (Table II-3).

During the winter of 1984-85, juvenile chinook in the middle Susitna River exhibited negligible growth, averaging only a 6 mm increase in length from 64 mm in early October to 70 mm by mid-May (Stratton 1985). However, there was then a surge of growth in the spring. Smolts collected at the Talkeetna outmigrant trap in 1985 were averaging 89 mm by the end of June. Ninety mm was the average length of outmigrating 1+ chinook in previous years (ADF&G 1983a). Figure II-3 gives the length/weight relationship for both 0+ and 1+ chinook salmon collected at the Talkeetna outmigrant trap during 1984.

Modeling of Juvenile Chinook Habitat

To assess the influence of changes in fluvial processes on rearing juvenile chinook in the middle Susitna River, a mechanism is necessary to quantify changes in habitat availability. As outlined in the Introduction, one of the principal effects of the project will be the alteration of the flow regime in the river. Because of the direct relationship between flow and habitat availability, the Instream Flow Incremental Methodology (IFIM) was used to estimate weighted usable area (WUA) for juvenile chinook rearing. Rearing habitat was modeled using three variables: velocity, depth and cover. Field data were collected by ADF&G at a number of sites to develop habitat suitability criteria for these variables.

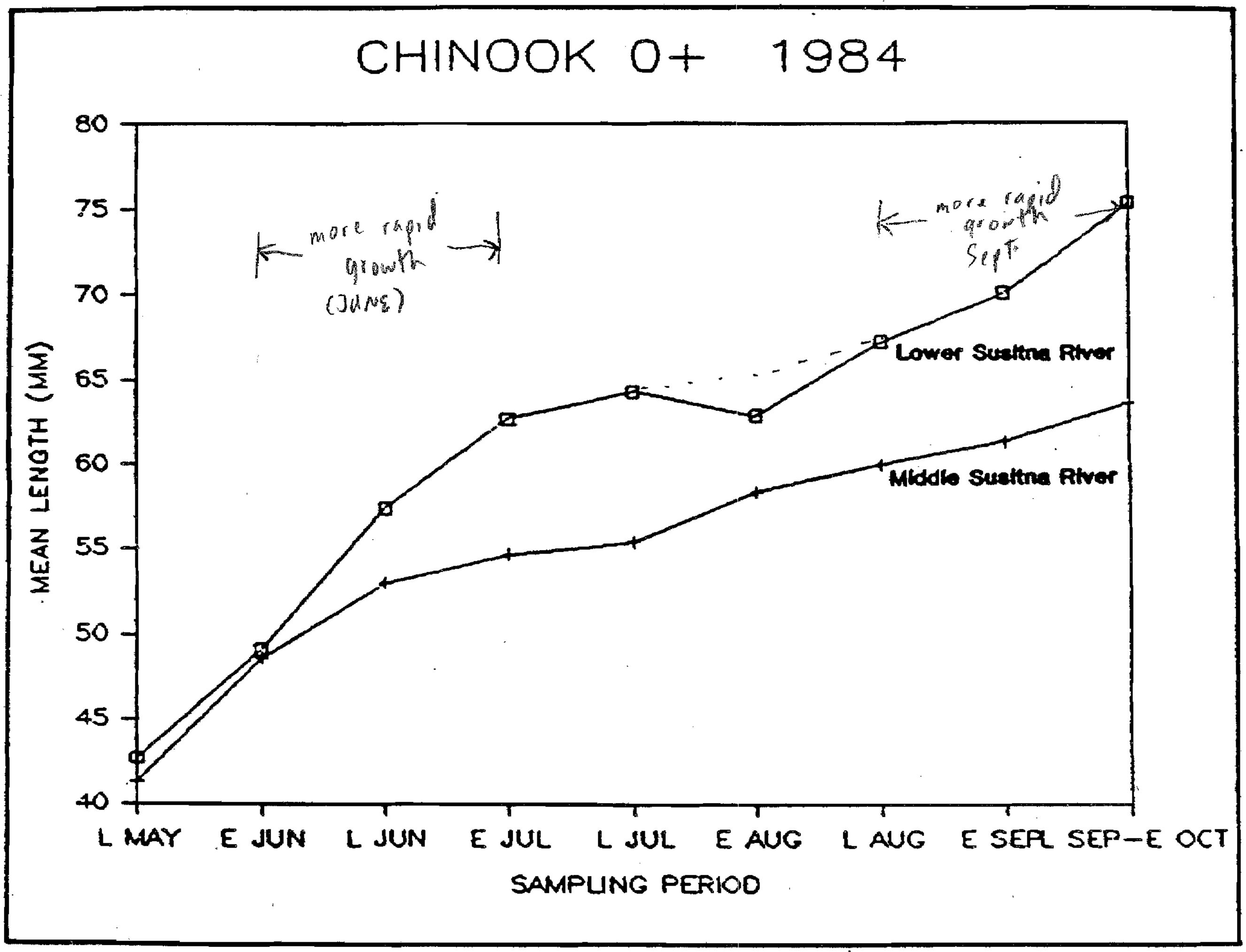


Figure II-2. Chinook salmon (age 0+) mean length and range of lengths by sampling period for fish collected in the lower and middle reach of the Susitna River, 1984 (from Roth and Stratton 1985).

Table II-2. Number of fish, mean length, and range of lengths for age 0+ chinook salmon by sampling period on the Susitna River between Talkeetna and Devil Canyon, 1984 (from Roth and Stratton 1985).

Sampling Period	Talkeetna Station			Mainstem middle Susitna River[a]			Indian River		
	n	Mean	Range	n	Mean	Range	n	Mean	Range
May	2	55.5	53-58	60	40.8	35-45	*	-	-
June 1-15	54	48.6	36-66	*	-	-	*	-	-
June 16-30	475	53.0	37-70	*	-	-	*	-	-
July 1-15	538	56.2	38-75	100	47.8	38-67	50	48.9	42-64
July 16-31	1131	55.5	37-80	50	52.2	42-69	50	54.9	47-67
August 1-15	748	57.9	40-90	50	52.4	40-77	100	58.8	47-90
August 16-31	612	59.5	39-95	100	56.1	43-72	100	61.1	49-80
September 1-15	119	62.7	45-91	100	57.6	47-88	100	63.8	47-90
September 16 - October 15	13	60.8	51-90	200	61.0	45-90	300	65.5	50-89

* Not sampled.

b Includes all mainstem, slough and side channel sites sampled during the JAHS study in the Susitna River between Cook Inlet and the Chulitna River confluence.

Table 11-3. Mean length and range of lengths for age 0+ chinook salmon by sampling period in the lower reach of the Susitna River, 1984.

Sampling Period	Talkeetna River			Deshka River			Mainstem Lower Susitna River [a]		
	n	Mean	Range	n	Mean	Range	n	Mean	Range
May	*	-	-	77	42.7	36-49	*	-	-
June 1-15	0	-	-	21	42.4	40-46	74	48.5	34-63
June 16-30	26	52.2	43-64	56	55.7	46-69	63	52.0	36-70
July 1-15	159	56.0	44-70	236	66.8	52-83	84	54.5	39-74
July 16-31	155	56.1	40-74	201	69.7	52-93	171	58.1	39-80
August 1-15	257	60.7	44-84	53	74.4	60-91	330	58.9	40-82
August 16-31	114	65.2	51-84	65	71.7	55-89	238	61.5	42-94
September 1-15	0	-	-	15	77.9	69-88	52	66.8	52-95
September 16 - October 15	*	-	-	102	76.0	68-85	53	73.2	51-92

* Not sampled.

[b] Includes all mainstem, slough and side channel sites sampled during the JAHS study in the Susitna River between Cook Inlet and the Chulitna River confluence.

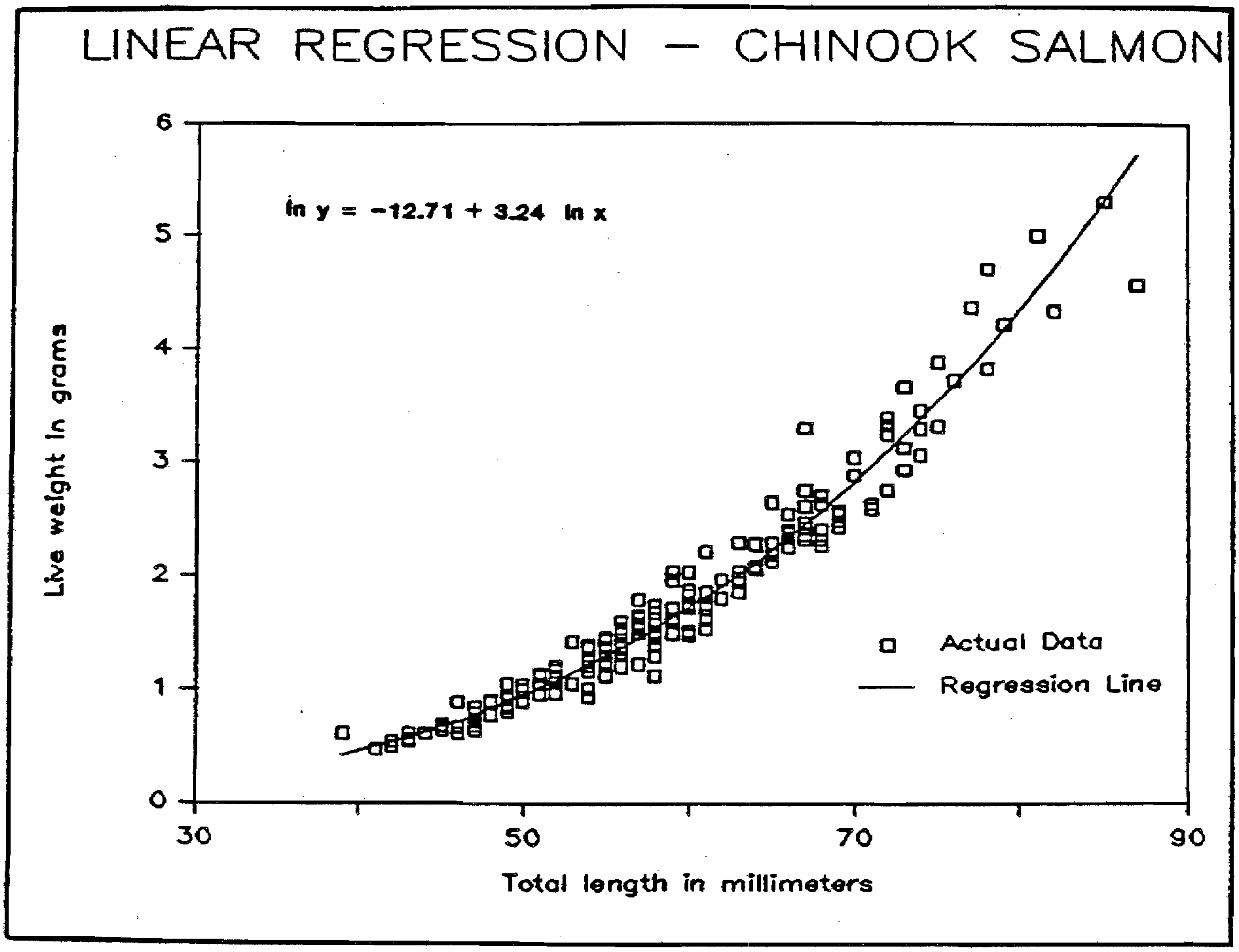


Figure II-3. Linear regression of the weight/length relationship for juvenile chinook salmon collected at the Talkeetna stationary outmigrant traps, 1984 (from Roth and Stratton 1983).

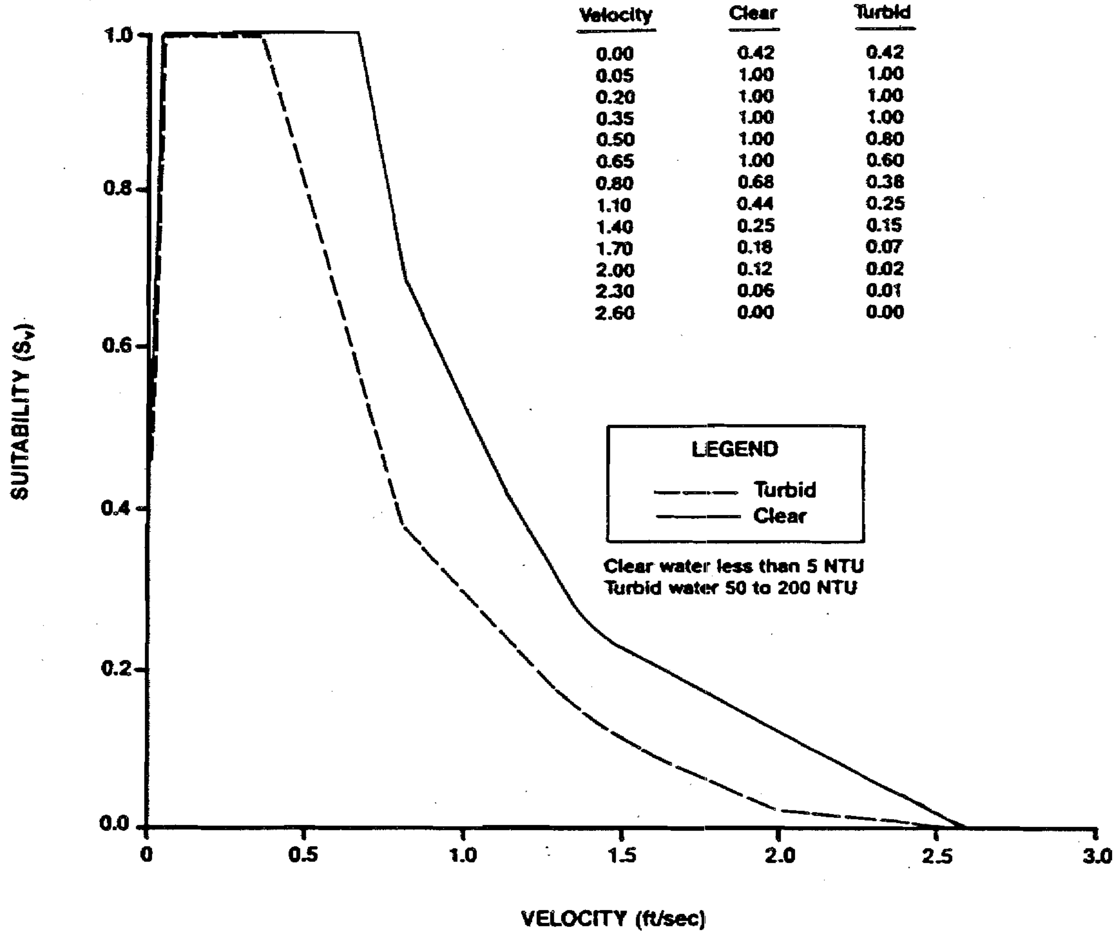
Suitability Criteria

Velocity. Velocity is a function of flow regime and is an important factor influencing the availability of juvenile chinook habitat in the middle Susitna River. The relationship between velocity and juvenile fish distribution depends on fish size because as they become larger, they are able to move into faster, deeper water.

Suchanek et al. (1984) report that in the middle Susitna River juvenile chinook prefer lower velocities and shallower depths in turbid water than in clear water. Suitability criteria indicate that optimum velocities occur between 0.05 and 0.35 feet per second (fps) in water with turbidities greater than 30 nephelometric turbidity units (NTU), and between 0.35 and 0.65 fps in water of less than 30 NTU. Literature values typically indicate that optimal velocities in clear water are less than 0.5 fps (Everest and Chapman 1972, Stuehrenberg 1975, Burger et al. 1982, Bechtel 1983). Although the chinook velocity criteria from the literature were developed from data collected in clear water, they are more similar to the middle Susitna River criteria for turbid water. This is because of differences in field methods employed by ADF&G and other investigators (EWT&A and Entrix 1985). However, it should not be assumed that velocities less than 0.35 fps in the middle Susitna River are unfavorable to juvenile chinook in clear water. Consequently, the optimum velocity range of the clear water suitability criteria have been extended to include velocities between 0.05 and 0.65 fps (Fig. II-4). The reasons for the preference of juvenile chinook for lower velocities in areas of higher turbidity may be twofold: 1) at faster currents there is a lack of visual cues to maintain position; and 2) at higher velocities it is more difficult to detect drifting prey items.

Water Depth. Water depth is determined by streamflow, channel form and streambed materials. Rearing juvenile chinook salmon in the middle Susitna River use a wide range of water depths (ADF&G 1984) as indicated by the open-ended suitability curve in Figure II-5. Provided that other microhabitat conditions are suitable, juveniles tend to prefer depths exceeding 0.15 feet to an equal degree. These observations have been corroborated by other habitat utilization studies of juvenile chinook salmon (Burger et al. 1983).

VELOCITY SUITABILITY CRITERIA FOR JUVENILE CHINOOK SALMON



	SUITABILITY (S_v)	
Velocity	Clear	Turbid
0.00	0.42	0.42
0.05	1.00	1.00
0.20	1.00	1.00
0.35	1.00	1.00
0.50	1.00	0.80
0.65	1.00	0.60
0.80	0.68	0.38
1.10	0.44	0.25
1.40	0.25	0.15
1.70	0.18	0.07
2.00	0.12	0.02
2.30	0.06	0.01
2.60	0.00	0.00

Figure II-4. Velocity suitability criteria used to model juvenile chinook habitat (WUA) under clear and turbid water conditions in the middle Susitna River (from Steward 1985).

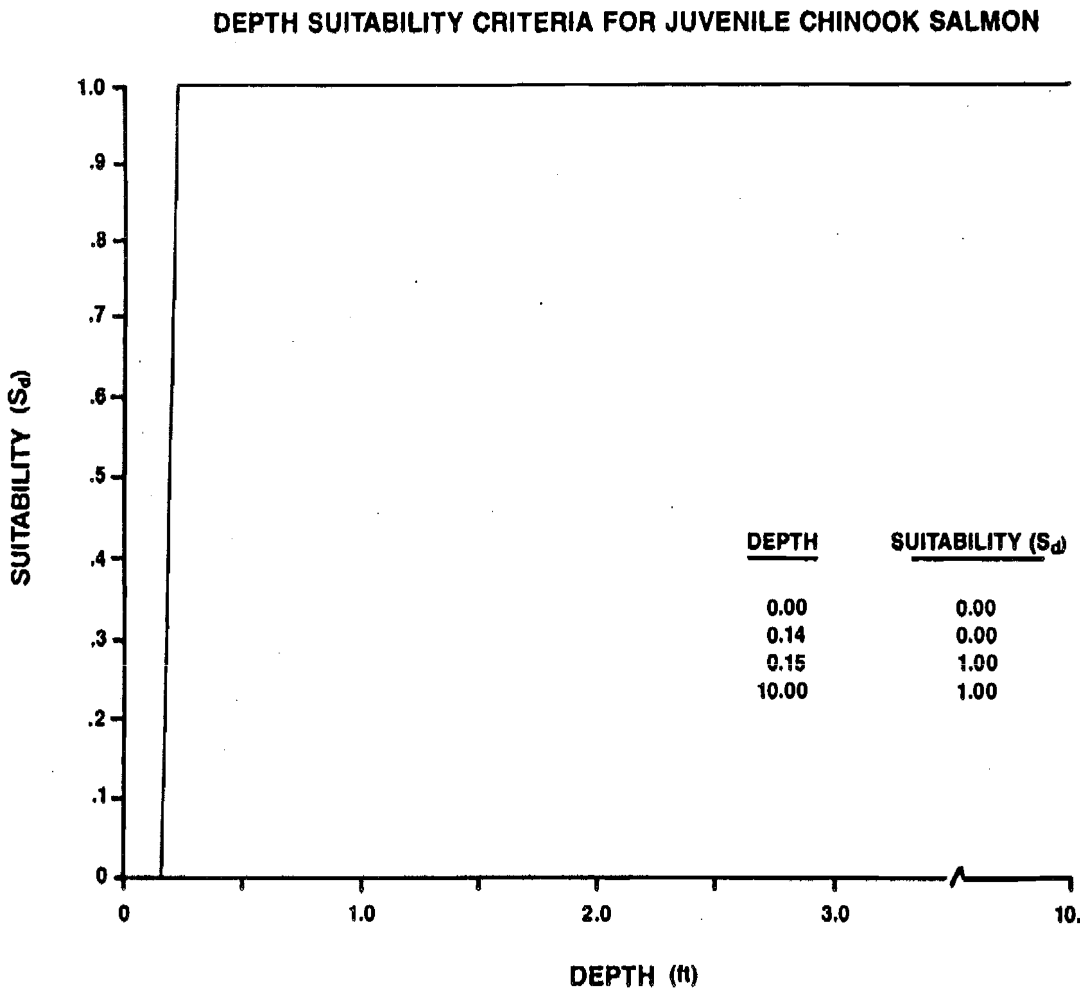


Figure II-5. Depth suitability criteria used to model juvenile chinook habitat (WUA) under clear and turbid water conditions in the middle Susitna River (from Steward 1985).

Cover. Cover is extremely important to rearing anadromous salmonids to avoid predation by other fish, birds, and terrestrial animals and to avoid unsuitable velocities. Predation can cause significant mortalities among rearing juveniles, particularly after emergence from the gravel (Allen 1969). Cover requirements vary diurnally, seasonally or by species and fish size (Reiser and Bjornn 1979). In the middle Susitna River, a well-developed riparian zone does not exist along the edges of most side channels and side sloughs because of ice processes and flow variations. In the absence of vegetation, banks are unstable and, hence, do not become undercut. Large organic debris is rare in side channels and only small amounts are present in side sloughs. Hence, riparian vegetation, undercut banks and large organic debris are not forms of cover typically available for juvenile chinook in these habitats. These types of cover are more prevalent in upland sloughs.

Cover for juvenile chinook in the middle Susitna River is more typically provided by suitably sized substrate and turbid water. Field observations and catch data from ADF&G indicate that juvenile chinook salmon abundance differs between turbid water and clear water. Catch rates at turbidities greater than 30 NTU were significantly higher ($p = <0.001$) than at turbidities less than 30 NTU in cells without any type of object cover. Thus, in the absence of object cover, turbid water is used for cover by rearing chinook salmon (Suchanek et al. 1984). The utilization of turbidity as cover appears to be most prevalent during July and August, following redistribution from the tributaries. When a turbid side channel becomes non-breached and transforms to a clearwater slough, the number of juvenile chinook per cell typically decreases (Suchanek et al. 1984). When the water clears, some juvenile chinook in turbid pool habitat will school and move up to riffles near the upstream end of the site where they seek out object cover. These different preferences for the same type and percent of object cover under clear and turbid water are reflected by the derivation of two sets of suitability criteria for cover (Table II-4, Fig. II-6).

Extrapolation of Modeled to Non-modeled Sites

The modeling techniques used and the extrapolation of the results to provide a response for the entire middle Susitna River were outlined by Steward et al. (1985). WUA functions were derived which define the relationship between

Table II-4. Cover suitability criteria recommended for use in modeling juvenile chinook habitat under clear and turbid water conditions. Sources: Suchanek et al. 1984; Steward 1985.

Percent Cover	No Cover	Emergent Vegetation	Aquatic Vegetation	Large Gravel	Rubble 3"-5"	Cobble or Boulders >5"	Debris & Deadfall	Overhanging Riparian	Undercut Banks
Clear Water (Suchanek et al. 1984)									
0-5%	0.01	0.01	0.07	0.07	0.09	0.09	0.11	0.06	0.10
6-25%	0.01	0.04	0.22	0.21	0.27	0.29	0.33	0.20	0.32
26-50%	0.01	0.07	0.39	0.35	0.45	0.49	0.56	0.34	0.54
51-75%	0.01	0.09	0.53	0.49	0.63	0.69	0.78	0.47	0.75
76-100%	0.01	0.12	0.68	0.63	0.81	0.89	1.00	0.61	0.97
Turbid Water (EWT&A and WCC 1985)[1]									
0-5%	0.31	0.31	0.31	0.31	0.39	0.39	0.48	0.26	0.44
6-25%	0.31	0.31	0.39	0.37	0.47	0.51	0.58	0.35	0.56
26-50%	0.31	0.31	0.46	0.42	0.54	0.59	0.67	0.41	0.65
51-75%	0.31	0.31	0.52	0.48	0.62	0.68	0.77	0.46	0.74
76-100%	0.31	0.31	0.58	0.54	0.69	0.76	0.85	0.52	0.82

[1] Multiplication factors: 0-5% - 4.38; 6-2% - 1.75; 26-50% - 1.20; 51-75% - 0.98; 76-100% - 0.85

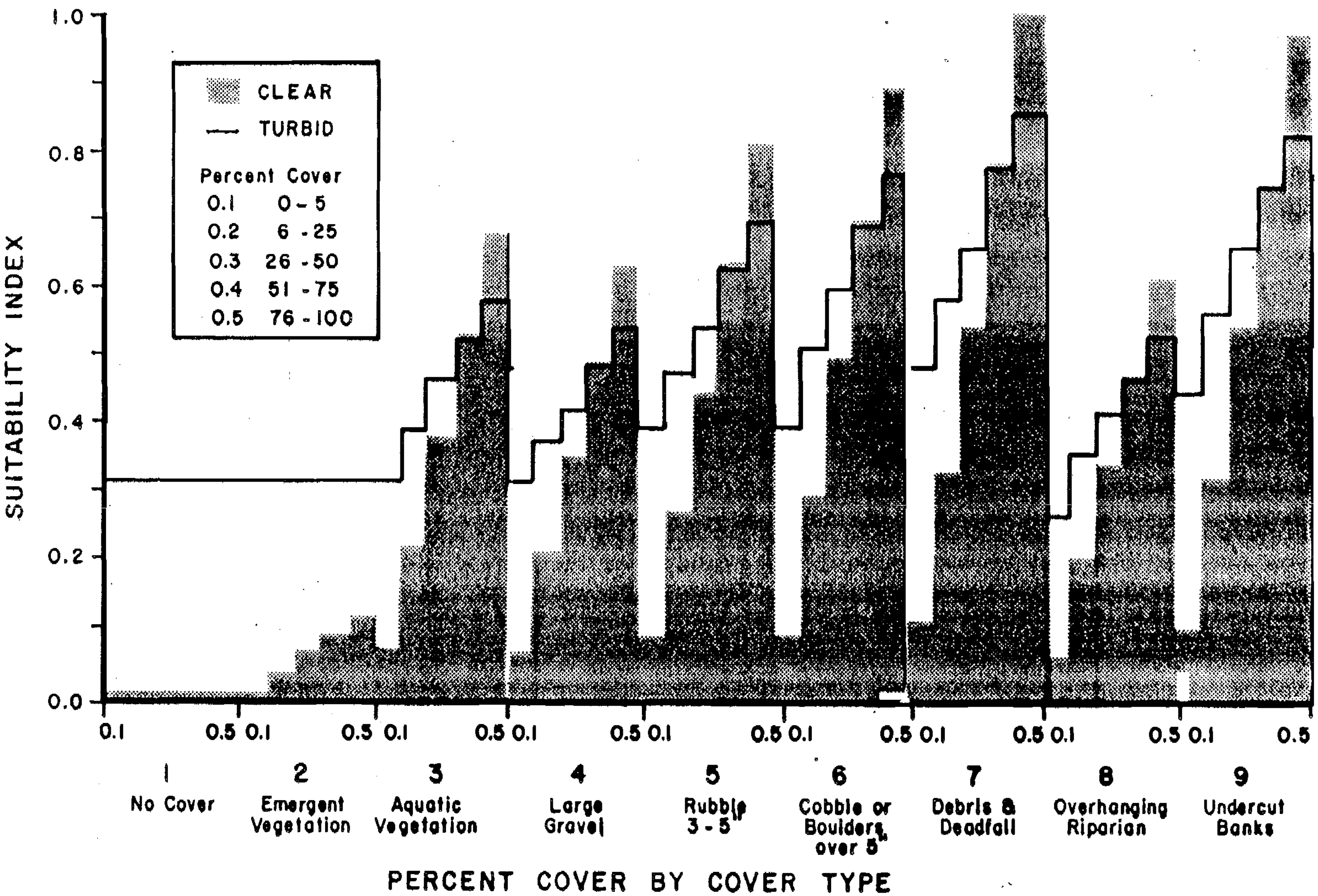


Figure II-6. Cover suitability criteria used to model juvenile chinook habitat (WUA) in the middle Susitna River. Separate criteria are presented for clear and turbid water conditions (from Steward 1985).

mainstem discharge and chinook rearing habitat potential at 20 side slough and side channel modeling sites in the middle Susitna River. The mainstem is not used by juvenile chinook for rearing. Mainstem margins and tributary mouths will be relatively unaffected by project-induced changes.

Conventional methods of extrapolating WUA in single channel rivers based on the concept of continuous homogeneous subsegments represented by individual modeling sites are not applicable to braided rivers like the Susitna River due to large spatial variations in hydraulic and morphologic character (Aaserude et al. 1985). This prompted the development of an extrapolation methodology, outlined by Steward and Trihey (1984), which weights WUA values developed for each modeling site according to the proportion of the middle reach possessing similar hydrologic, hydraulic and water clarity attributes. The results of the habitat modeling analyses are WUA forecasts for sites which frequently transform from one habitat type to another (i.e. side slough to side channel). The static quality implicit in the habitat type concept of Klinger and Trihey (1984) made it inappropriate as a method of stratifying the river for extrapolation purposes.

The concept of representative groups as a further set of distinct areas of the middle Susitna River and the criteria used by Aaserude et al. (1985) to define them ensures that habitat transformations are addressed in the stratification process. Aaserude et al. (1985) delineated 172 specific areas of the middle Susitna River which were divided among ten representative groups. They are listed with location of their associated modeling sites in Table II-5. The extrapolation of modeling results to non-modeled specific areas and their combination into WUA response function for each representative group has been described in detail by Steward et al. (1985).

However, proper interpretation of the WUA curves requires a review of the WUA modeling process, as well as the method used to extrapolate the models to non-modeled sites. The Representative Group WUA curves are the sums of the WUA curves for the specific areas, some modeled and some non-modeled within the groups. The WUA curve of a modeled site is the sum of the WUA curves of the cells comprising the site. A typical cell is shown in Figure II-7. It is at this "cellular" level that WUA is actually modeled.

Table II-5 Primary hydrologic, hydraulic and morphologic characterisitcs of representative groups identified for the middle Susitna River.

REPRESENTATIVE GROUP	NUMBER OF SPECIFIC AREAS	DESCRIPTION	HABITAT MODELING SITES
I	19	Predominantly upland sloughs. The specific areas comprising this group are highly stable due to the persistence of non-breached conditions (i.e., possess high breaching flows). Specific area hydraulics are characterized by pooled clear water with velocities frequently near 0.0 fps and depths greater than 1.0 ft. Pools are commonly connected by short riffles where velocities are less than 1.0 fps and depths are less than 0.5 ft.	107.6L, 112.5L
II	28	This group includes specific areas commonly referred to as side sloughs. These sites are characterized by relatively high breaching flows (19,500 cfs), clear water caused by upwelling groundwater, and large channel length to width ratios (15:1).	101.4L, 113.7R, 126.0R, 144.4L
III	18	Intermediate breaching flows and relatively broad channel sections typify the specific areas within this Representative Group. These sites are side channels which transform into side sloughs at mainstem discharges ranging from 8,200 to 16,000 cfs. Lower breaching flows and smaller length to width ratios distinguish these sites from those in Group II. Upwelling groundwater is present.	101.2R, 128.8R, 132.6L, 141.4R
IV	21	Specific areas in this group are side channels that are breached at low discharges and possess intermediate mean reach velocities (2.0-5.0 fps) at a mainstem discharge of approximately 10,000 cfs.	112.6L, 137.7L 134.9R, 136.0L
V	9	This group includes mainstem and side channel shoal areas which transform to clear water side sloughs as mainstem flows recede. Transformations generally occur at moderate to high breaching discharges.	141.6R
VI	13	This group is similar to the preceding one in that the habitat character of the specific areas is dominated by channel morphology. These sites are primarily overflow channels that parallel the adjacent mainstem, usually separated by a sparsely vegetated gravel bar. Upwelling groundwater may or may not be present. Habitat transformations within this group are variable both in type and timing of occurrence.	133.8L, 136.3R
VII	7	These specific areas are typically side channels which breach at variable yet fairly low mainstem discharges and exhibit a characteristic riffle/pool sequence. Pools are frequently large backwater areas near the mouth of the sites.	119.2R
VIII	24	The specific areas in this group tend to dewater at relatively high mainstem discharges. The direction of flow at the head of these channels tends to deviate sharply (30 degrees) from the adjacent mainstem. Modeling sites from Groups II and III possessing representative post-breaching hydraulic characteristics are used to model these specific areas.	132.6L, 144.4L
IX	21	This group consists of secondary mainstem channels which are similar to primary mainstem channels in habitat character, but distinguished as being smaller, and conveying a lesser proportion of the total discharge. Specific areas in this group have low breaching discharges and are frequently similar in size to large side channels, but have characteristic mainstem features, such as relatively swift velocities (5 fps) and visibly coarser substrate.	101.5L, 147.1L
X	13	Large mainstem shoals and the margins of mainstem channels which show signs of upwelling are included in this representative group.	105.81L, 119.11L, 138.71L, 139.41L, 133.81R

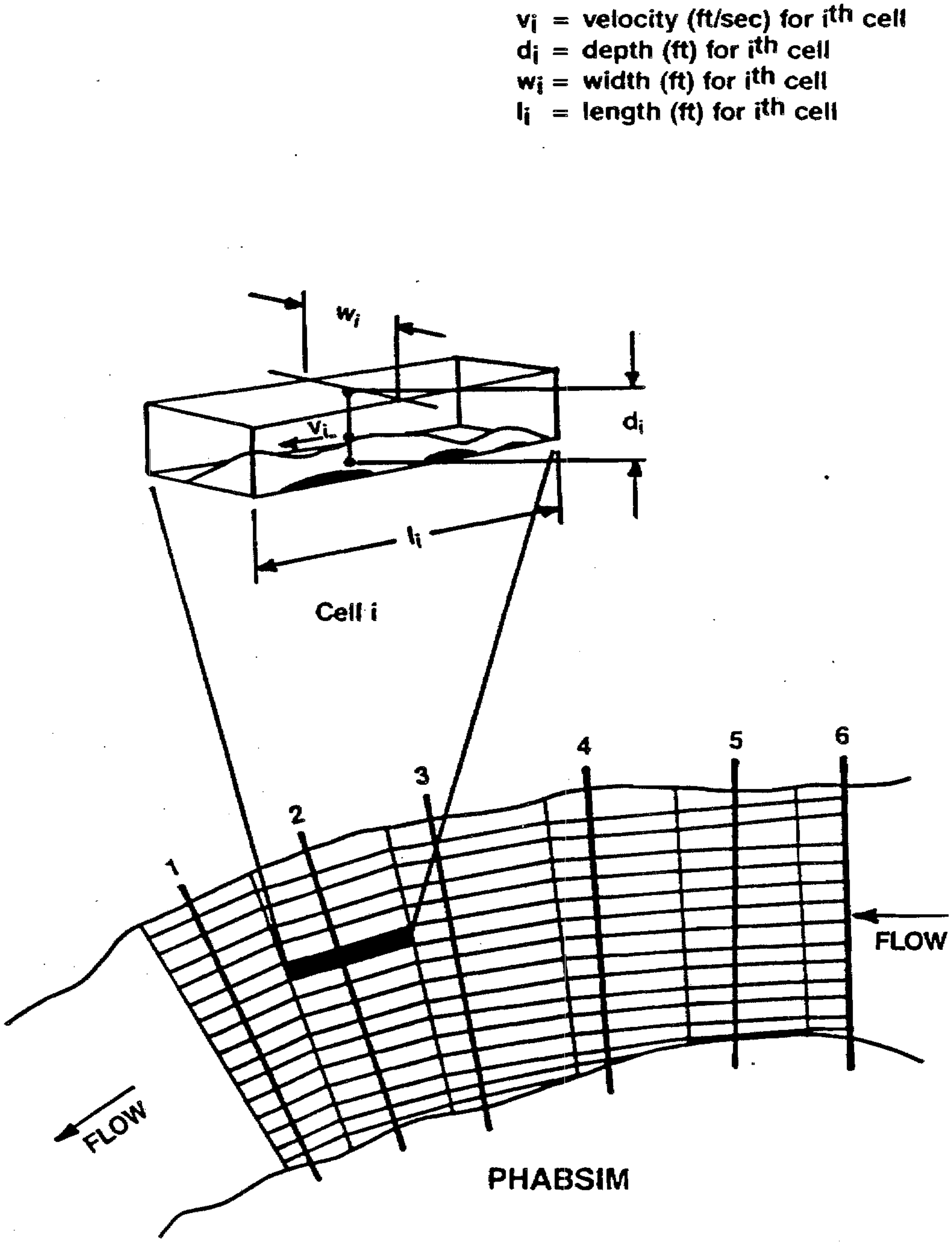


Figure II-7. Sampling design for PHABISM modeling sites (from Steward et al. 1985).

We need to examine the process by which the WUA response of a cell is calculated at a particular flow. Hydraulic models, or field observations, provide the surface area, representative water depth, and velocity for the cell. Generally, the area of the cell doesn't change with flow, and is considered a constant. Therefore, the hydraulic module of the model reduces to two variables, water depth and velocity. The habitat module adds one more cell variable, cover, which contains information concerning the type and size of instream objects present within the cell. Resident and juvenile fish studies generated suitability criteria functions for these three variables, which describe their degree of suitability as juvenile chinook habitat. The suitability of the cell is simply the product of the probability of use relative to depth, the probability of use relative to velocity, and the probability of use relative to cover. Since each of these probability factors ranges from zero (no use) to one (highest use), their product ranges from zero to one. The WUA of the cell is simply the surface area of the cell times the cell's suitability and can range from zero to the full value of the cell area. Therefore, the cell's WUA is the output of a model incorporating three variables, their respective probability functions, and area. As was mentioned previously, the WUA response to mainstem discharge for a modeled site is obtained by repeating the above process for each cell in the site over a range of flows.

The primary reason for the stratification of specific areas into representative groups and subgroups was to provide the similarity information necessary for extrapolation. Implementation of the extrapolation methodology produced WUA curves for 172 specific areas, of which 20 were modeled using RJHAB and PHABSIM. RJHAB is the Resident Juvenile Habitat model developed by ADF&G and PHABISM is the Physical Habitat Simulation System developed by U.S. Fish and Wildlife Service's Instream Flow and Aquatic Systems Group. The summation of the WUA curves within each representative group yielded the Representative Group WUA curve.

At this point, it is reasonable to ask what we have on a systemwide level. We have 172 individual pieces of the middle Susitna River which covers over 95 percent of the wetted surface area outside the mainstem. For each site, we have a quantified response of three variables to mainstem discharge, modified by fish preference factors from suitability criteria. Cell WUA curves within a site were summed as they are contiguous. Because we assume the juveniles have little difficulty moving from one cell to another it is logical to think of the site as a whole and site WUA curves are appropriate. The ten representative groups give us a categorization scheme which used hydraulic similarity as a key. Summing site WUA curves within representative groups is an attempt to achieve a higher level of integration, that is, a system WUA response to mainstem discharge. However, before discussing the results of the WUA modeling process we must first identify other factors which, although they were not modeled, may also affect the abundance and distribution of salmon in the middle Susitna River.

Non-Modeled Habitat Factors

Figure II-8 illustrates other factors, not modeled in the WUA representative group functions, that may influence the rearing of juvenile chinook salmon in the middle Susitna River. Each will be outlined in turn.

Temperature

Water temperature affects juvenile fish metabolism, growth, food capture, swimming performance and disease resistance (AEIDC 1984). Below 4°C juvenile fish tend to be less active and rest in secluded, covered habitats (Chapman and Bjornn 1969). Brett (1952) reported that the preferred temperature range for juvenile chinook is 7.3 to 14.6°C and noted that chinook under yearlings displayed increasing percentage weight gains as temperature increased from 10.0° to 15.7°C.

As outlined in the introduction, mainstem water temperatures normally range from 0°C during the period November to April up to 11 or 12°C from late June to mid-July. Maximum recorded temperatures at Gold Creek is 15°C. On the other hand, clear water habitats such as unbreached side sloughs and tributaries may be colder in the summer than the turbid water habitats of mainstem and side channels. The colder unbreached tributaries and side sloughs may be below 7°C during the summer, the lower end of the optimum range for chinook

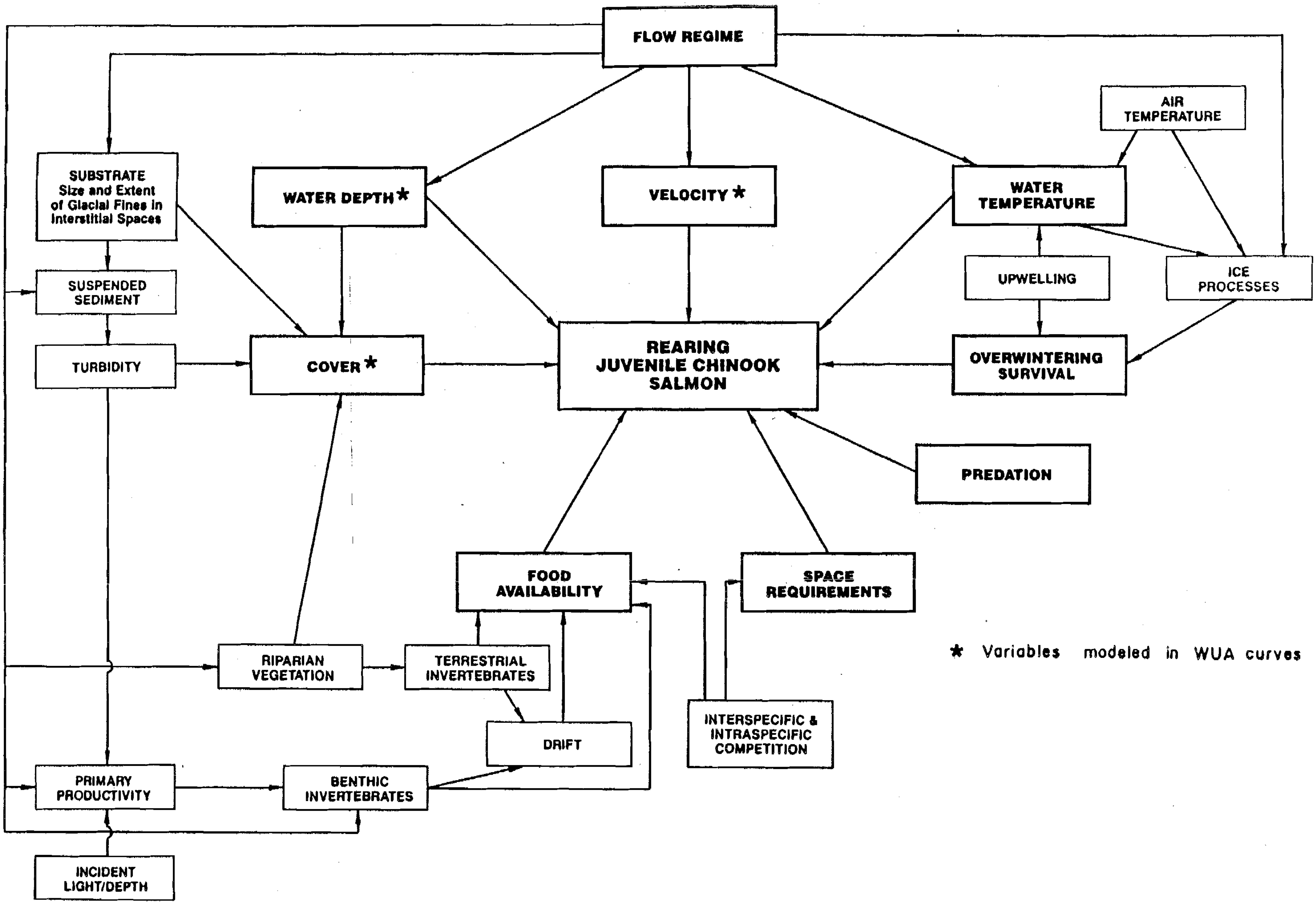


Figure II-8. Factors that potentially influence rearing juvenile chinook.

(Brett 1952). In addition, slough temperatures show a marked diurnal variation. During the summer of 1981, diurnal temperature fluctuations in Slough 21 ranged from 4.5 to 8.5°C. However, juvenile chinook of Susitna stock may be better adapted genetically to sustained growth at lower temperatures than fish from rivers in Oregon and Washington where much of the temperature preference information originates. Although Dugan et al. (1984) conclude that water temperature is not a significant factor in affecting chinook distribution during the open water season, more juvenile chinook are found in the turbid waters of the side channels during July and August than in clear water habitats. It is possible that they are more attracted to the warmer temperatures of side channels than they are to clearwater habitats. Water temperature does appear to be a factor in the fall redistribution of some chinook into sloughs (see section on overwintering).

Water temperature may stimulate smolt outmigration (Sano 1966) and juvenile chinook have been observed to cease outmigrating when temperatures fall below 7°C (Cederholm and Scarlet 1982, Bustard and Narver 1975). Outmigration of chinook smolts begins in early May from the middle Susitna River when temperatures can range from just above freezing to 7°C (University of Alaska 1984).

Food Availability

Fish food production and availability is probably the most important of the biotic factors affecting juvenile chinook rearing and distribution in the middle Susitna River. Becker (1970), Loftus and Lennon (1977), Gray and Page (1980) and Burger et al. (1981) report that juvenile chinook feed predominantly on chironomids, available principally through the drift. During August and September, 1982, ADF&G investigated food habits of juvenile chinook at five side slough and two clear-water tributaries of the middle Susitna River (ADF&G 1983a). At all sites, chironomids were numerically most important with a variable ratio of larvae to adults. A food availability study was undertaken during June to September of 1984 by ADF&G at four study sites - Slough 9, Side Channel 10, Upper Side Channel 11, and Side Slough 21. Chironomids were again shown to be the principal food organism followed by ephemeropterans and plecopterans. Drift at study sites increased significantly when the sites breached. Chironomids formed over 50 percent of the drifting invertebrates.

However, the study did not identify the source of the drift in the mainstem entering these side channels and side sloughs. Terrestrial insects usually enter the drift by falling or being blown off riparian vegetation or washed in from side channel areas inundated by rapid flow fluctuations (Mundie 1969; Fisher and LaVoy 1972). However, terrestrial insects numerically averaged less than 15 percent of the total stomach contents in the 1982 study (ADF&G 1983a). The relatively low importance of terrestrial insects in the diet of juvenile chinook in the middle Susitna River is probably related to low numbers in the drift, as the mainstem, side channels and side sloughs, in most instances, lack a close border or riparian vegetation. Finally, juvenile chinook have been observed entering the clearwater sloughs in the fall to feed on salmon eggs and salmon carcasses.

However, an important factor in the abundance and distribution of aquatic insects is the availability of invertebrate food items (Cummins 1975, Egglshaw 1969, Hynes 1970). Van Nieuhenhyse (1985) demonstrated the association of chironomid larvae with filamentous algae in a side channel of the middle Susitna River and hypothesized that fish food production is based primarily on benthic algae production. Although the filamentous algae may not be a food source directly, the microfauna and flora they support are. Algal filaments are also important to chironomids in providing support and protection from the current and abrasive sediments. Milner (1983) reported a similar association of filamentous algae and chironomids in turbid glacial meltwater streams of southeast Alaska. Consequently, factors that affect primary production; notably, bed load transport rate and the degree of light penetration; exert an influence on fish food production. Sediment deposition on the streambed may bury sites suitable for algal colonization and reduce the ability of filamentous forms to obtain firm attachment. An analysis of the photosynthetically available light under different discharge and turbidity regimes in the middle Susitna River has been presented by Reub et al. (1985).

On the one hand, increased production of benthic insects will result in an increase in drift. On the other hand, drift at a particular site is also greatly enhanced when the site is breached by mainstem flow. Juvenile chinook typically locate drifting food items by sight (Mundie 1974). The ability of fish to detect food items is reduced in the turbid water of the side channels and breached side sloughs and may explain the preference that juvenile chinook have for shallower depths and lower velocities in these waters, as reflected by the suitability criteria. This preference would enhance feeding on the drift at these sites.

Predation

Predation can cause significant mortalities among rearing juveniles, particularly after emergence from the gravel (Allen 1969). Cover is extremely important for the ability of rearing fish to avoid predation. Fish predators of juvenile chinook in the middle Susitna River include rainbow trout, rearing coho, resident dolly varden, burbot and sculpins. Mortality from fish predation is probably reduced for juvenile chinook that migrate to the side channels and obtain cover from the turbid water. In clearwater habitats the juvenile fish may also be taken by piscivorous birds, notably kingfishes, dippers and mergansers. Stratton (1985) reports on predation during the winter and concludes that although ice and snow replace turbidity as a source of cover from birds, juvenile chinook are still vulnerable to these predators through open leads. Dippers were observed capturing juvenile fish at almost all open water areas of the middle Susitna River. Stratton also believes that sculpin predation could be an important factor influencing winter survival rates of juvenile salmon. Overall, the amount of predation on juvenile chinook in the middle Susitna River is not well-defined.

Space Requirements

Territorial behavior and intra- and interspecies competition for food influence the space requirements of fish, which vary according to the size and life stage of the fish and the time of year. Studies in California by Burns (1971) showed significant correlations between living space requirements and resultant salmonid biomass. In the natal tributaries Indian River and Portage Creek, territorial behavior and competition with other chinook and emergent coho may account for the downstream migration of significant numbers of juvenile chinook from the tributaries. Juvenile chinook densities in the side channels and side sloughs do not appear high enough for space requirements to be an influential factor in the determination of habitat quality.

Overwintering Survival

Overwintering survival is a significant factor in the production of juvenile rearing salmonids and is certainly an important factor influencing juvenile chinook in the middle Susitna River. The overwintering period, as defined by the IFRR Vol. 1 (EWT&A and Entrix 1985), is from September 15 to May 20 and includes the fall transition period before ice formation. The juvenile chinook which remain within the middle Susitna River overwinter predominantly in tributary, tributary mouth and slough type habitats (APA 1985). Stratton (1985) identifies two groups:

(a) Fish which remain an entire year within their natal tributaries before beginning their smolting migration

(b) Fish which leave their natal tributaries and overwinter in slough, and to a lesser extent side channel, habitats in the middle Susitna River.

Little overwintering takes place in the mainstem Susitna (ADF&G 1983a, 1983c, Stratton 1985).

Juvenile chinook are attracted to the side sloughs during September and October by the warmer temperatures resulting from groundwater upwelling and possibly by the presence of salmon eggs laid by spawning fish (Dugan et al. 1984). In these habitats juvenile chinook no longer obtain cover from turbid water and, hence, object cover probably becomes more significant. Burger et al. (1983) observed that below 6°C juvenile chinook in the Kenai River moved closer to substrate cover. Bjornn (1971) also considers substrate to be essential for winter cover. Ice and snow may act as a source of cover but the warmer water associated with upwelling frequently creates open leads during the winter.

Although there appeared to be a significant number of benthic aquatic insects at the sites examined by Stratton (1985), drift of food organisms is reduced at the lower winter flows (Richards and Milner 1985) and feeding activity is probably low. Stratton found that juvenile chinook stomachs occasionally examined throughout the winter always contained aquatic insects but chinook growth is minimal, as discussed earlier. Juvenile chinook become less active at low water temperatures and feeding is probably related to maintenance of body functions. Therefore, food availability is probably not a relatively significant factor during the winter months.

Stratton (1985) found that predation, particularly from sculpins during the winter played a significant role in overwintering mortality. Predation by dippers in open leads was also observed.

Ice processes dominate the hydrological and biological characteristics of the middle Susitna River from November to April and significantly influence overwintering survival. The formation and characteristics of the ice are summarized by R&M (1985) and EWT&A and Entrix (1985). The leading edge of the ice cover usually arrives at the confluence of the Susitna and Chulitna Rivers during November or early December and reaches Gold Creek by late December or early January. A potential problem for overwintering fish in sloughs occurs because of staging, a result of anchor ice formation, ice damming or snow loading. The relatively warm water in the sloughs is replaced by large volumes of 0°C water and slush ice. If the condition persists the warming influence of the upwelling is diminished and the fish are probably displaced and move downstream (Stratton 1985). Anchor ice may encase the substrate, making it useless as cover to fish. Side channels and side sloughs without significant upwelling may dewater and freeze completely killing any rearing fish unable to escape.

Another potential problem to overwintering juvenile chinook caused by ice processes occurs during spring break-up. Break-up ice jams commonly cause rapid, local increases in stage that flood side channels and side sloughs, or that divert ice into them eroding away sections of the streambank. The final destruction of the ice cover occurs in early to mid-May when a series of ice jams break in succession, adding their mass and momentum to the next jam downstream. This continues until the river is swept clear of ice. Algal growth, benthic macroinvertebrates and 1+ chinook may become displaced during these events. However Stratton (1985) concluded from the ADF&G winter study that there is a downstream movement of a significant number of chinook from the tributaries and side sloughs of the upper sections of the middle Susitna River before break-up occurs.

WUA Response Curves for Representative Groups I-IX

The juvenile chinook WUA responses to mainstem discharge at Gold Creek for representative groups I-IX are represented in Figures II-9 and II-10. Representative Group X has been omitted because the specific areas modeled in this group do not represent the entire population of specific areas in Group X and because the composite WUA curve is relatively insensitive to changes in mainstem discharge (Steward et al. 1985).

The response of wetted surface area (WSA) to mainstem discharge and the combined (aggregate) response of WUA for all 172 specific areas is shown in Figure 9. Although the change in WSA, is quite pronounced (ca. 1150 acres) over the range of mainstem discharges indicated, a response in WUA is not apparent. In part, this is attributable to the scale at which the response function is plotted. However, it is also attributable to the interaction between streamflow and the rather complex channel morphology of the middle Susitna River. Because of the irregularity of streambeds and streambanks in peripheral habitats, approximately the same amount of low velocity rearing habitat exists over a broad range of streamflows. As streamflow varies, the location rather than the amount of rearing habitat responds. Similar observations have been reported by other investigators evaluating rearing conditions within a river system (see, for example, Wilson et al. 1981).

The response of rearing habitat by location can be inferred from the WUA response functions provided in Figure II-10. Although the aggregate response function shows little change to receding streamflows, WUA response functions for individual representative groups indicate some habitat types undergo substantial change. Most notable are the response functions for Representative Groups II, III, IV and VI, each of which shows maximum WUA values at different mainstem discharges. A second point is that at 25,000 cfs, each of these representative groups possess approximately the same amount of WUA. However, at 10,000 cfs Group IV dominates. Thus, as streamflows decrease so does habitat diversity, even though approximately the same amount of habitat exists in the middle Susitna River.

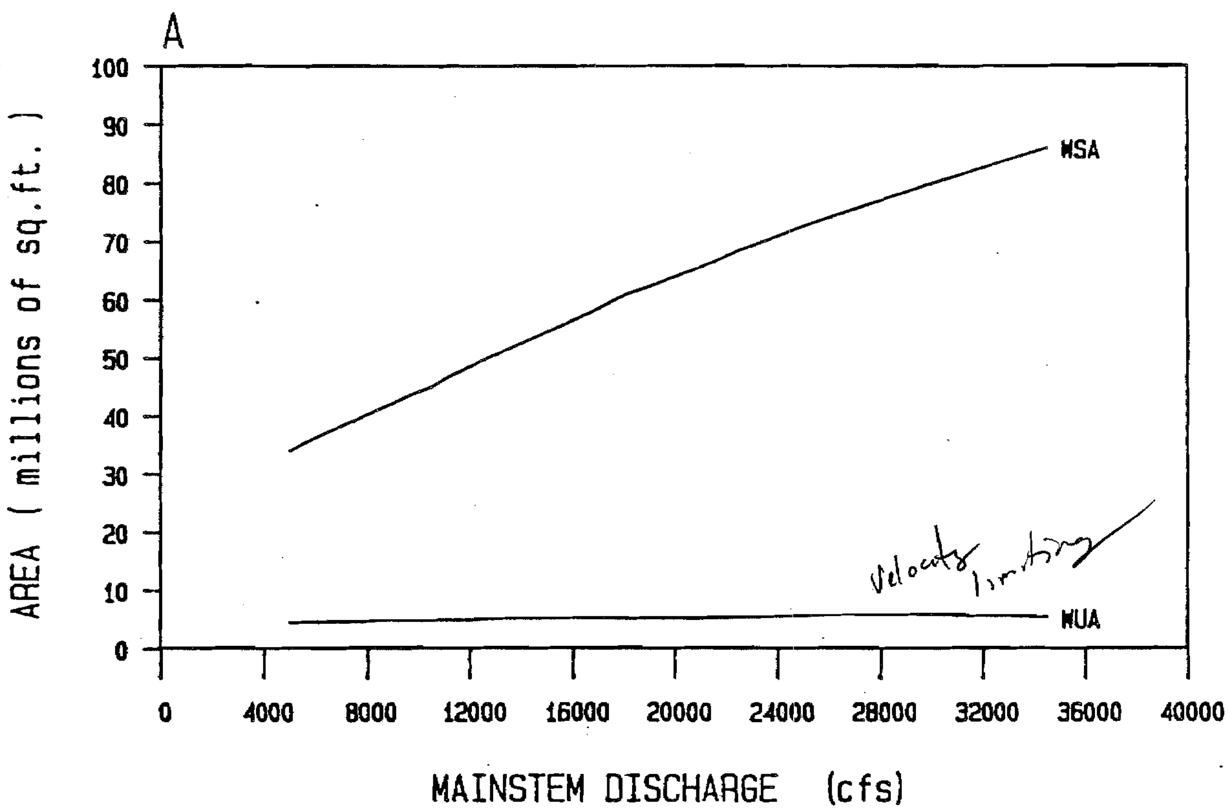


Figure II-9 Comparison of total wetted surface area (WSA) and weighted usable area (WUA) in the middle Susitna River as functions of mainstem discharge.

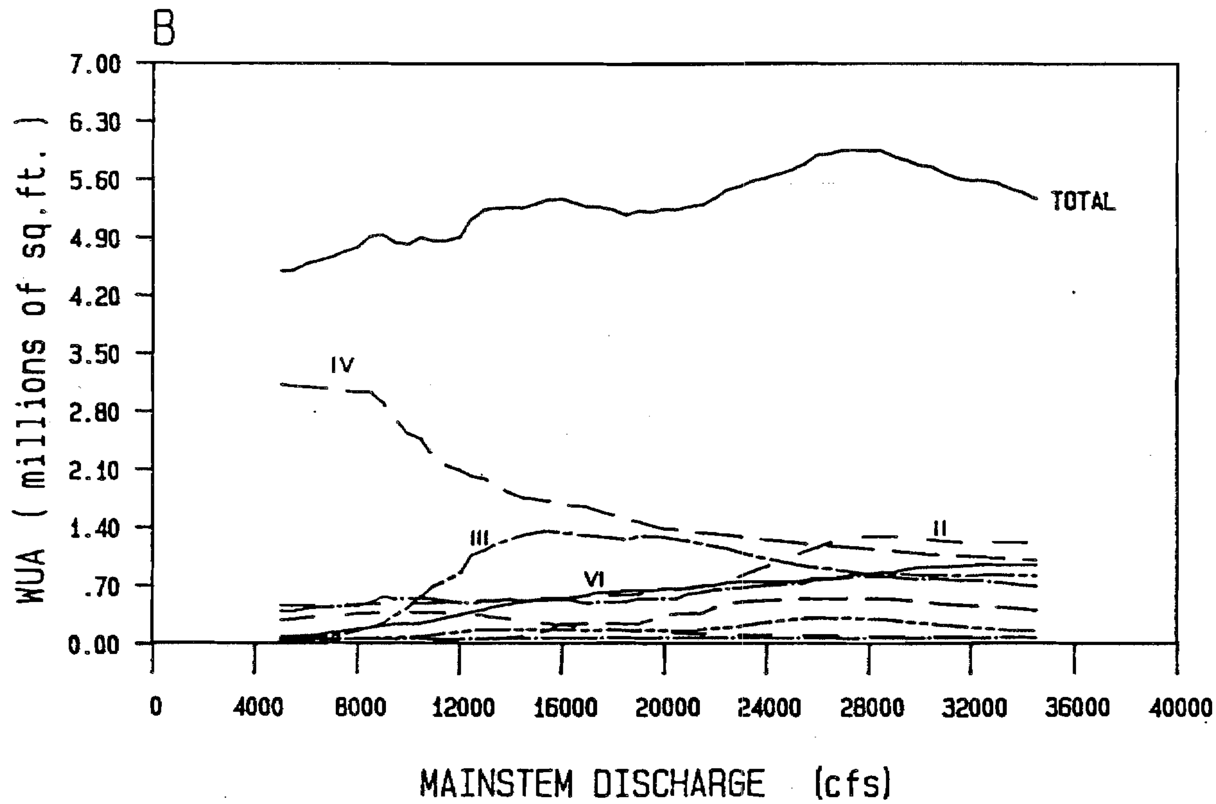


Figure II-10. Aggregate and individual group responses of WUA for juvenile chinook to mainstem discharge for Representative Groups I-IX (form Steward et al. 1985).

The significance of this change is not defined. Assuming temperature, food availability, predation and other factors were similar in all representative groups, a decrease in streamflow would have little consequence on the overall amount and quality of WUA, even though significant changes could occur in any one representative group. If, on the other hand, food availability and biologic factors were better in Group IV, then substantial improvement in rearing conditions not reflected in the aggregate WUA curve would result at lower streamflows. If stream temperatures or food availability were unsuitable in representative group IV, then a negative effect not reflected in the aggregate WUA curve would result.

Individually, Group IV possesses the largest WUA values, particularly at lower flows. This is because Group IV includes specific areas which are side channels that breach at low discharges. At these discharges relatively large amounts of wetted surface area exist in comparison to specific areas from other representative groups. Generally, the WUA response curves indicate that the amount of rearing habitat available at a particular specific area is strongly influenced by the mainstem discharge at which its upstream berm is overtopped. Under non-breached conditions, juvenile chinook habitat typically is relatively small. When a site breaches, the availability of rearing habitat increases significantly because of the influx of turbid water and the increase in wetted surface area. For example, the peak amounts of WUA in Groups II and III at high and intermediate flows, respectively, are a result of breaching. The other groups, which all have very high breaching flows, have relatively low amounts of WUA and are relatively unresponsive to normal changes in mainstem discharge. The responses of WUA for each specific area in the representative groups has been discussed at length by Steward et al. (1985).

Interpretation of Response Curves

The question arises: Do the weighted usable area forecasts for juvenile chinook in each representative group, based on depth, velocity and cover criteria, accurately represent the system-wide response of juvenile chinook habitat to varying discharges in the middle Susitna River? One method for answering this question is to ascertain if the abundance and distribution of juvenile chinook is reflected by the weighted usable area forecasts for the representative groups. If this is shown to be the case then other potentially significant factors which were not modeled are adequately incorporated in the forecasts either through them having a relatively small effect or they are correlated with the factors selected for suitability criteria development. If there is a disparity between the relative distribution and abundance of juvenile chinook in representative groups and the weighted usable area forecasts for those groups then the aggregation of the response curves will not provide an accurate forecast for the entire middle Susitna River system. Modification may then be required at one of two levels.

(1) The site model level - to incorporate the additional significant variables.

(2) The representative group level - use factors to weight curves to reflect abundance and distribution information.

The modification of weighted usable area curves based on fish utilization patterns has been employed in other IFIM studies (Crumley & Stober 1984, Wilson et al. 1981).

Correlation with Juvenile Chinook Distribution Data

A first step in the approach was to ascertain if the abundance and distribution data collected for juvenile chinook during the ADF&G resident and juvenile anadromous fish studies program were adequate to provide comparative information between representative groups. An ADF&G report summarizing salmon fishery data for selected middle Susitna River sites (Hoffman 1985) were used as the principal source of information. The data was examined to see if the following patterns could be ascertained on a representative group basis.

(a) Seasonal variations - both on a monthly and a yearly basis from 1981 through 1984.

(b) Geographical variations - to determine if a greater abundance of juvenile chinook occurs in certain sections of the middle Susitna River (e.g. closer to the chinook natal tributaries).

After examination it was apparent that there was insufficient information to examine variations on a yearly basis. Therefore, the years 1981 through 1984 were pooled. Of the 172 specific areas, 52 had abundance data for at least one month over the four years, yet only 20 of these areas had more than 3 separate months from June to October. Winter abundance information was available for 20 specific areas. Another problem with the abundance data is that different sampling methods were used to collect fish depending on the site or information source, namely electroshocking, beach seine or minnow traps. The counts were either presented as catch per unit effort (CPUE) defined as number of fish per 300 square foot cell (6' x 50') at a specific area or as counts per sampling station at a specific area. Unfortunately, neither set of data was sufficient to provide an adequate comparison between representative groups either seasonally or geographically.

Consequently, to approximate comparative abundance trends of juvenile chinook between representative groups, a relative abundance factor was introduced in an attempt to combine the CPUE and count data. This factor, using a scale of 0 to 10 is outlined in Table II-6. Each specific area with data for a particular month was scored with the relative abundance factor and then the factors were averaged on a representative group basis. This was possible for four representative groups - Groups I, II, III and IV which are the most important in terms of WUA.

The relative abundance factors are summarized in Tables II-7 and II-8 for the months June through October. Unfortunately, there are insufficient data to produce relative abundance factors for June, July or August in Group IV. To ascertain if the WUA forecast reflects the distribution of juvenile chinook for these particular months, the WUA values for the typical average flow at Gold Creek for that month were determined from Figure II-7 and are presented in Table II-9.

TABLE II-6

CPUE	RELATIVE ABUNDANCE FACTOR	NUMBER
No fish	0	No fish
0.5	1	7
0.5 - 1.0	2	8 - 14
1.0 - 1.5	3	15 - 22
1.5 - 2.0	4	23 - 30
2.0 - 2.5	5	31 - 38
2.5 - 3.0	6	39 - 46
3.0 - 3.5	7	47 - 54
3.5 - 4.0	8	55 - 62
4.0 - 4.5	9	63 - 70
4.5	10	70

Table II-7. Relative Abundance Factors for specific areas in Groups I and II for June to October.

TABLE 1

GROUP I Specific Areas	JUNE CPUE	JUNE NOS.	JULY CPUE	JULY NOS.	AUGUST CPUE	AUGUST NOS.	SEPTEMBER CPUE	SEPTEMBER NOS.	OCTOBER CPUE	OCTOBER NOS.
107.6L	-	0	-	2	-	4.5		4.5	-	-
135.6R	0.025	-	0	-	0.86	-	1.13	-	-	-
112.5L	0.30	35	0.56	21	0.08	14	1.94	10	-	-
105.2R	-	-	-	-	-	-	-	P	-	-
121.9R	-	-	-	-	-	-	-	P	-	-
139.9R	-	-	0	-	0.3	-	0.9	-	-	-
133.9L	0	-	0.25	-	-	-	6.6	-	-	-
136.9R	-	-	-	-	-	-	3.2	-	-	-
Mean	0.10	17.5	0.20	11.5	0.41	9.25	2.64	6.12		
Relative Abundance Factor (RAF)	1.40		1.16		1.40		3.44			

2

GROUP II Specific Areas	JUNE CPUE	JUNE NOS.	JULY CPUE	JULY NOS.	AUGUST CPUE	AUGUST NOS.	SEPTEMBER CPUE	SEPTEMBER NOS.	OCTOBER CPUE	OCTOBER NOS.
101.4L	0.57	6	0.2	-	0.47	-	1.4	-	-	-
115.6R	-	-	-	-	-	-	0.3	-	-	-
143.4L	-	-	-	-	-	-	-	-	-	-
113.7R	0	0	0.25	-	0.95	8.5	0.42	36	-	-
122.5R	-	-	-	-	-	-	-	-	-	-
123.6R	-	-	-	-	0.1	-	-	-	-	-
140.2R	0	7	0.15	33.5	0.77	-	4.0	-	-	-
126.0R	0.08	-	0.10	1.0	0.60	-	0.40	-	-	-
144.4L	-	-	-	5	-	75	-	60	-	40
117.9L	-	-	-	-	-	-	-	-	-	-
137.5L	.05	-	0	-	0.05	-	0	-	-	-
142.1R	-	0	-	27	-	32	-	32	-	-
133.9R	-	-	-	-	-	-	-	P	-	-
Mean	0.14	3.25	0.14	18	0.49	39	1.08	34	-	-
Relative Abundance Factor (RAF)	0.67		1.7		2.9		3.5			

Table II-8. Relative Abundance Factors for specific areas in Groups III and IV for June to October.

GROUP III Specific Areas	JUNE CPUE	JUNE NOS.	JULY CPUE	JULY NOS.	AUGUST CPUE	AUGUST NOS.	SEPTEMBER CPUE	SEPTEMBER NOS.	OCTOBER CPUE	OCTOBER NOS.
101.2R	-	-	-	-	-	-	-	8	-	2
101.6L	-	-	-	-	-	-	-	-	-	19
110.4L	-	-	-	23	-	30.5	-	27	-	7
115.0R	0	22	0.05	10	0.15	21.5	0.45	21	-	-
119.3L	-	-	-	-	-	-	-	P	-	-
130.2R	-	-	-	-	-	-	-	P	-	-
128.8R	0.25	2	0.025	51	1.05	44	0.15	36	-	-
133.7R	-	-	-	-	-	-	-	-	-	-
132.6L	-	-	-	42	-	260	-	30	-	-
100.4R	-	-	-	-	-	-	-	0	-	-
137.2R	-	-	-	-	-	-	-	0	-	-
141.4R	-	-	-	-	-	-	-	20	-	0
128.5R	-	-	-	10	-	5	-	P	-	3
Mean				31.5	-	73	0.3	14.2		
Relative Abundance Factor (RAF)			3.3		3.8		2.0		1.20	

GROUP IV Specific Areas	JUNE CPUE	JUNE NOS.	JULY CPUE	JULY NOS.	AUGUST CPUE	AUGUST NOS.	SEPTEMBER CPUE	SEPTEMBER NOS.	OCTOBER CPUE	OCTOBER NOS.
112.6L	-	-	-	-	-	-	-	12	-	17
131.7L	-	-	-	-	-	-	-	66	-	22
114.0R	-	-	-	-	-	-	-	P	-	-
121.7R	0	-	0	-	0	-	0.1		0.1	-
139.6L	-	-	-	-	-	-	-	P	-	-
125.2R	-	-	-	-	-	-	-	11	-	3
129.5R	-	-	-	-	-	-	-	0	-	0
136.0L	0.2	-	-	-	-	-	-	62	-	32
139.4L	-	-	-	-	-	-	-	P	-	-
134.9R	-	-	-	-	-	22	-	12	-	5
145.3R	0.1	-	0	-	0	-	0	-	0	-
Mean							0.05	18.3	-	13.2
Relative Abundance Factor (RAF)							2.45		1.50	

Table II-9. **Comparison of Relative Abundance Factors and WUA forecasts** for Groups I, II, III and IV for June to October.

MONTH	JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER	
Average flow (cfs)	27,500		24,300		22,000		13,300		5,000	
Representative Group	Relative Abundance Factor	WUA	Relative Abundance Factor	WUA	Relative Abundance Factor	WUA	Relative Abundance Factor	WUA	Relative Abundance Factor	WUA
I	1.25	68733	1.1	70289	1.22	72042	3.0	69210	(3.0)	50673
II		1301756	1.7	961233	2.9	695729	3.5	368906	(3.5)	239041
III		852639	3.3	1031913	3.8	1164413	2.0	1178743	1.20	60333
IV		1153321	(3.5)	1246570	4.0	1319442	2.45	1943339	1.50	3152001

2:00

To examine geographical (longitudinal) variations, relative abundance factors were determined for Groups I, II, III and IV combined for the following sections of the middle Susitna River during the months of August and September.

1. Chulitna/Susitna confluence (RM 98.5) to Lane Creek (RM 114.0).

2. Lane Creek (RM 114.0) to 4th of July (RM 131.0).

3. 4th of July (RM 131.0) to Fat Canoe Island (RM 147.0)

The comparative WUA forecasts for these sections for Representative Groups I-IX are given in Figure II-11 through II-13.

The least amount of WUA occurs downstream from RM 114 (Fig. II-11). The WUA in this subreach is concentrated in Representative Groups III, VI, and IX. WUA is relatively constant in all representative groups until streamflow drops below 12,500 cfs. At mainstem discharges below 12,500 cfs nearly all rearing habitat within this subreach is found in large side channels. The importance of this habitat, as represented by WUA, increases markedly in Representative Group IV but declines in all other groups at low streamflows.

The greatest amount of WUA occurs in the multiple channel subreach from RM 114 to 131 (Fig. II-12). WUA is well distributed among all representative groups and a relatively high habitat diversity occurs around 20,000 cfs. Diversity gradually declines as mainstem discharge decreases. Below 12,500 cfs nearly all WUA is associated with Representative Group IV.

Above RM 131 the same trends in habitat diversity exist (Fig. II-13) as in the middle subreach. However, high diversity persists over a broader range of flows. Representative group IV contributes to the majority of WUA at flows below 12,500.

The principal conclusion from this analysis is that the WUA forecasts for Representative groups I through IV seem to adequately predict juvenile chinook habitat for the months June, July and August. It is reasonable to assume that

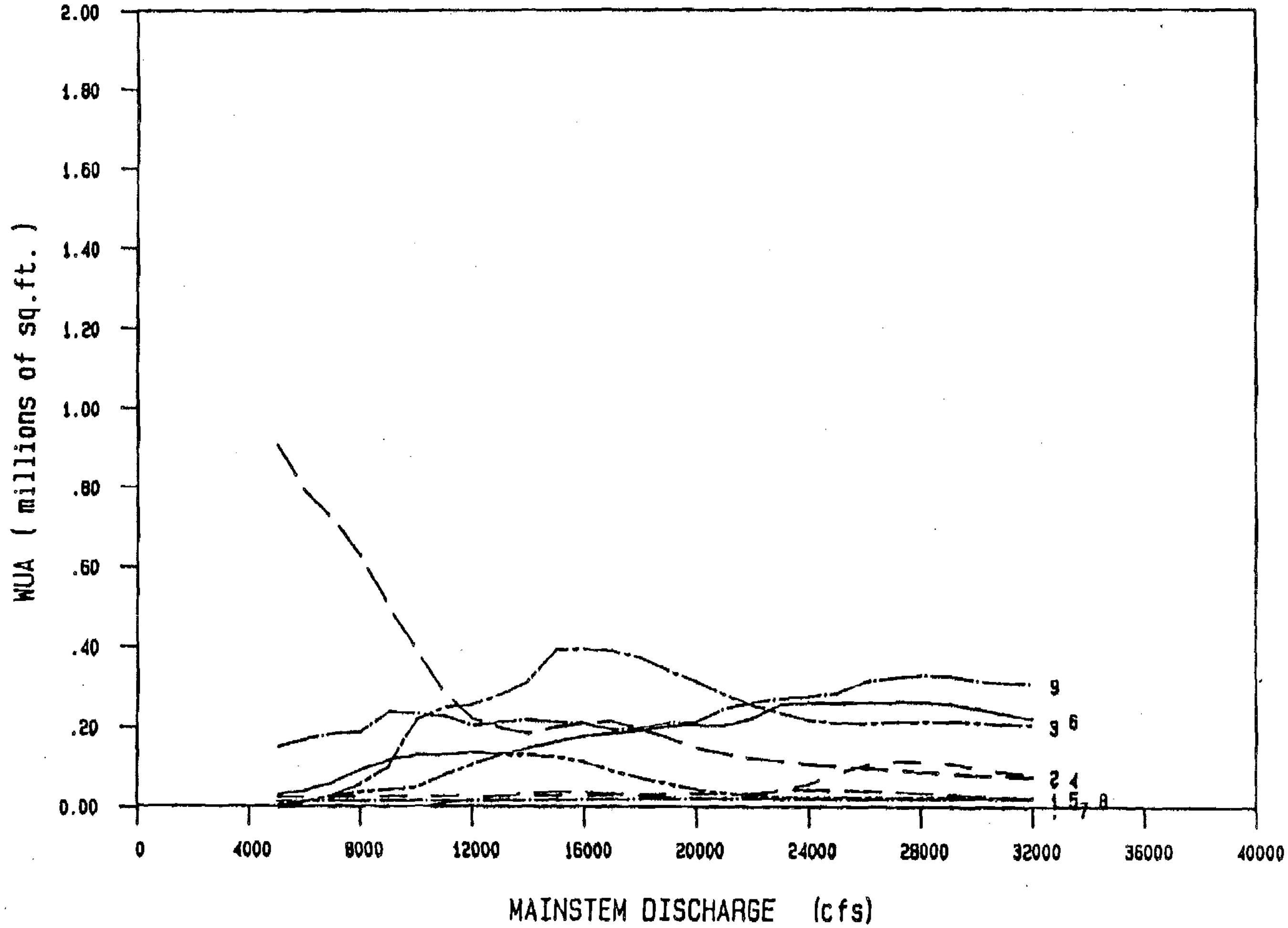


Figure II-11. WUA responses of Representative Groups I - IX for RM 98.5 to 114.0.

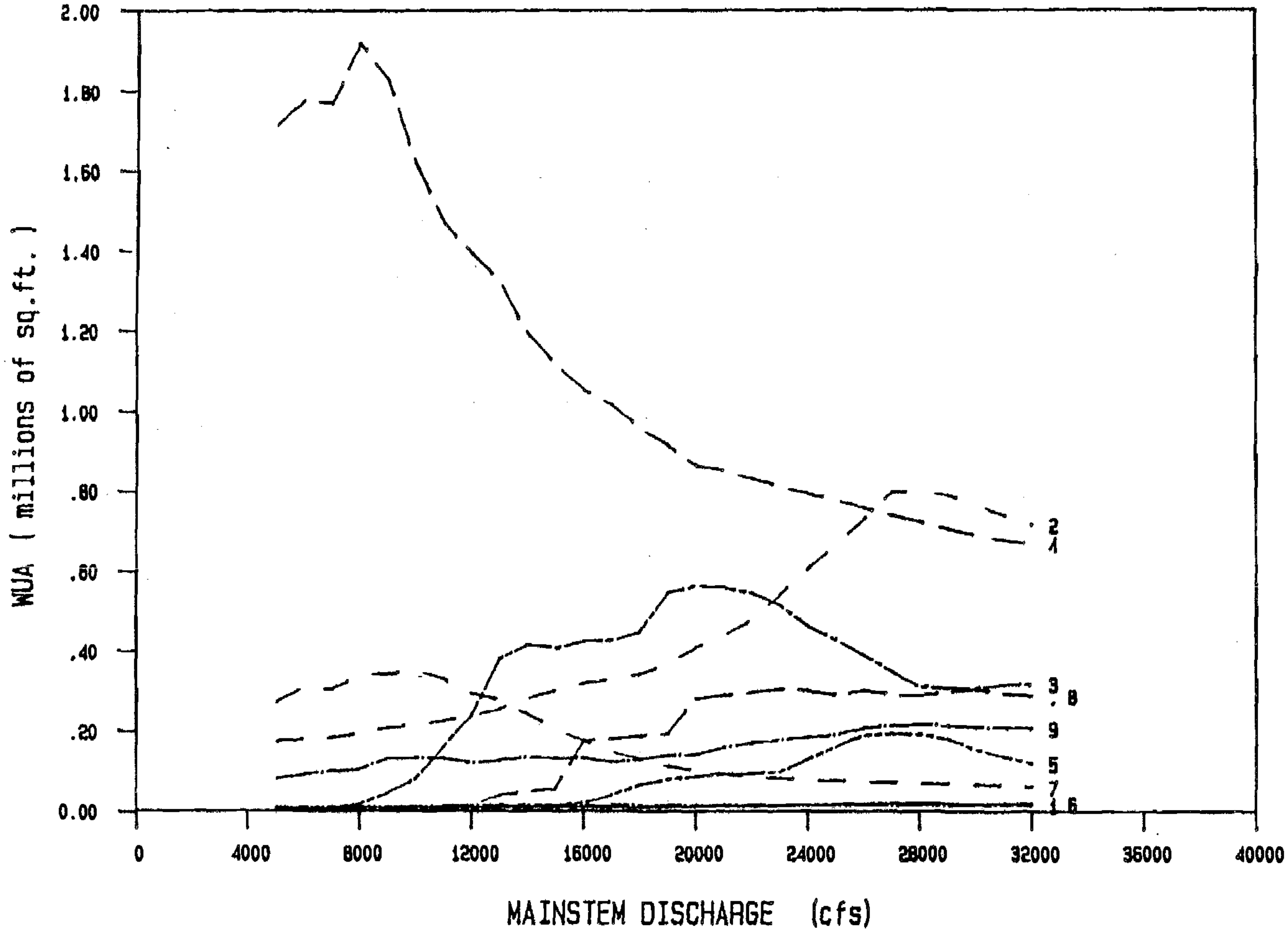


Figure II-12. WUA responses of Representative Groups I - IX for RM 114.0 to 131.0.

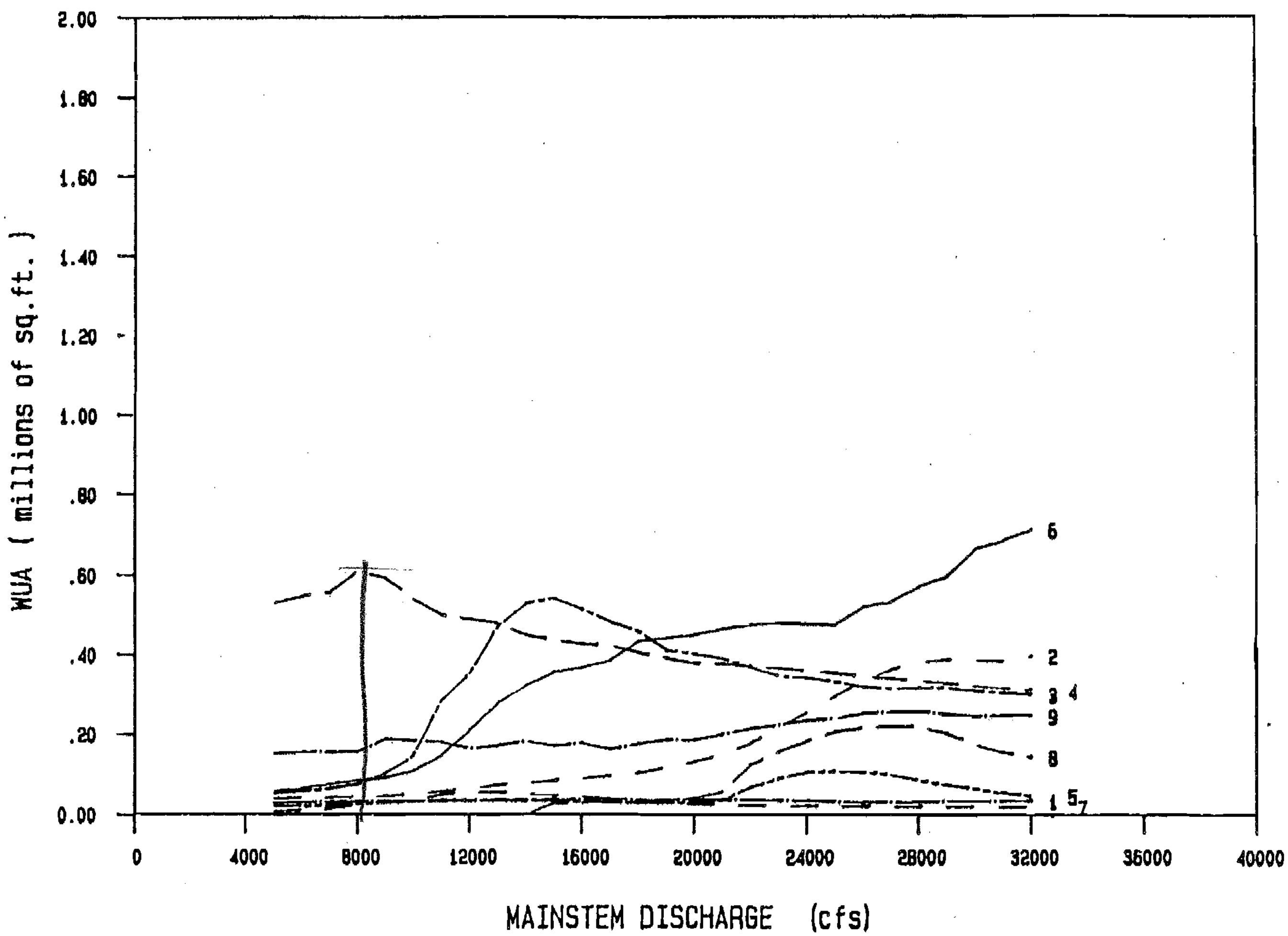


Figure II-13. WUA responses of Representative Groups I - IX for RM 131.0 to 147.0

the other representative groups are also adequate for these months. Therefore, they do not require modification before aggregation into a system-wide response.

However, the implications of the trends evident in Figures II-11 through II-13 are not yet well understood. Larger numbers of juvenile chinook have been captured above RM 131 than below. Very few captures have occurred below RM 114. This suggests that the aggregate response curves are reasonable indicators of utilization by juvenile fish and of the relative importance of individual subreaches for rearing. However, the consequences of shifting a relatively even distribution of WUA between five or six representative groups under natural flows to one dominated by Group IV at streamflows below 12,500 cfs may depend upon the importance of non-modeled factors. It is logical to assume that habitat diversity, as modeled, is high, a greater range of non-modeled habitat qualities is available. This may not be true as diversity decreases and proportionately more WUA is found at only one or a few sites. For example, food availability, a non-modeled factor, may be extremely important in the summer months. Under with-project conditions, when streamflows are reduced and Representative Group IV is contributing proportionately larger amounts of WUA to the total available, it may be that system-wide habitat availability and quality is either reduced or enhanced depending upon the availability of food at sites within Group IV.

Aggregation of Curves for System-Wide Response

The composite WUA for Groups I through IX was given in Figure II-10. The use of the representative group curves without modification implies that factors such as temperature and food availability are not significant when compared to the criteria used. However, these may be otherwise accounted for in the modeling process because the cover criteria for juvenile chinook, which weights turbid water as being more suitable habitat, implicitly includes a food availability or temperature preference component. The rationale is that the introduction of turbid water into a clearwater channel increases the amount of drifting food organisms and the turbid mainstem water is warmer than the clearwater. The aggregate response for June, July and August can probably

This assumes that the factors driving food availability will not change significantly under with-project conditions.

be extended to apply to the open water season of May 15 to September 15 identified in the IFRR Volume I.

However, the aggregate WUA response curve for May 15 to September 15 is not applicable to the fall transition period from the middle of September to the end of October as indicted by the juvenile chinook abundance and distribution information given in Table II-10. The relative abundance factors for Rep Groups I and II during this time period were significantly higher than Rep Groups III and IV. However the WUA forecasts are higher for Group III an IV in September and Group IV in October. In addition, the geographical distribution of the fish during this time period is not addressed by the WUA forecasts. A significantly greater number of juvenile chinook are found at sites above 4th of July Creek than below it. The middle section of the river from Lane Creek (RM 114.0) to 4th of July Creek (RM 131.0) has a high WUA of 1,972,000 ft^2 in September and a relative abundance factor of 1.50, but above 4th of July Creek the factor increases to 4.73 while the WUA forecast is only 1,058,000 ft^2.

Clearly, one or more factors that significantly influence juvenile chinook habitat during this time period are not included in the suitability criteria. This transition period is when juvenile chinook not overwintering in tributaries seek out suitable overwintering sites in mainstem associated habitats. Some chinook leave the tributaries at this time and thus, suitable areas in close proximity to Portage Creek and Indian River are favored to a greater extent. The movement of juvenile chinook from turbid water areas into sloughs (Representative Groups I and II) during this period is probably related to the warmer water temperatures that are associated with groundwater upwelling in the sloughs (Dugan et al. 1984). Upwelling in side sloughs may result in open leads throughout the winter thereby contributing to more favorable overwintering habitat. The areas with the highest degree of upwelling, as indicated by the chum spawning analyses, occur above 4th of July Creek. Unlike the summer months, the turbid water in September and October is not warmer than the clearwater and thus a temperature preference at this time is not accounted for by the cover criteria of turbid water. Juvenile chinook may also be attracted to upwelling areas in side sloughs to feed on chum salmon eggs and carcasses.

Table II-10. Comparison of Relative Abundance Factors and WUA forecasts for Groups I, II, III and IV combined during August and September for different sections of the river.

MONTH	AUGUST		SEPTEMBER	
Average flow (cfs)	22,000		13,300	
Groups I, II, III, and IV combined	Relative Abundance Factor	WUA	Relative Abundance Factor	WUA
RM 98.5 to RM 114.0	1.78	429466	1.90	522890
RM 114.0 to RM 131.0	3.72	1869149	1.50	1972252
RM 131.0 to 147.0	3.0	943181	4.73	1057891

Consequently, to obtain an aggregate system response of WUA for juvenile chinook that is applicable to the fall transition period the representative group curves require inclusion of temperature and possibly food preference factors at this time.

Fall Transition Modifications

It is suggested that the open-water curves be modified so that they are applicable to the fall transition period by first weighting them geographically, thereby giving greater emphasis to WUA above 4th of July Creek (RM 131.0). The curves would then be adjusted to incorporate temperature preference. A flow diagram for this approach is given in Figure II-14.

Applicability of Existing WUA Forecast for Overwintering Assessments

Two fundamental problems make the application of the open water or fall transition WUA response curves inappropriate for use under winter conditions to predict juvenile chinook habitat availability.

First, one assumption in the modeling is that instream hydraulic conditions, to a large degree, influence habitat conditions for rearing fish. Open channel hydraulic theories are applied to define relationships between discharge, river channel geometry, flow velocity and water surface elevations. The presence of river ice, however, negates the hydraulic models calibrated for summer flow conditions and makes them inappropriate for predicting reliable depths and velocities associated with winter flow conditions.

The second problem is related to the significant difference between the behavior of the juvenile chinook according to the time of the year. During the summer, as the juvenile fish are actively feeding and moving about in the water column, flow velocity has a significant influence on habitat suitability. As discussed earlier, in the winter feeding by fish becomes reduced at the lower temperatures (particularly below 4°C) and the juvenile fish move closer to the substrate. Consequently, the velocity suitability criteria developed for open water conditions are not applicable. Therefore, existing WUA forecasts for Representative Groups I through IX are not considered applicable when water temperatures are less than 4°C.

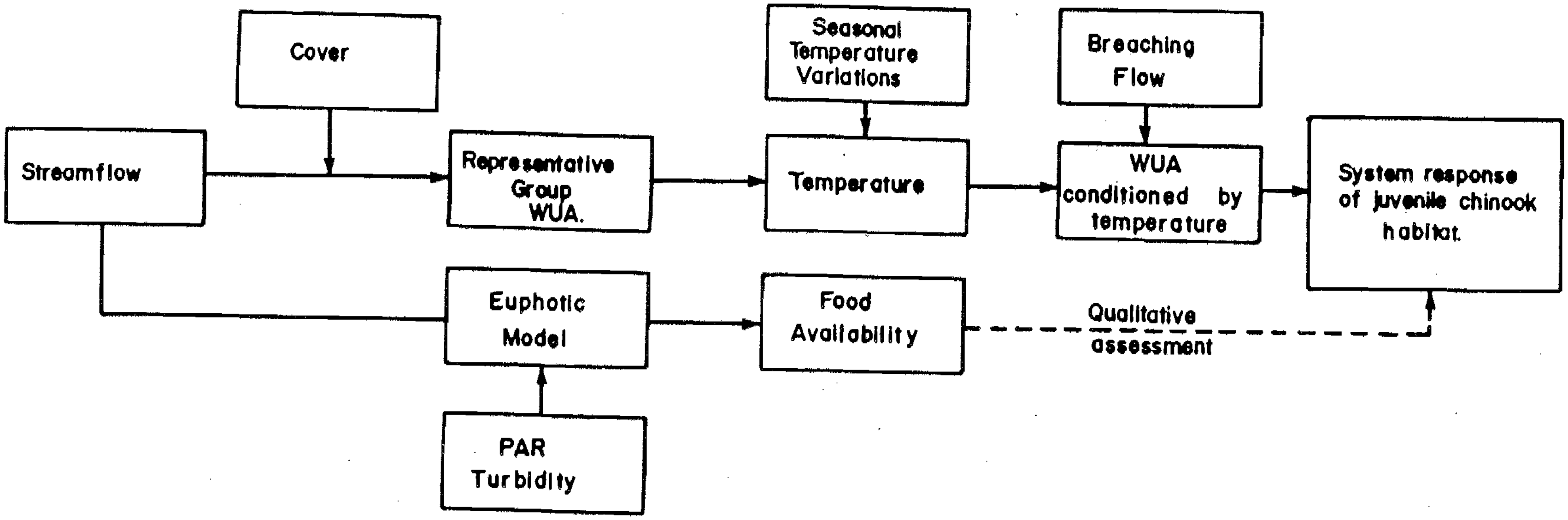


Figure II-14. Conceptual flow diagram of incorporation of temperatures into the model.

Application of WUA Curves

The application of aggregate juvenile chinook habitat response curves to mainstem discharge, as outlined, involves the assumption that conditions under which they were modeled remain the same. If, however, factors not incorporated in the model become significant under altered discharges in a with-project condition then their application may not be appropriate. Although the major project effect is to alter the flow regime, significant changes will occur in temperature and ice processes and, also, in the period of the year in which they become important.

A method of ascertaining the applicability of a response curve for various time periods is to construct preliminary subjective flow diagrams as illustrated in Figure II-15 which, in this example, compares natural conditions with Case E-VI Stage II. As discussed earlier, the formation of ice in the river precludes the use of the WUA response curves in the winter from the middle of November to the middle of May. However, the period of time over which ice will be a significant factor under Stage II conditions will be reduced and, thus, use of the fall transition period curve may be extended.

As outlined in the introduction mainstem water temperatures will be colder in the summer under Stage II conditions and may fall below those in the sloughs. These temperatures may be lower than the optimum range for chinook and affect growth as discussed by AEIDC (University of Alaska 1984). Consequently, temperature may be a factor during the summer and, if desired, could be incorporated in the open water model using the same technique as that employed for the fall transition period response curve. However, the mainstem water temperatures will be warmer during the fall transition period. Thus, the difference in temperature that now occurs during September between side sloughs with upwelling and mainstem-influenced habitat and which causes juvenile chinook to select side sloughs for overwintering will be delayed. Therefore, it may be more appropriate to extend the application of the open water response curve before applying that for the fall transition period. By considering the significant factors in this manner, the application of the WUA response curves is more appropriate. After defining the use of the appropriate response curves, habitat time series and habitat duration curves can be constructed.

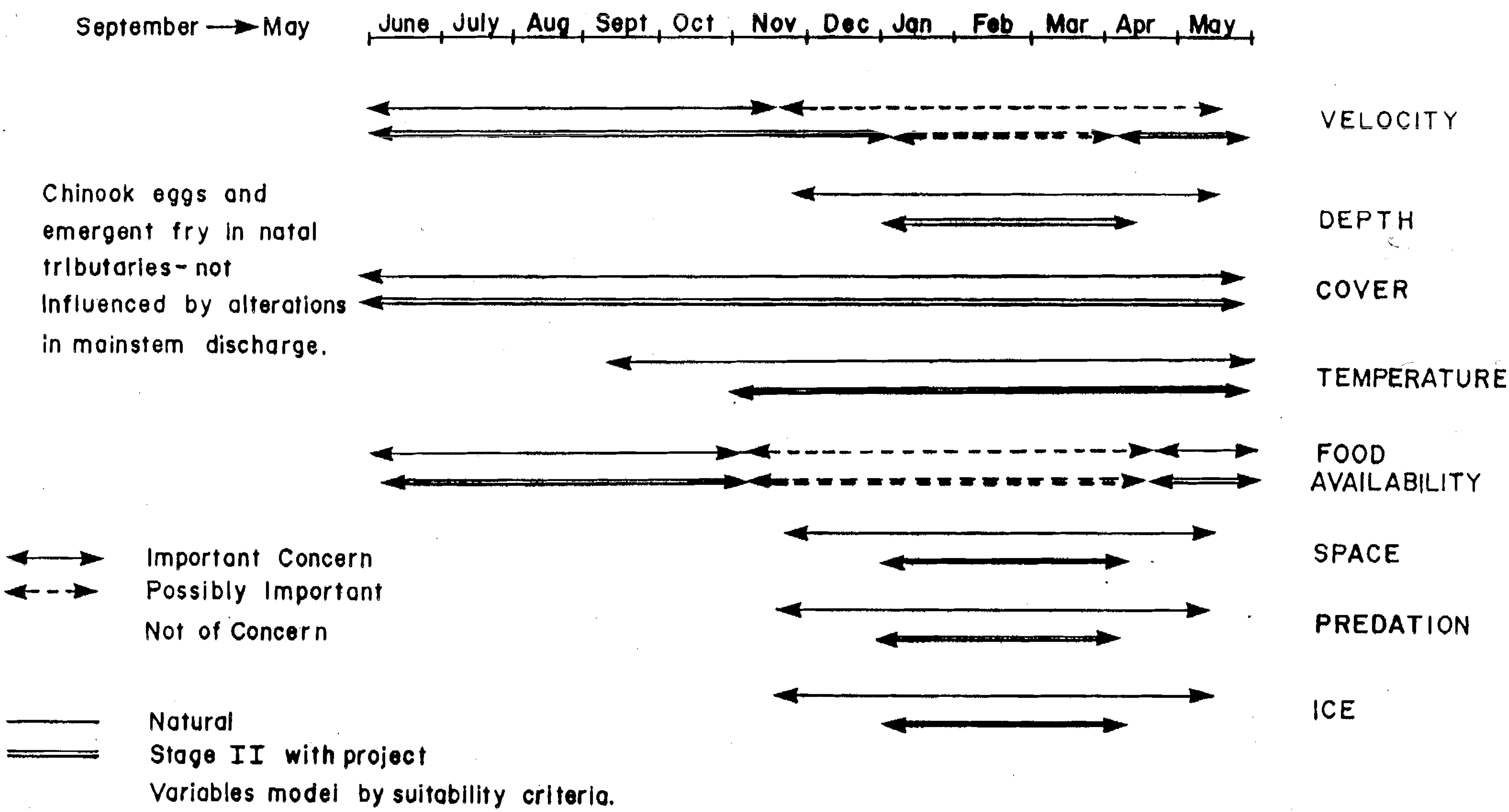


Figure II-15. Comparison of habitat factors by time period under natural and with-project stage II conditions.

III. RESPONSE OF CHUM SALMON

Will be provided later.

IV OTHER SPECIES

Introduction

(will be provided later)

Table IV-1

(will be provided later)

Sockeye Salmon

Adults

Susitna River sockeye salmon make a substantial contribution to the upper Cook Inlet commercial fishery. The average annual catch of Susitna River sockeye in the fishery (between 134,000 to 402,000 fish) over the past 31 years (1954-1984) is surpassed by only the pink salmon catch during even years and the annual chum salmon catch (Barrett et al. 1984, Jennings 1985).

There are two distinct runs of sockeye salmon in the Susitna River. The first run does not spawn in the middle Susitna River but the second run usually enters the middle Susitna River near the first of August. Their migration continues through late August (Barrett et al. 1984, 1985). The timing of the sockeye migration appears to be relatively consistent from year to year. Spawning activity usually occurs from mid August through mid September (Barrett et al. 1985).

The average annual sockeye salmon escapement to the middle Susitna River was estimated to be 6,300 fish at Talkeetna Station (RM 103) and 2,400 fish at Curry Station (RM 120) (Table IV-2). These estimates were based on tagging studies conducted in 1981-1984 (Barrett et al. 1984, 1985). Spawning ground surveys conducted subsequently indicate that these escapements overestimate the number of fish spawning in the middle Susitna River. ADF&G field studies have indicated that a substantial portion of the escapement passing Talkeetna Station later returns downstream to spawn in habitats other than those in the middle Susitna River.

In 1981 to 1984, an estimated 52 to 83 percent of the sockeye escapement passing Talkeetna Station could not be accounted for on the spawning grounds and may have returned downstream. The number of milling sockeye passing Curry Station was less than at Talkeetna Station, as only 35 percent of the escapement apparently left the middle Susitna River. The milling components of the escapements are approximations as they were developed by comparing the escapements at Talkeetna and Curry Stations with the estimated total slough escapement of sockeye in the middle Susitna River. Since almost all sockeye

Table IV-2. Average salmon escapements in the Susitna River by species and location.

Location/ River Mile	Sockeye[1]	Chum[2]	Coho[2]	Pink[3]	Chinook[4]	Total
Yentna Station RM 28, TRM 04	126,750	21,200	19,600	odd 48,400 even 408,300	---	odd 215,950 even 575,850
Sunshine Station RM 80	121,650	431,000	43,900	odd 45,000 even 730,100	88,200	odd 729,750 even 1,414,850
Talkeetna Station RM 103	6,300	54,600	5,700	odd 5,900 even 125,500	16,700	odd 89,200 even 208,800
Curry Station RM 120	2,400	28,200	1,600	odd 3,300 even 87,900	13,000	odd 48,500 even 133,100
Minimum Susitna River[5]	248,400	452,200	63,400	odd 93,400 even 1,138,400	---	odd 857,500 even 1,902,500

1 Second-run sockeye escapements. Four-year average of 1981, 1982, 1983 and 1984 escapements.

2 Four-year average of 1981, 1982, 1983 and 1984 escapements.

3 Odd is average of 1981 and 1983 escapements. Even is average of 1982 and 1984 escapements.

4 Three-year average of 1982, 1983 and 1984 escapements.

5 Summation of Yentna Station and Sunshine Station average escapements. Does not include escapement to the Susitna River and its tributaries below RM 80 (excluding the Yentna River).

Source: Barrett et al. 1984, 1985

spawn in sloughs in the middle Susitna River, the total slough escapement is an estimate of the spawning population of sockeye within the middle Susitna River. The difference between the total slough escapement and the escapement at a fishwheel station has been attributed to fish that move into the middle Susitna River and later return downstream to spawn elsewhere (i.e. milling fish). The milling component also includes any sampling error introduced from escapement surveys or population estimates at the fishwheel stations and within the sloughs.

Escapement of sockeye salmon to the middle Susitna River was estimated using the total slough escapement since almost all sockeye salmon spawn in slough habitats. For 1981 through 1984, the total slough escapement of sockeye salmon in the middle Susitna River ranged from 1,100 to 2,200 fish (Barrett et al. 1985). Thus, the middle Susitna River contains less than one percent of the sockeye spawning within the Susitna River basin.

<u>Habitat Utilization</u>. Although sockeye salmon spawn almost exclusively in slough habitats in the middle Susitna River, a limited amount of spawning occurs in mainstem, side-channel and tributary habitats. Approximately 95 percent of the sockeye salmon spawned in side sloughs and upland sloughs, while the remaining percent used side channel, mainstem, and tributary habitats. Spawning occurred in sloughs during the last week of August and the first week of September. Chum salmon spawned in all areas where sockeye were reported (Barrett et al. 1984, 1985).

Three out of 23 sloughs contributed about 90 percent of the peak count of spawning sockeye in the middle Susitna River (Table IV-3). These three sloughs 11, 8A, and 21 (Barrett et al. 1984, 1985) are also important chum salmon spawning areas and contained 60 percent peak count of slough spawning chum salmon.

Spawning sites other than sloughs were located in the following areas. Three mainstem spawning sites were located between RM 138.6 and 138.9, at RM 139.0, and at RM 141.6 (Barrett et al. 1985). Seven side-channel spawning sites were used by sockeye between RM 131 and 142 with Side Channel 11 at RM 134.6, and Side Channel 21 at RM 141.0 containing the most fish. Only 33 sockeye were

Table IV-3. Second-run sockeye salmon total slough escapement in the middle Susitna River, 1981-1984.

Slough	River Mile	1981	1982	1983	1984	Four-Year Average
1	99.6	0	0	0	26	7
2	100.2	0	0	0	18	5
3B	101.4	0	0	10	36	12
3A	101.9	13	0	0	29	11
5	107.6	0	0	0	3	1
8	113.7	0	0	0	5	1
8C	121.9	0	5	0	0	1
8B	122.2	0	13	0	0	3
Moose	123.5	0	20	31	0	13
8A	125.1	195	131	130	532	247
B	126.3	0	20	10	23	13
9	128.3	18	13	0	16	12
9B	129.2	212	0	0	18	58
9A	133.8	4	0	0	0	1
11	135.3	1,620	1,199	564	1,280	1,166
15	137.2	0	0	0	3	1
17	138.9	11	0	11	26	12
19	139.7	42	0	10	29	20
21	141.1	63	87	294	154	150
22	144.5	0	0	0	5	1
Total		2,178	1,488	1,060	2,203	1,732(1)

Source: Barrett et al. 1984, 1985

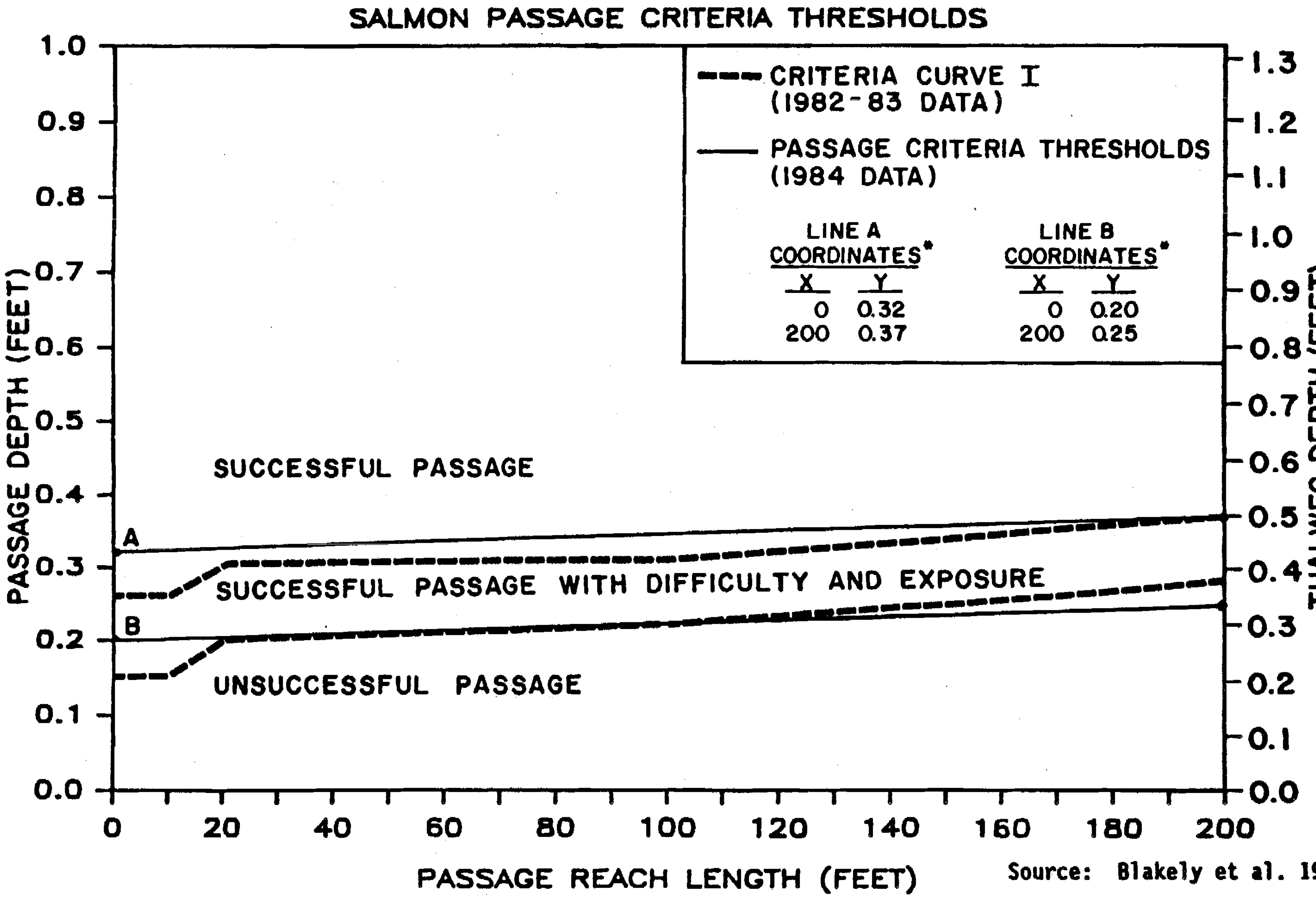
(1) Four-year average of totals

observed spawning in mainstem and side channels (Barrett et al. 1985, Jennings 1985). Unlike chum salmon, spawning sockeye made little use of tributaries. Spawning activity was recorded only in Portage Creek and then only one pair of fish (Barrett et al. 1985).

Habitat Requirements. Adult sockeye salmon have specific habitat requirements for spawning and the selection of redd sites. Since most of the spawning in the middle Susitna river occurs in side-slough habitats, passage into these habitats is an important consideration. For fish passage, hydraulic conditions appear to be the controlling factors; a specific water depth must be exceeded and water velocities must be within the swimming capabilities of the fish (Bell 1973, Thompson 1972). Tolerance limits associated with depth and velocity depend on size and swimming capabilites. Generally, smaller fish tolerate shallower depths and require lower velocities.

In general, depths less than 0.5 ft have been associated with passage difficulty for adult salmon (Thompson 1972, Blakely et al. 1985). However, shallower depths can be negotiated over short distances. Studies conducted in side sloughs of the middle Susitna River indicate that adult chum salmon can pass through passage reaches with thalweg depths of 0.3 ft for a distance of 80 feet (Figure IV-1) (Blakely et al. 1985, ADF&G 1985). Sockeye salmon are smaller than chum salmon and have better swimming performance (Barrett 1984, 1985; Bell 1973). Thus, sockeye salmon can successfully negotiate shallower depths than chum salmon, and the analyses of chum salmon passage can be used to provide a conservative passage evaluation for sockeye salmon.

Habitat requirements for spawning salmon in Susitna River habitats were defined using four variables: depth, velocity, substrate and upwelling. Habitat suitability criteria were developed for spawning sockeye salmon in side-slough habitats are presented in Figures IV-2 and IV-3 (Vincent-Lant et al. 1984b). Compared with sockeye salmon in other river systems, slough-spawning sockeye salmon used a relatively narrow range of depth and velocities, but a wider range of substrates. Mean depth and velocity associated with sockeye spawning in slough habitats were 0.8 ft and 0.2 fps respectively (n=81). In other drainages, usable depths ranged from 0.5 to 6.0 ft and optimal water velocities from 0.5 to 2.5 fps (Hoopes 1961; Chambers



Source: Blakely et al. 1985.

Figure IV-1. Comparison of revised passage criteria thresholds for successful and unsuccessful passage of chum salmon with Criteria Curve I.

SOCKEYE SALMON
SUITABILITY CRITERIA CURVE
DEPTH

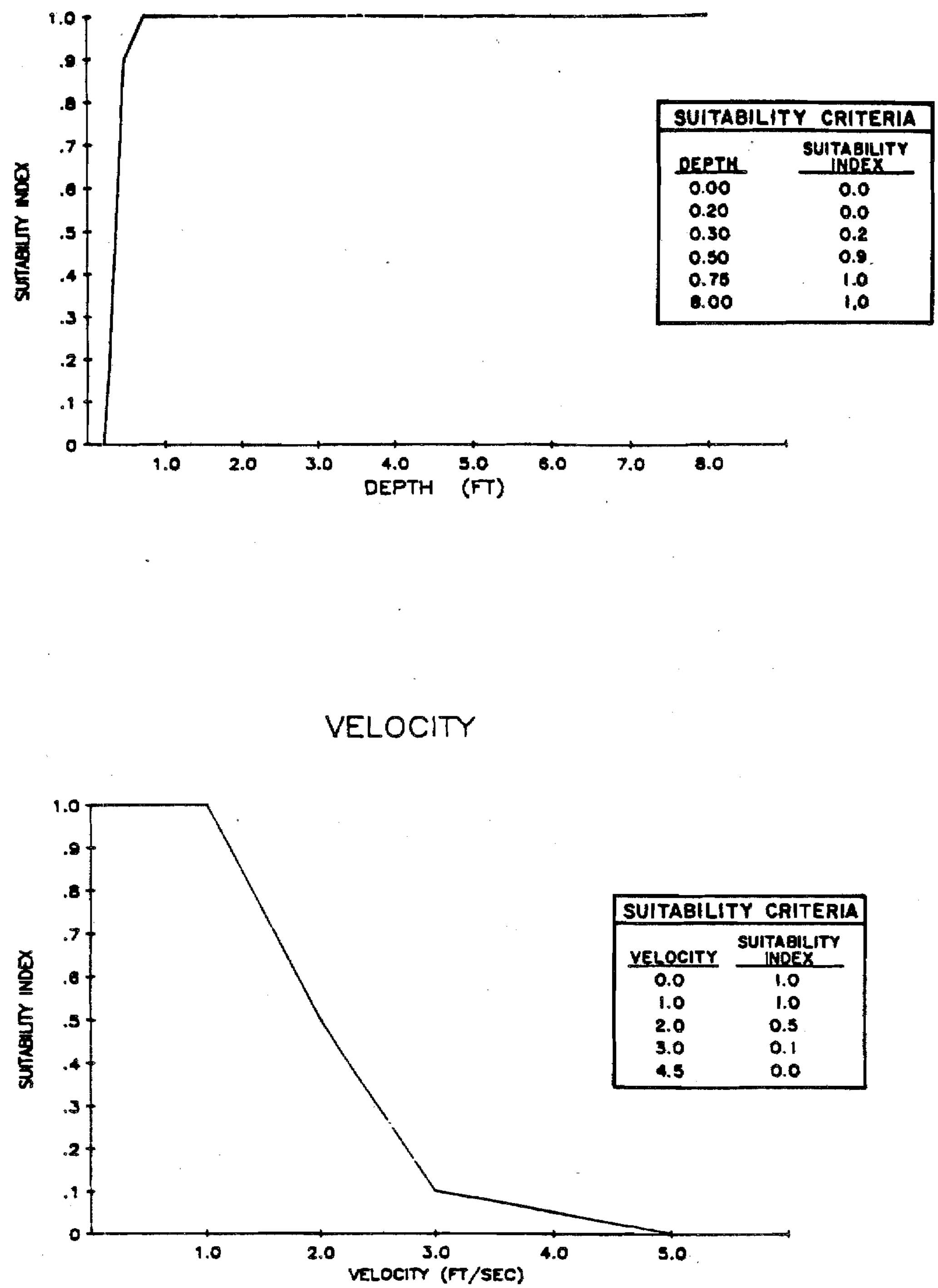


Figure IV-2. Depth and velocity habitat requirements for spawning sockeye in the middle Susitna River.

Source: Vincent-Lang et al. 1984b.

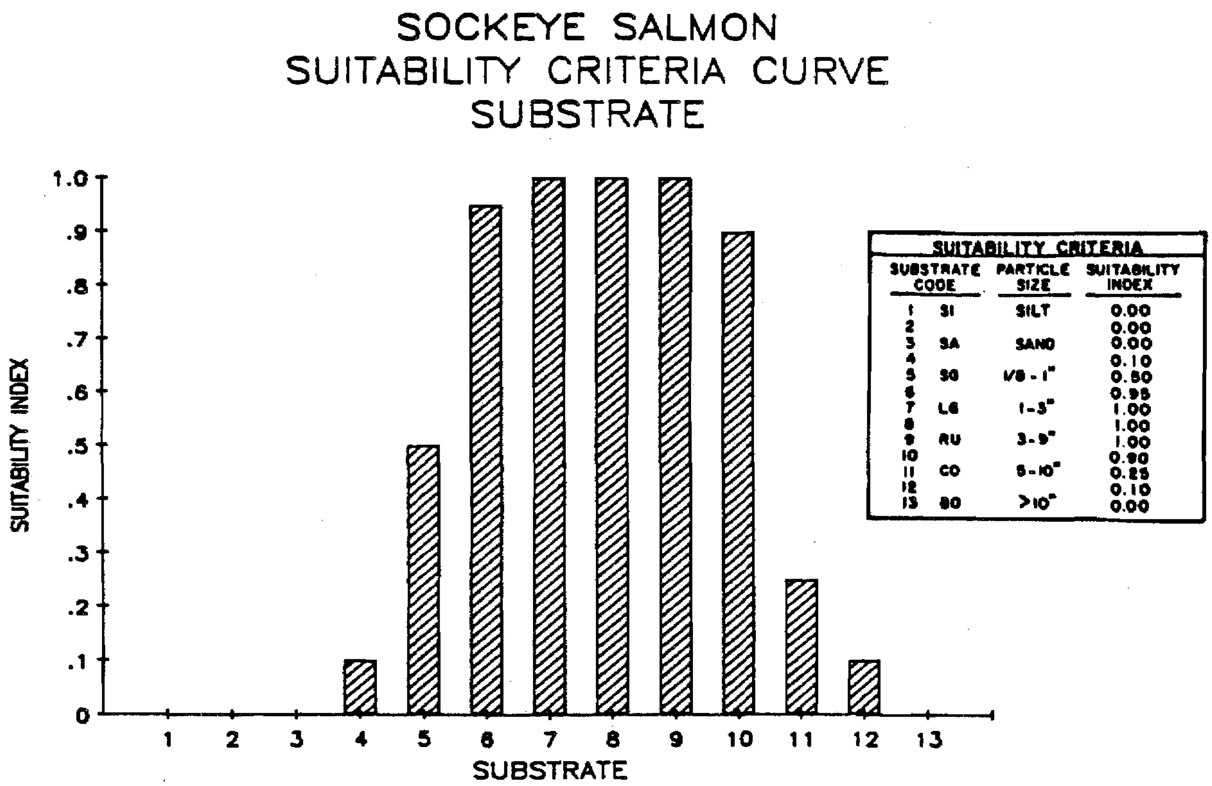


Figure IV-3. Substrate utilization by spawning sockeye salmon in the middle Susitna River.

Source: Vincent-Lang et al. 1984b.

1954, 1955, Dehlisle and Clay 1961, Baldrige and Trihey 1982). The narrow range of velocities and depths utilized by sockeye salmon in the middle Susitna River appear to be related to available conditions rather than distinct preferences for lower values. Water depths in slough habitats during spawning usually ranged from 0.1 to 2.5 ft with a mean depths of approximately 0.6 ft. Velocities present during spawning ranged from 0.0 to 1.5 fps with a mean of approximately 0.3 fps.

A wide range of substrate sizes were used by spawning sockeye salmon in the middle Susitna River. Redds were excavated in silt-covered gravels and in large gravel-cobble mixtures. Usable substrate for spawning was limited by the fishes' ability to excavate the redd. A review of other studies indicates that sockeye appear to prefer substrate sizes between 1 and 5 in. in diameter (Hoopes 1962, Baldrige and Trihey 1982, Jennings 1985).

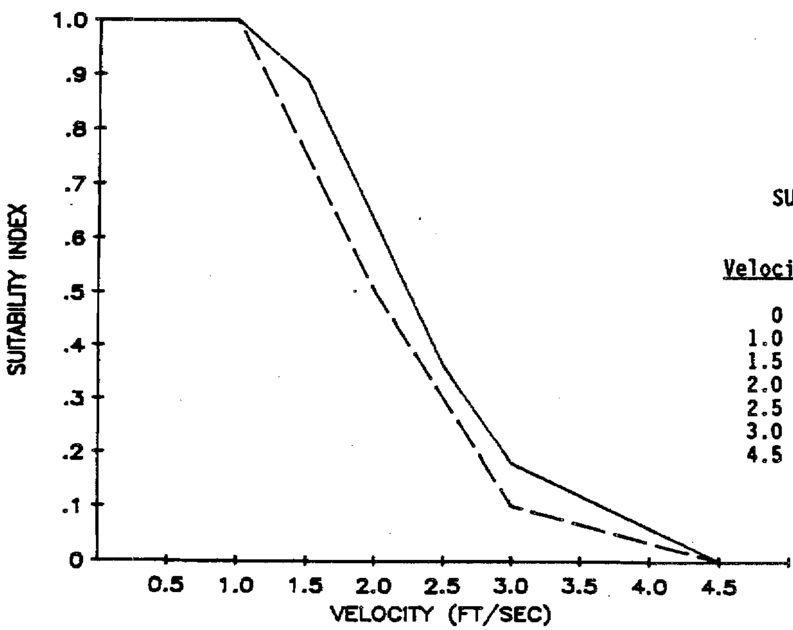
Upwelling is an important component of sockeye spawning habitat in the middle Susitna River (Vincent-Lang et al. 1984b). In sloughs and side channels, sockeye salmon spawn in areas associated with upwelling. The presence of upwelling allows fish to use smaller size substrate particles for spawning conditions that have been found to be detrimental to embryo development in other systems (Silver et al. 1963, Shumway et al. 1964, Koski 1966). Upwelling water prevents the disruption of intragavel flow and inhibition of oxygen and metabolic waste transport usually associated with silty substrates.

The habitat requirements of spawning sockeye in the Susitna River drainage are similar to those associated with chum salmon, a primary evaluation species. Figure IV-4 presents a comparison of habitat suitability criteria developed in slough and side channel habitats for spawning chum and sockeye salmon (Vincent-Lang et al. 1984b). The depth and velocity habitat suitability curves for the two species are almost overlapping; sockeye salmon use slightly lower depths and velocity. Sockeye utilization of smaller substrate particles is less than chum. However, these differences are slight.

Habitat Availability. Since the habitat utilization patterns and requirements of sockeye salmon are similar to those for chum salmon, the detailed habitat modelling presented for chum salmon can be applied to sockeye salmon. Habitat

CHUM AND SOCKEYE SALMON SUITABILITY CRITERIA CURVE

VELOCITY



LEGEND

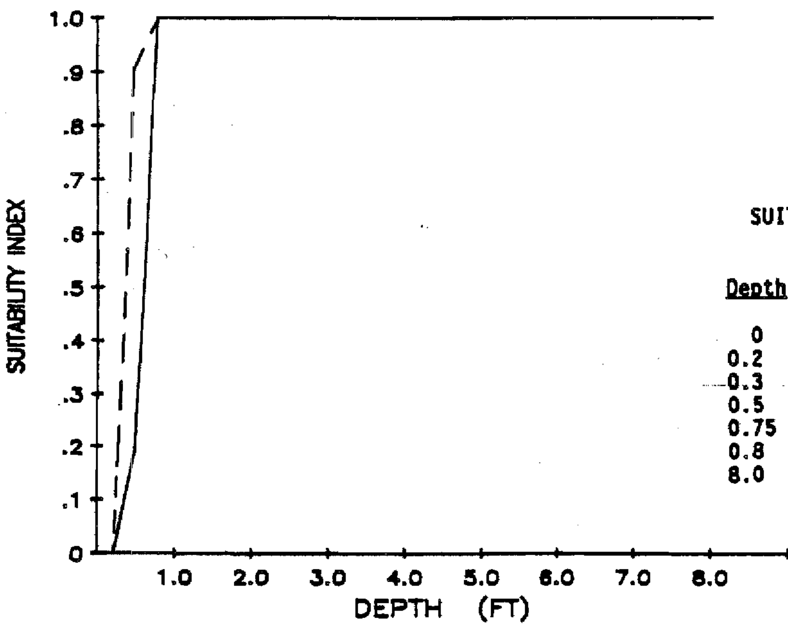
—— CHUM

— - SOCKEYE

SUITABILITY CRITERIA

Velocity	SUITABILITY INDEX Chum	Sockeye
0	1.00	1.00
1.0	1.00	1.00
1.5	0.89	0.75
2.0	0.63	0.50
2.5	0.36	0.30
3.0	0.18	0.10
4.5	0.00	0.00

DEPTH



LEGEND

—— CHUM

— - SOCKEYE

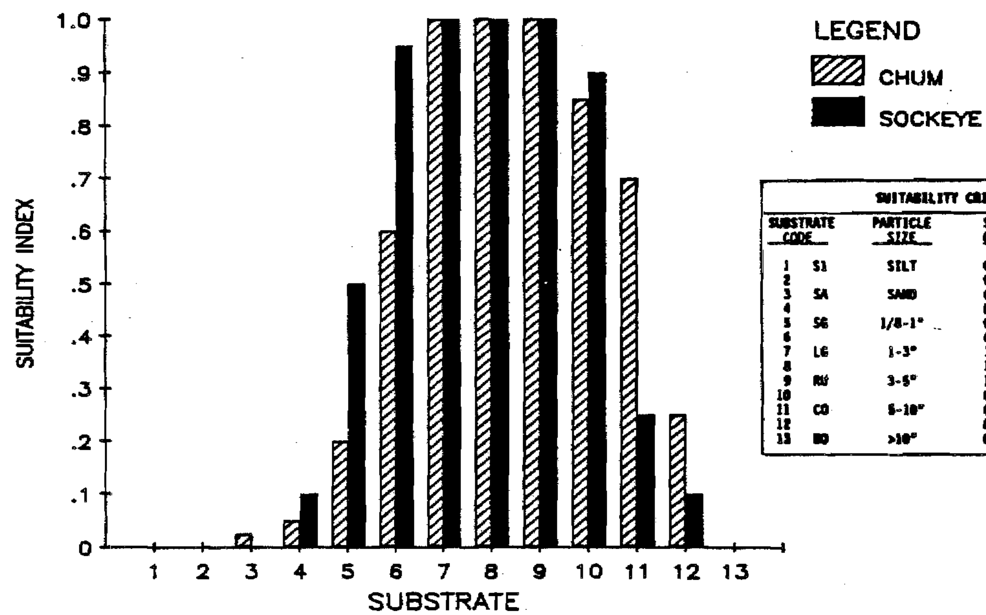
SUITABILITY CRITERIA

Depth	SUITABILITY INDEX Chum	Sockeye
0	0.00	0.00
0.2	0.00	0.00
0.3	0.07	0.20
0.5	0.20	0.90
0.75	0.87	1.00
0.8	1.00	1.00
8.0	1.00	1.00

Source: Vincent-Lang et al. 1984b.

Figure IV-4. Comparison of habitat requirements for sockeye and chum salmon.

CHUM AND SOCKEYE SALMON
SUITABILITY CRITERIA CURVE
SUBSTRATE



SUITABILITY CRITERIA				
SUBSTRATE CODE		PARTICLE SIZE	SUITABILITY INDEX CHUM	SOCKEYE
1	SI	SILT	0.00	0.00
2			0.00	0.00
3	SA	SAND	0.025	0.00
4			0.05	0.10
5	SG	1/8-1"	0.20	0.50
6			0.60	0.95
7	LG	1-3"	1.00	1.00
8			1.00	1.00
9	RU	3-5"	1.00	1.00
10			0.85	0.90
11	CO	5-10"	0.70	0.25
12			0.25	0.10
13	BO	>10"	0.00	0.00

Source: Vincent-Lang et al. 1984a.

Figure IV-4, Continued. Comparison of habitat requirements for sockeye and chum salmon.

simulations completed for chum salmon in side-slough and side-channel habitats would describe almost all (98%) sockeye spawning activity in the middle Susitna River.

ADD SECTION BASED ON CHUM SALMON RESULTS.

Juveniles

Middle Susitna River juvenile sockeye can be separated into three groups based on different life histories. The first pattern is for juvenile sockeye to spend their entire freshwater period rearing in the middle river, then outmigrating to the ocean during the spring of their second year. The second pattern is for fish to spend 3 to 4 months of their first summer in the middle river, move to areas below the Chulitna River confluence to overwinter, and then outmigrate to Cook Inlet during the spring of their second year. The third pattern is for juvenile sockeye to spend up to six months in the middle Susitna River before beginning a downstream migration, entering the ocean in the summer or fall as 0^+ fish. Those fish that go directly to sea as age 0^+ have a low survival rate (ADF&G 1982a, Barrett et al. 1984, 1985). Most of the returning adult sockeye had spent 1 year in freshwater.

The population size of age 0^+ sockeye was estimated in the middle Susitna River. In 1983 and 1984, the population size was estimated to be 575,000 and 299,000 respectively, using Schaeffer's estimate (Schmidt et al. 1984, 1985). Most juvenile sockeye leave the middle Susitna River at age 0^+ and move into the Susitna River below Talkeetna. In 1983 and 1984, ADF&G reported that age 1^+ fish accounted for less than 1 percent of outmigrants sampled in the middle Susitna River.

Peak outmigration generally occurs from late June to early July, although outmigration from the middle Susitna River continues from mid June through mid October (ADF&G 1983b, and Schmidt et al. 1984).

Habitat Utilization. In the middle Susitna River, juvenile sockeye salmon use upland sloughs and side sloughs (Figure IV-5) (Schmidt et al. 1984, 1985). In 1982 and 1983, 90 percent were found in upland and side sloughs and 10 percent

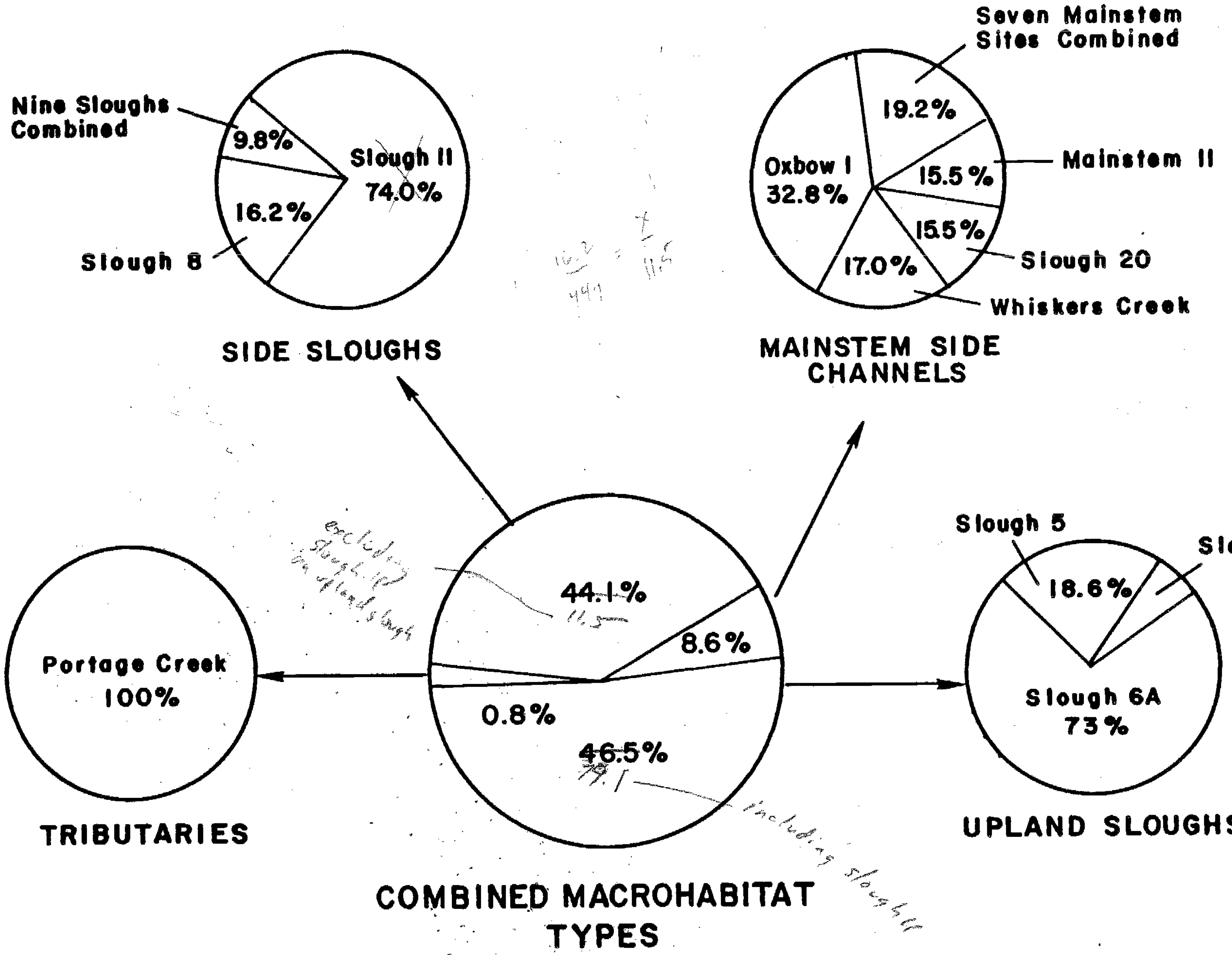


Figure IV-5. Habitat utilization by juvenile sockeye salmon.

Source: Schmidt et al. 1984.

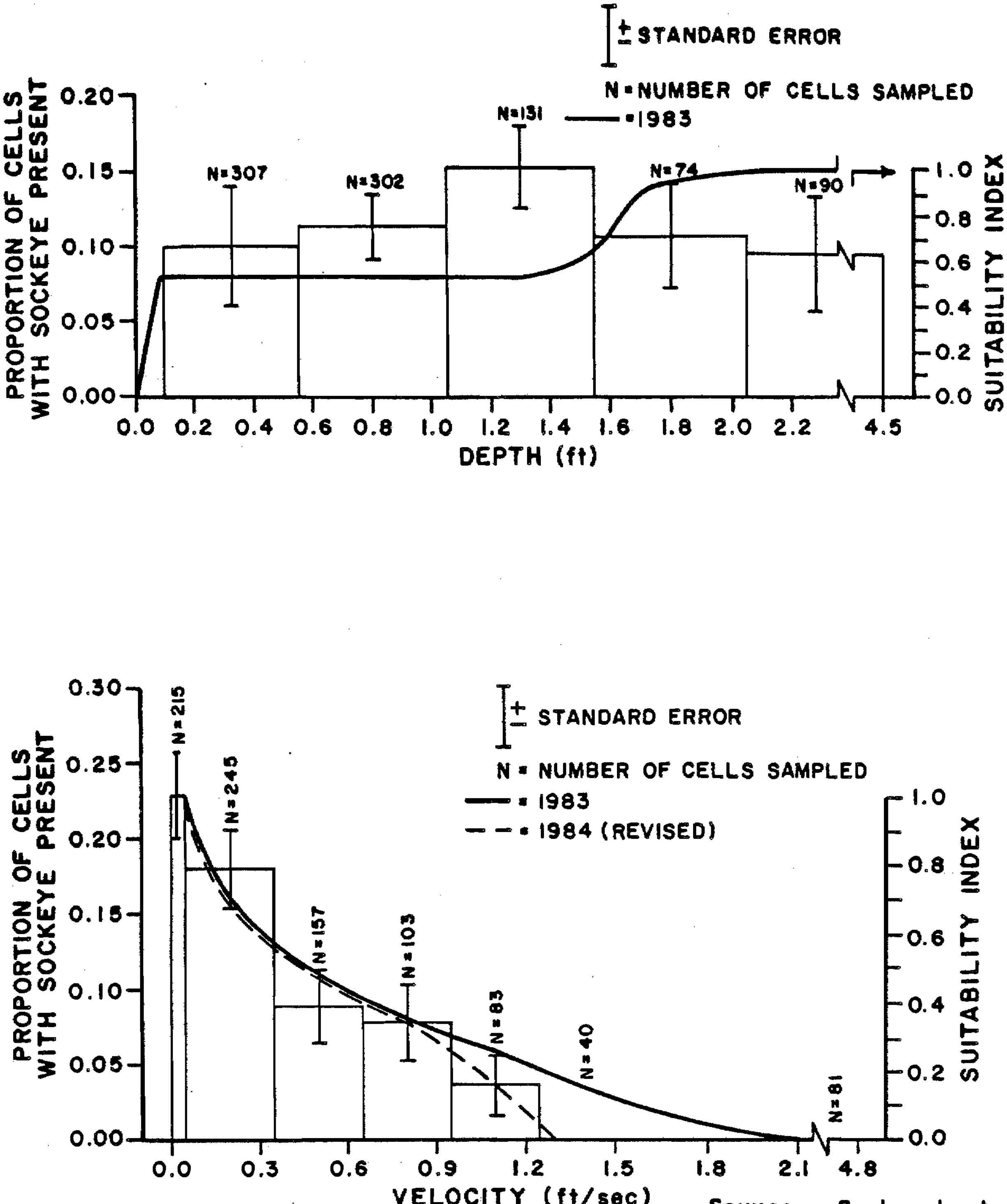
in tributary mouths and side channels (ADF&G 1983b, Schmidt et al. 1984). Utilization of rearing areas by sockeye juveniles appears to be related to proximity of spawning areas and many juvenile sockeye are found in natal sloughs like Slough 11. Upland Slough 6A, however, is an exception as the nearest spawning areas are 10 to 12 miles upstream. The most important of these rearing areas were Upland Slough 6A and Side Slough 11 which account for 34 and 33 percent, respectively, of juveniles in middle Susitna River (Schmidt et al. 1984, 1985).

Some overwintering of juvenile sockeye in the middle Susitna River has been documented in sloughs 9 and 11 (ADF&G 1983c, Schmidt et al. 1984, 1985). However, catches have been low, indicating that the middle reach is not used extensively for overwintering by juvenile sockeye.

Habitat Requirements. Habitat suitability criteria was developed in side and upland sloughs to describe juvenile habitat preferences (Figures IV-6 and IV-7). Depths utilized by juvenile sockeye salmon range from 0.1 to 4.5 ft and within this range, depths greater than 1.6 ft were preferred. Velocities utilized ranged from 0.0 to 1.3 fps and preferred velocities from 0.0 to 0.3 fps. Juvenile sockeye appear to prefer emergent and aquatic vegetation and undercut banks. Habitat utilization data for cover suggest that sockeye salmon juveniles are less dependent on cover than other salmon. Sockeye use schooling behavior as a defense against predation rather than refuge habitat associated with cover (Suchanek et al. 1985). Sockeye juveniles also appear to avoid turbid water (Dugan et al. 1984).

Habitat requirements of juvenile sockeye in the Susitna River are similar to those reported for the Kenai River by Burger et al. (1983). Burger et al. found juvenile sockeye occupying areas with velocities from 0.0 to 0.3 fps, and often in association with aquatic vegetation that was used as cover. They found sockeye juveniles using shallower depths than noted for the Susitna River but this may be related to low water conditions occurring during the sampling.

Sockeye juveniles appear to respond most to water velocities and cover is of secondary importance. Depth, after it exceeds a threshold value, does not



Source: Suchanek et al.

Figure IV-6. Depth and velocity habitat requirements for juvenile sockeye in the Susitna River.

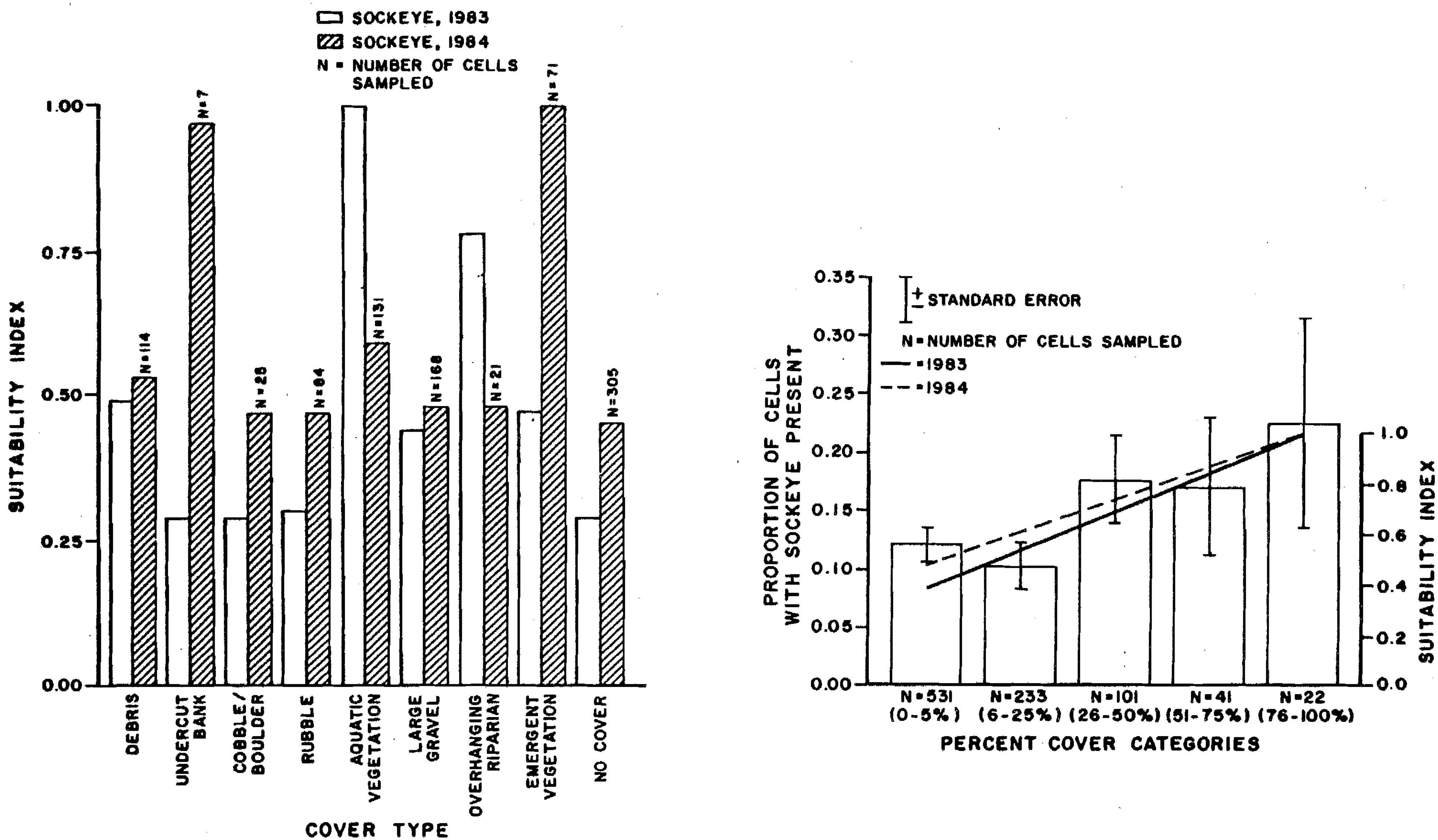


Figure IV-7. Cover suitabilities for juvenile sockeye salmon in the Susitna River.

Source: Suchanek et al. 1985

appear to be an important factor in determining habitat utilization. Velocity habitat suitability curves for Kenai River sockeye juveniles had optimum at 0.0 fps, with little use at velocities greater than 0.6 fps (Burger et al. 1983).

Food habits of juvenile sockeye were examined in July and August of 1982. In sloughs 8A and 11, chironomid larvae, pupae, and adults were found to be the numerically dominant food item selected. Juvenile sockeye preferred chironomid larvae. Other food items consumed included cladocerans and copepods in Slough 11, and a variety of aquatic and terrestrial insects from both sloughs.

Growth rates of juvenile sockeye were estimated. Growth ceased at a critical size around 50-55 mm. Schmidt et al. (1984) suggested that juveniles migrated downstream during July and August in search of better rearing habitat (plankton-rich areas). Growth was measured after August in less than 2 percent of the outmigrating age 0+ fish from the middle Susitna River. Growth was also measured on age 1+ fish indicating that both age 0+ and age 1+ fry were growing through the winter and early spring prior to outmigration from the middle Susitna River.

Habitat Availability. Habitat requirements for rearing sockeye salmon differ from those of chinook salmon, the primary evaluation species with respect to both macro- and microhabitat utilization. Therefore the detailed habitat simulations presented for chinook salmon juveniles would not be applicable to juvenile sockeye salmon. Habitat availability for sockeye salmon juveniles can be evaluated using gross surface area (Figure IV-8). Rearing habitat for juvenile sockeye in the middle Susitna River appears to be scarce. Deeper, lower velocity, and clear water are uncommon in middle Susitna River (Hale 1984, Schmidt et al. 1984). Slough 11 was favorable for rearing as it breaches only at high discharges (42,000 cfs) therefore maintaining more lake-like rearing conditions. Slough 6A, the most important slough, also has low velocity and clear water (Schmidt et al. 1984).

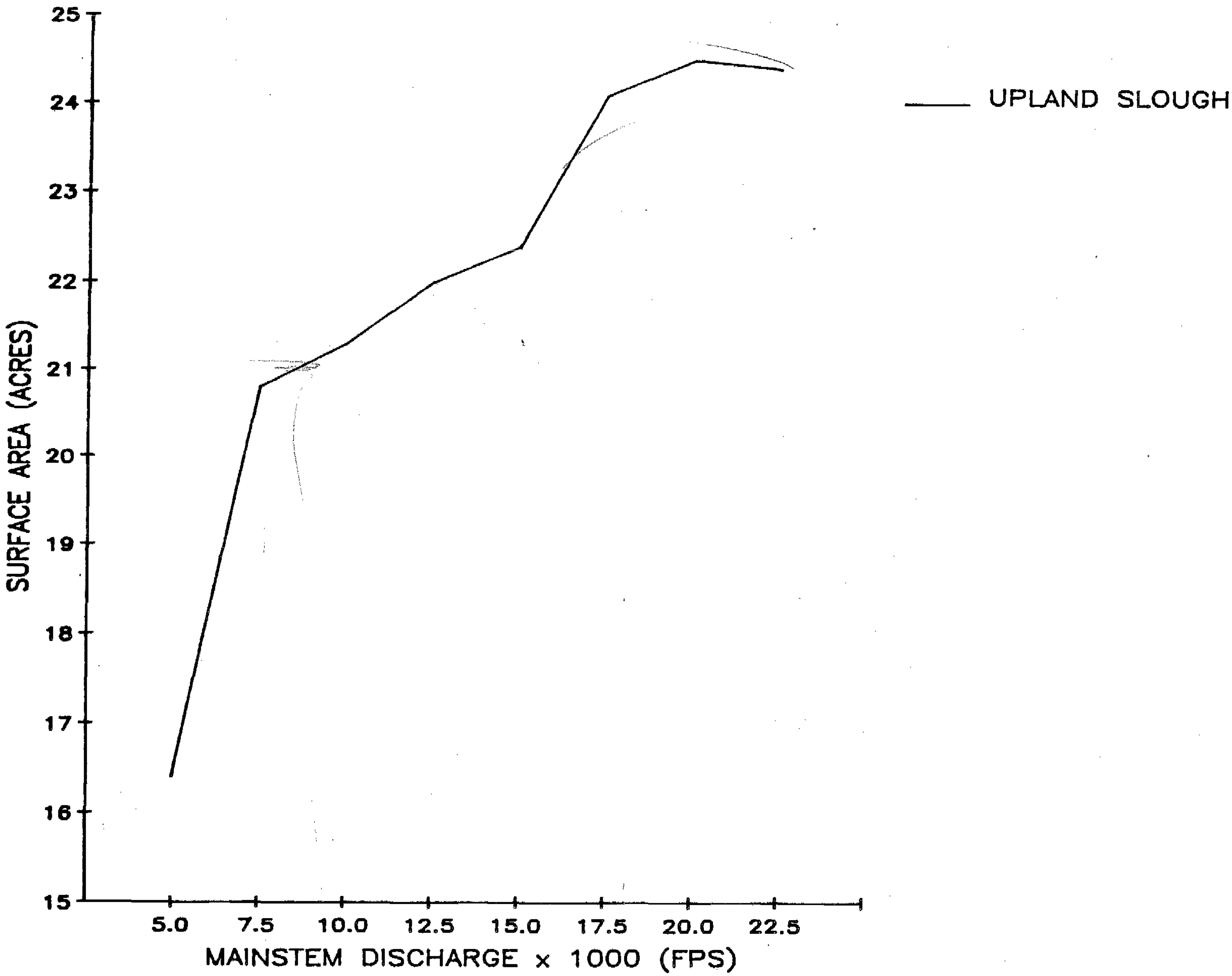


Figure IV-8. Habitat availability for juvenile sockeye salmon based on surface area response of important habitat types.

Coho Salmon

Adults

Susitna River coho salmon rank third in commercial value to sockeye and chum salmon. The average annual catch of Susitna River coho in the fishery for the past 31 years is 264,000 fish (Jennings 1985). Coho salmon enter the middle Susitna River during the last week of July and are numerous until the first week of September (Barrett et al. 1984, 1985). The timing of the migration appears to be relatively consistent from year to year with peak migration occurring between August 1 and August 16 (Barrett et al. 1984, 1985). Spawning activity begins in late August and continues through early October (ADF&G 1981a, 1982a, Barrett et al. 1984, 1985).

Most of the coho salmon entering the Susitna River spawn in tributaries downstream of RM 80 (Barrett et al. 1985) and relatively few spawn in the middle Susitna River. An average of 5,700 adult coho passed the Talkeetna Station (RM 103) annually, while 1,600 coho passed the Curry Station (RM 120) (Table IV-2).

Spawning ground surveys indicate these escapements overestimate the number of fish spawning in the middle Susitna River. In 1984, an estimated 75 percent of the adult coho escapement to Talkeetna Station could not be accounted for on the spawning grounds and may have returned downriver to spawn. Based on this estimate of milling, 2,950 coho spawned in the middle Susitna River in 1984 which represents less than 2 percent of the 1984 coho escapement to the Susitna River (Barrett et al. 1985).

Habitat Utilization. In the middle Susitna River, coho salmon spawn principally in tributaries. Twelve tributaries in the middle river supported spawning (Table IV-4). Tributary spawning occurs during the third week of September to the 2nd week of October. The most important tributaries for coho spawning are Gash Creek (RM 111.6), Indian River (RM 138.6), Whiskers Creek (RM 101.4), and Chase Creek (RM 106.9) (Barrett et al. 1984, 1985).

Table IV-4. Coho salmon peak index counts in streams upstream of RM 98.6, 1981-1984.

Stream	River Mile	1981	1982	1983	1984	Four-Year Average
Whiskers Creek	101.4	70	176	115	301	166
Chase Creek	106.9	80	36	12	239	92
Slash Creek	111.2	0	6	2	5	3
Gash Creek	111.6	141	74	19	234	117
Lane Creek	113.6	3	5	2	24	9
Lower McKenzie Creek	116.2	56	133	18	24	58
Little Portage Creek	117.7	0	8	0	0	2
Fourth of July Creek	131.1	1	4	3	8	4
Gold Creek	136.7	0	1	0	0	0
Indian River	138.6	85	101	53	465	176
Jack Long Creek	144.5	0	1	1	6	2
Portage Creek	148.9	22	88	15	128	63
Total		458	633	240	1,434	691[1]

Source: ADF&G 1981a, 1982a; Barrett et al. 1984, 1985

[1] Four-year average of totals

Only 15 coho salmon spawned in habitats other than tributaries. The mainstem spawning sites included sites at RM 117.6, two sites between RM 114-148.2, and one site at RM 131.1 (Meyer et al. 1984; ADF&G 1982a). Coho spawned in Slough 8A in 1983 (Vincent-Lang et al. 1984a). Only one site RM 131.1 near Fourth of July Creek was used consistently. All others were used in one out of four years.

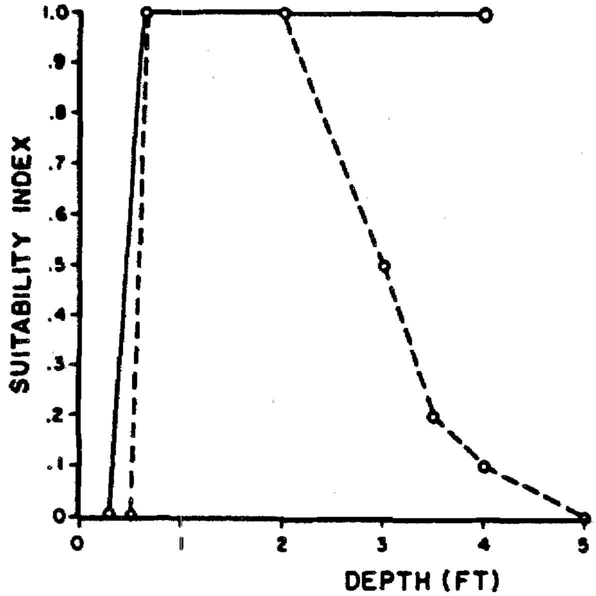
Habitat Requirements. Habitat suitability criteria were developed for spawning coho salmon in the middle Susitna River from previously published information (Figures IV-9 and IV-10). Suitability criteria developed on other Alaskan streams served as the basis for Susitna River coho criteria (Wilson et al. 1981). Criteria developed for two rivers on Kodiak were modified by biologists familiar with coho salmon in the Susitna River (Vincent-Lang et al. 1984a). Habitat requirements for spawning coho in the Susitna River included depths ranging from 0.3 to 5 ft with optimal values between 0.7 and 5.0 ft. Water velocity ranged from 0.1 fps to 4.0 fps with optimal values between 1.5 and 2.5 fps. Spawning substrates ranged in size from sand to rubble with small and large gravel provide optimal conditions (Vincent-Lang et al. 1984a).

Susitna River fish used a broader range of depth than Kodiak fish but similar velocities. They also used smaller substrates than Kodiak fish. Information reported on habitat characteristics of coho spawning areas in the Pacific Northwest are similar to Susitna values (Chambers et al. 1954, 1955, Smith 1973, Reiser and Bjornn 1979). These studies generally reported tolerance ranges narrower than those developed for Susitna River salmon.

Habitat Availability. Since habitat utilization patterns and habitat requirements differ between spawning coho and chum salmon, analyses conducted for habitat availability for spawning chum salmon are not applicable to coho salmon. The influence of mainstem flow on habitat availability is addressed using the response of surface areas of habitat types important to spawning coho.

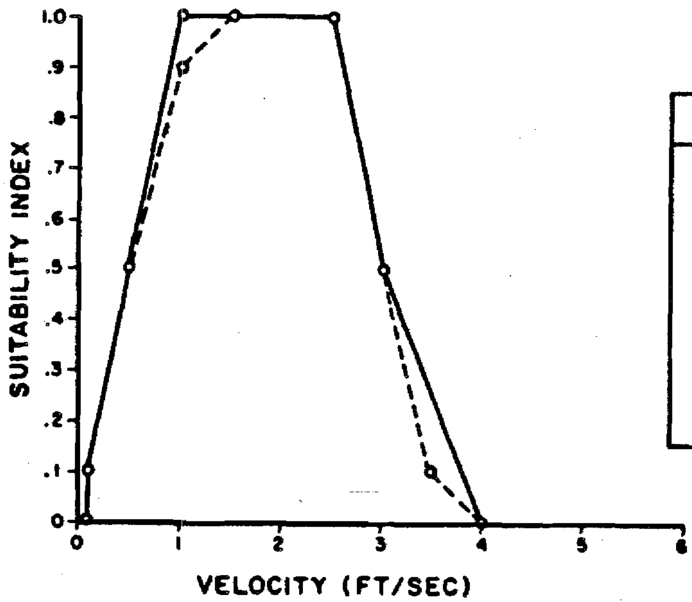
Most coho salmon spawn in tributary habitat that are not directly influenced by mainstem discharge. Some spawning occurs in tributary mouths and habitat conditions in tributary mouths can be affected by mainstem discharge.

COHO SALMON
SUITABILITY CRITERIA CURVE
DEPTH



SUITABILITY CRITERIA		
DEPTH	TERROR LAKE CRITERIA	SUSITNA CRITERIA
0.3	-	0.00
0.5	0.00	-
0.7	1.00	1.00
2.0	1.00	-
3.0	0.50	-
3.5	0.20	-
4.0	0.10	1.00
5.0	0.00	-

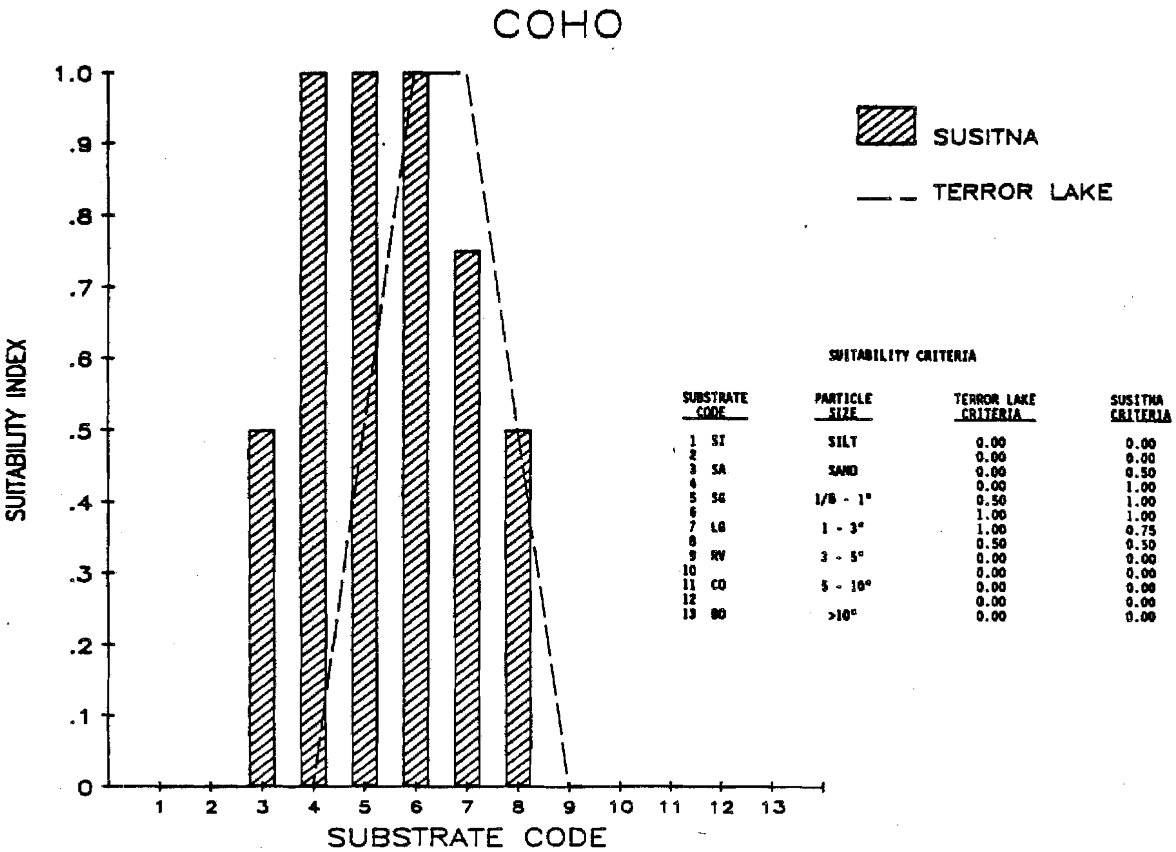
VELOCITY



SUITABILITY CRITERIA		
VELOCITY	TERROR LAKE CRITERIA	SUSITNA CRITERIA
0.06	0.00	0.00
0.10	0.10	0.10
0.50	0.50	0.50
1.00	0.90	1.00
1.50	1.00	-
2.50	1.00	1.00
3.00	0.50	0.50
3.50	0.10	-
4.00	0.00	0.00

Figure IV-9. Depth and velocity habitat requirements for spawning coho salmon in the middle Susitna River.

Source: Vincent-Lang et al. 1984a.



SUITABILITY CRITERIA

SUBSTRATE CODE		PARTICLE SIZE	TERROR LAKE CRITERIA	SUSITNA CRITERIA
1	SI	SILT	0.00	0.00
2			0.00	0.00
3	SA	SAND	0.00	0.50
4			0.00	1.00
5	SG	1/8 - 1"	0.50	1.00
6			1.00	1.00
7	LG	1 - 3"	1.00	0.75
8			0.50	0.50
9	RV	3 - 5"	0.00	0.00
10			0.00	0.00
11	CO	5 - 10"	0.00	0.00
12			0.00	0.00
13	BO	>10"	0.00	0.00

Source: Vincent-Lang et al. 1984a.

Figure IV-10. Substrate utilization by spawning coho salmon in the middle Susitna River.

Mainstem flow can affect water depth, water velocity, and areal extent of tributary mouths. Since adult coho must pass through tributary mouths to gain access to upstream spawning areas, passage may indirectly affect tributary spawning. In Susitna River habitats, passage conditions into tributaries is mainly controlled by tributary flow rather than mainstem stage.

An estimate of the response of tributary mouth habitats to mainstem flow was developed from the surface area response of tributary mouth habitats (Figure IV-11). At lower mainstem discharges (5000 to 7500), tributary mouth area remains constant. Between 7500 and 12,500 tributary mouth area increases, with the most gains between 10,600 and 12,500. At flows above 12,500 tributary mouth area gradually declines with higher flows.

Juveniles

Most juvenile coho spend two years or more in freshwater before outmigrating to the ocean (ADF&G 1981b, 1983b, Schmidt et al. 1984). Sampling conducted by ADF&G indicate that many age 0^{+} fish leave the middle river in August to rear in downstream habitats. However, outmigration of Age 1^{+} in May and June indicate that a substantial number of juvenile coho overwinter in middle river habitats and leave the following summer (Schmidt et al. 1984).

Juvenile coho salmon are second in abundance to juvneile chinook salmon in middle Susitna River habitats (Stratton 1985). The majority of fish are and 0^{+}. Capture data indicate that age 0^{+} fish comprise approximately 90 per cent of the summer populations. The remaining 10 percent is comprised mostly of age 1^{+} fish with a few age 2^{+} fish (less than 1 percent).

Habitat Utilization. Most juvenile coho were found in tributaries, and Upland Slough 51 and 35 percent respectively (Figure IV-12). The proximity of spawning areas may influence the utilization of rearing areas. The important tributaries showing the higest densities of juvenile fish were those recieving the largest escapements: Chase Creek, Whiskers Creek, and Indian River. The only slough habitats used were downstream of tributary spawning areas: Whiskers Creek Slough and Slough 8. Important upland sloughs were sloughs 6A and 5. Neither is near spawning areas, however, both are in the lower portion

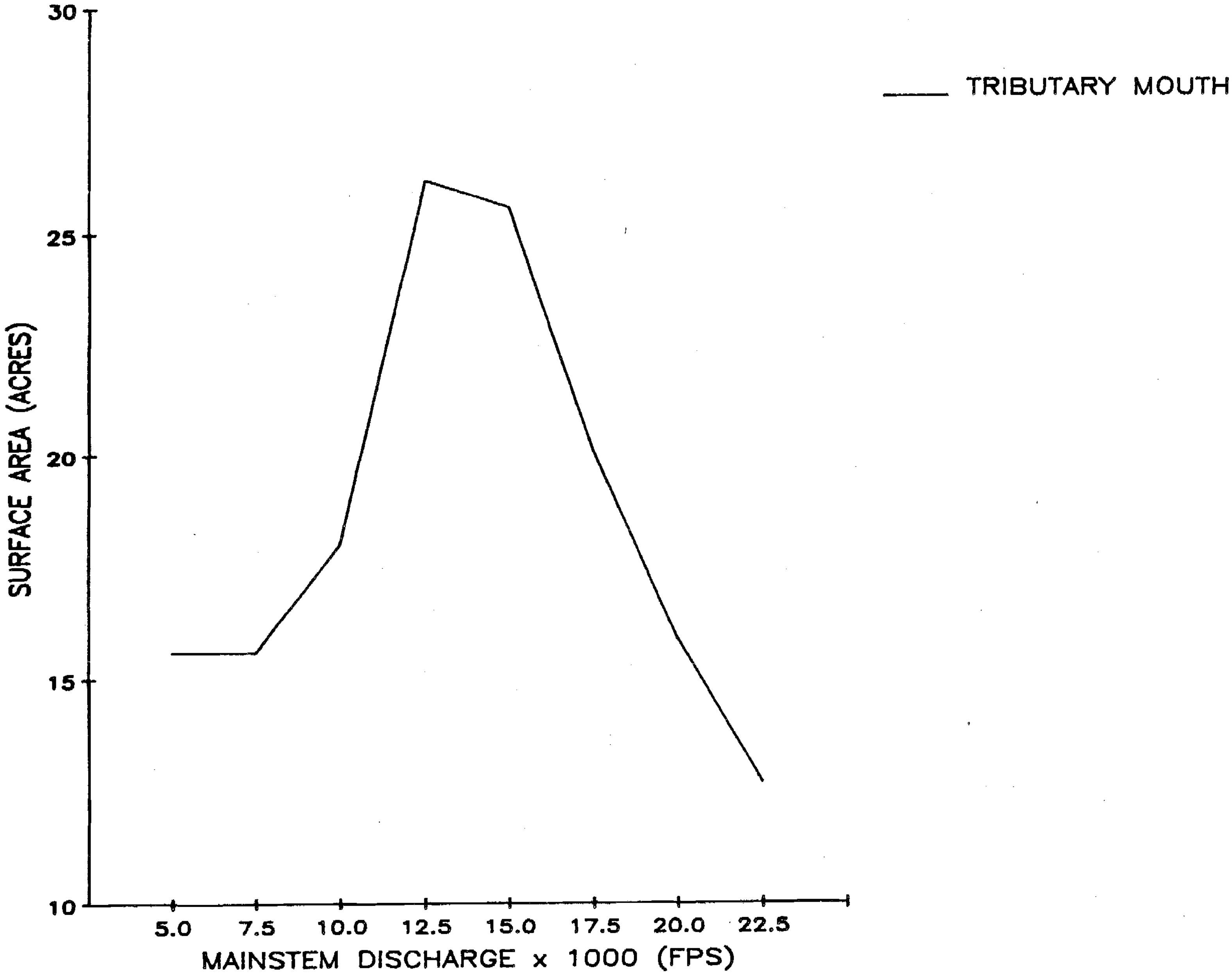


Figure IV-11. Habitat availability for spawning coho salmon based on area response of important habitat types.

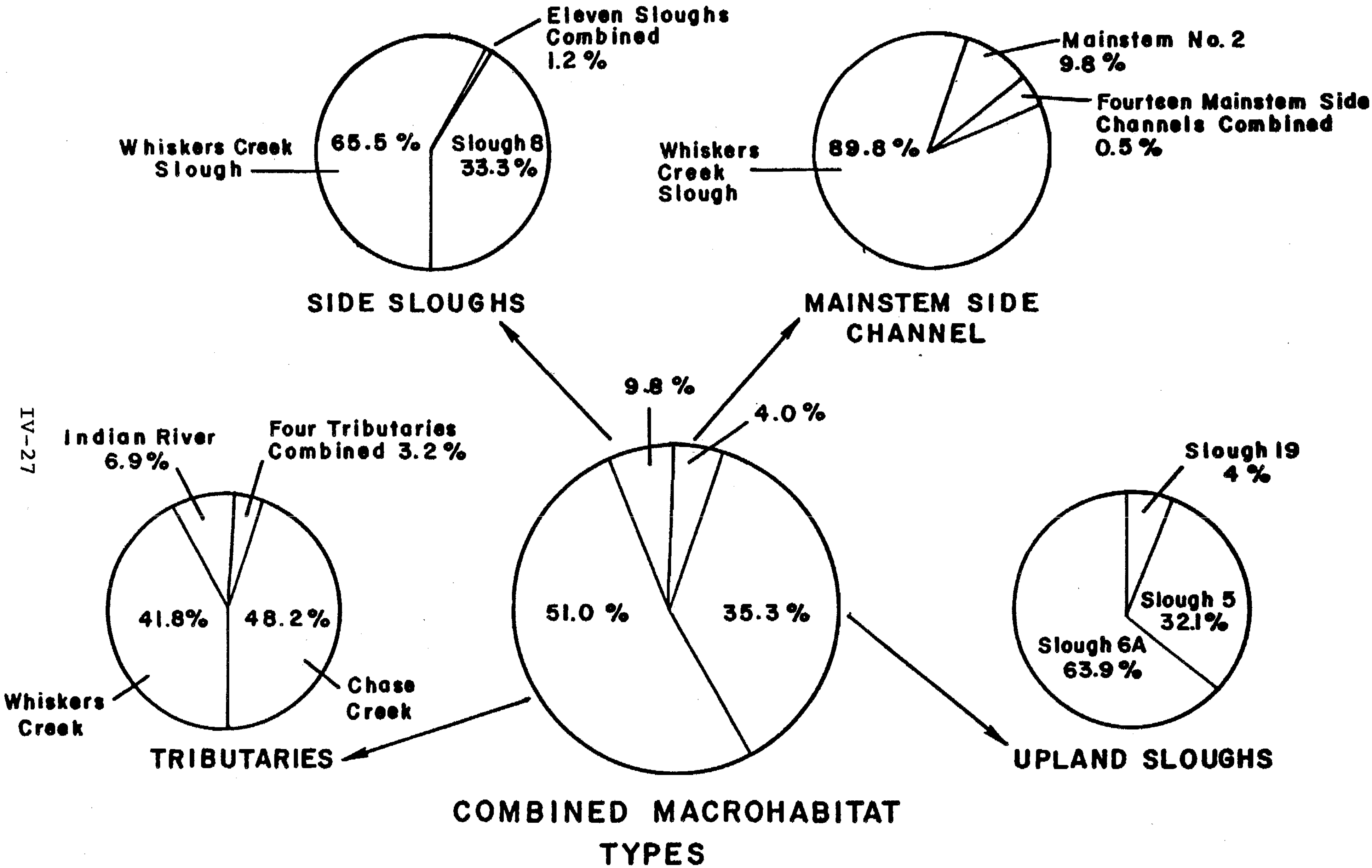


Figure IV-12. Habitat utilization by juvenile sockey salmon in the middle Susitna River.

Source: Schmidt et al. 1984

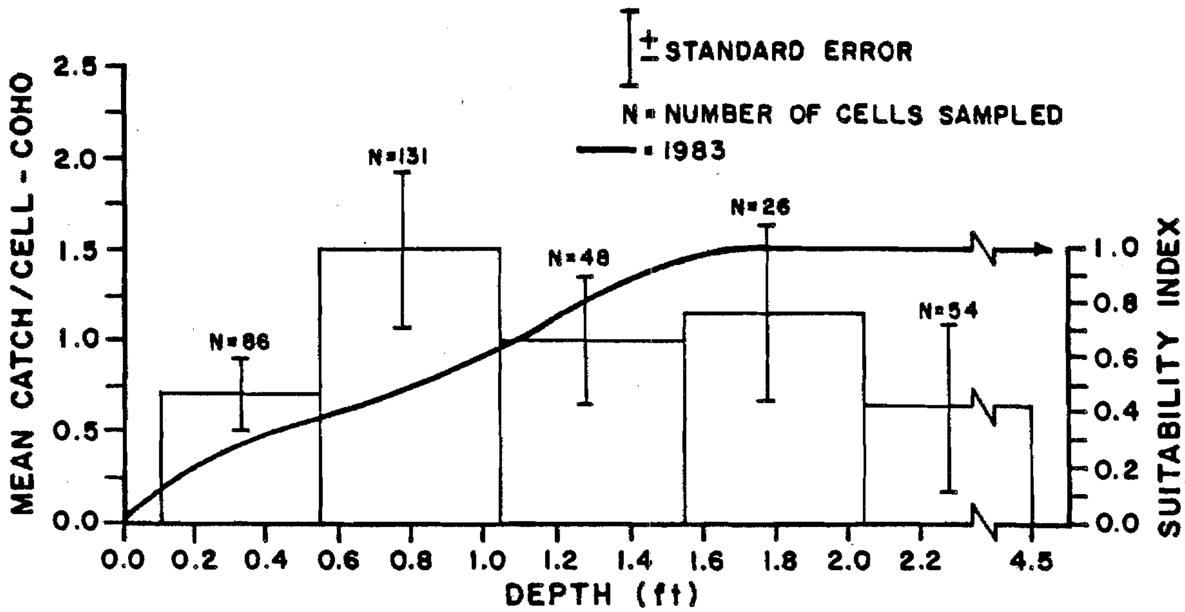
of the middle Susitna River. Fish are emigrating in these areas due to presence of suitable rearing conditions. Juvenile cohos were rarely found in side channels. Side channels appear to be used more as a corridor for redistribution rather than as a rearing area (Dugan et al. 1984).

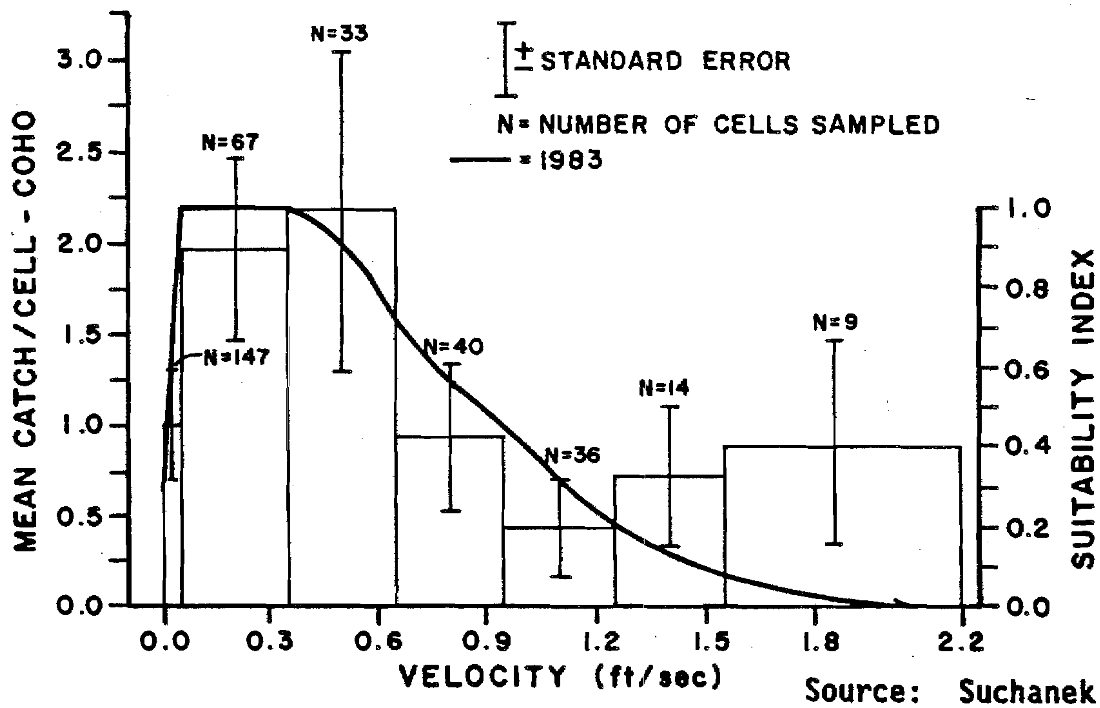
The habitat utilization changes seasonally for juvenile coho as they leave natal streams and seek rearing areas in other habitats. Juvenile coho densities were usually low and fish were widely distributed during July and August when densities peaked. Upland sloughs had higher densities of juvenile coho from late July through late September, whereas tributaries had higher densities during late June. Side slough densities of juvenile coho were higher during July and August. Overall, tributaries had the highest densities of rearing juveniles.

Many juvenile coho overwinter in middle Susitna River habitats. During winter juvenile coho were most abundant in Whiskers Creek Side Slough, and Upland Slough 6A during 1981 to 1983. In the winter of 1984-85, juvenile coho were most abundant in the Indian River and Slough 10. A few juveniles were also captured in sloughs 9A and 22.

There appears to be a relationship between juvenile coho outmigration and mainstem discharge (Roth and Stratton 1984). The outmigration rate of age 0+ cohos was higher in May through early July in 1984 than for the same period in 1983. This difference may have been caused by higher tributary streamflows in 1984 accelerating outmigration from tributary habitats (Roth and Stratton 1984).

Habitat Requirements. The habitat requirements for three physical variables were evaluated for juvenile coho salmon. Depth, velocity, and cover were analyzed to develop habitat suitability criteria (Figures IV-13 and IV-14). In the Susitna River, coho salmon used water depths ranging from 0.1 to 4.5 ft with depths greater than 1.6 ft being the most preferred depth. Water depths used by juvenile coho were similar to other rivers. On the Terror and Kizhuyak rivers, depths ranged from 0.5-5.0 ft with most fish found at depths between 0.5 and 2.2 ft. Bovee (1978) states that coho juveniles prefer





Source: Suchanek et al. 1985

Figure IV-13. Depth and velocity requirements for juvenile sockeye salmon in the Susitna River.

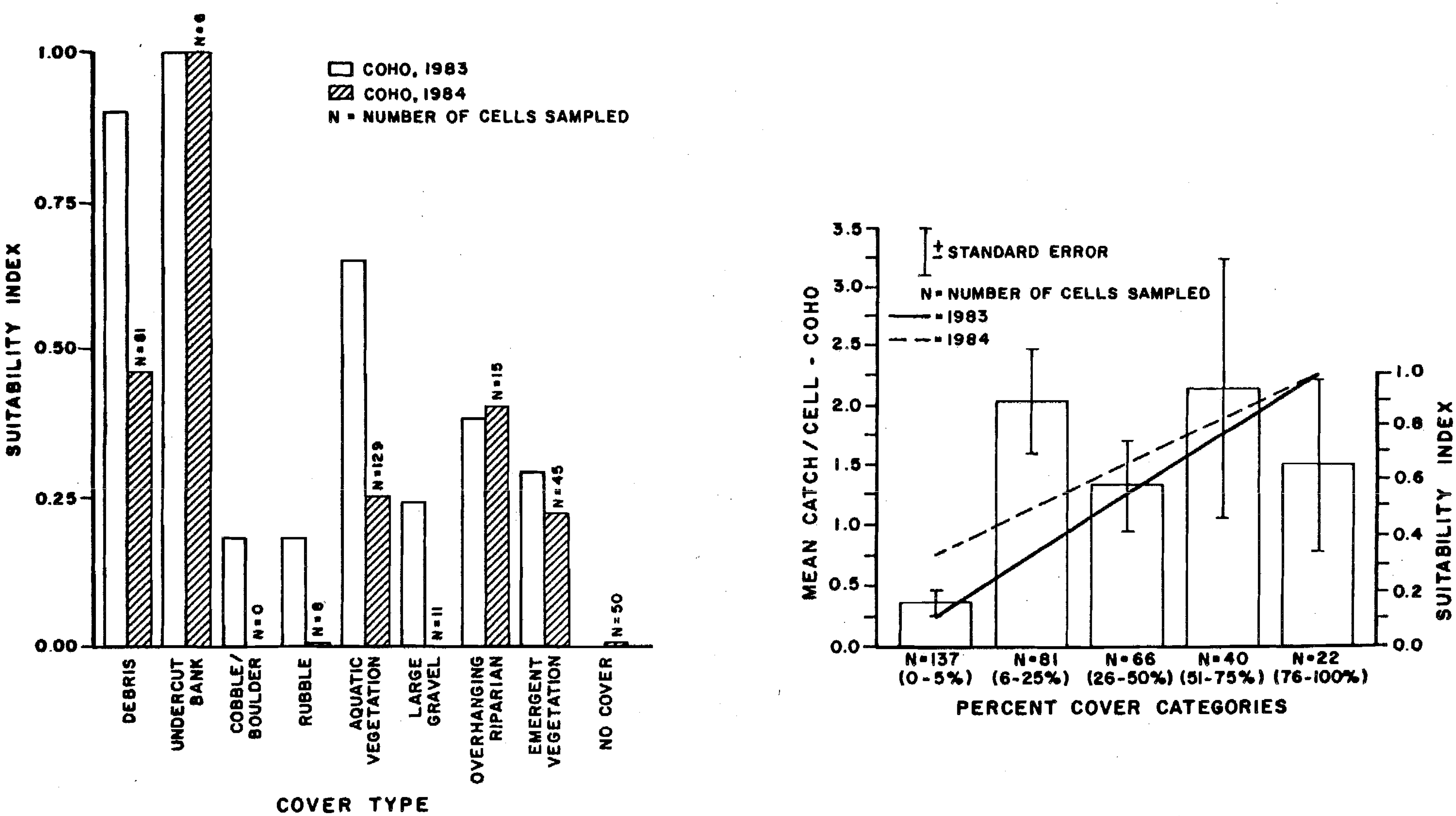


Figure IV-14. Cover suitabilities for juvenile sockeye salmon in the Susitna River.

Source: Suchanek et al. 1985

similar water depths ranging from 1.0 to 5.0 ft with the preferred depth at 2.0 ft.

Suitabilities assigned to water velocities were also similar to those in other rivers. In the middle Susitna River, suitable water velocities ranged from 0.1 to 3.0 fps with optimal velocities 0.1 and 0.3 fps. In the Terror and Kizhuyak rivers, water velocities utilized by coho salmon ranged from 0.0 to 3.5 fps with most fish found between 0.0 and 0.5 fps (Wilson et al. 1981). Suitable velocities presented by Bovee (1978) ranged from 0.0 to 2.5 fps with 0.5 fps most preferred.

Coho utilized cover types ranging from debris to various sizes of substrate to vegetation, with the highest preference for debris, undercut banks, and cobble (Schmidt et al. 1985).

Winter habitat characteristics are described for several overwintering sites. In general, these were characterized by a range in depth from 0.3 to 5.0 ft and range in water velocity from 0.0 to 0.6 fps. Cover and percent were variable.

The food habits of rearing juveniles were examined in 1978 and 1982. The dominant and most preferred food item was chironomids. Other food items eaten were other dipterans, and mayfly and stonefly nymphs. In 1978, stomach analyses showed that aquatic insect larvae were common in the spring, whereas adult insects were more common during the summer and fall. Coho have also been reported to feed on pink, chum, and sockeye juveniles when abundant (Scott and Crossman 1983).

<u>Habitat Availability</u>. Although juvenile coho salmon generally have habitat requirements similar to chinook in clear water, coho salmon depend on different habitat types. Juvenile coho salmon are associated predominantly with tributary, tributary mouth and upland slough habitats. Of these habitats, mainstem discharge influences conditions in tributary mouths and to a lesser extent, upland sloughs. Habitat availability as a function of mainstem discharge was evaluated using surface area response for the habitat types (Figure IV-15).

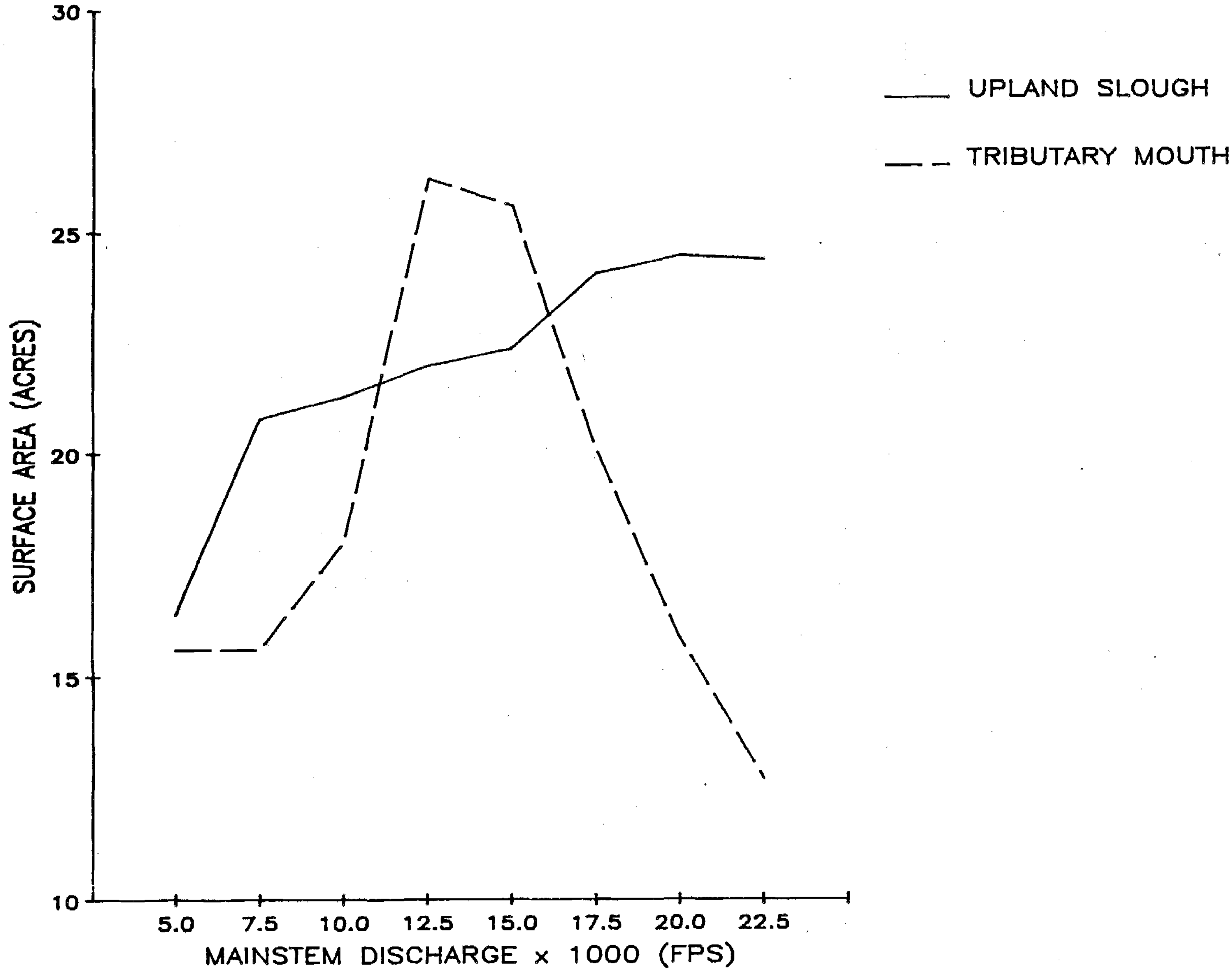


Figure IV-15. Habitat availability for juvenile coho salmon based on surface area response of important habitat types.

Pink Salmon

Adults

Susitna River pink salmon rank last in commercial value compared to the other salmon in the River. The average annual odd-year harvest in the past 31 years is 120,416 fish and the even-year harvest is 1,576,646. Pink salmon move into the middle river and spawn in the tributaries during the first three weeks of August. The timing of the migration is relatively consistent from year to year with the peak migration occurring between the last week of July and the second week of August.

In the Susitna River, the dominant year class for pink salmon is the even-year run (Table IV-2). The minimum even-year run averaged 1,138,400 fish annually during 1982 and 1984, whereas the minimum odd-year escapement averaged 93,400 fish annually (Barrett et al. 1984, 1985). Most of the pink salmon entering the Susitna River spawn in the lower river, downstream of the Chulitna River confluence (Barrett et al. 1984, 1985). Based on 1984 results, the pink salmon that spawned in habitats associated with the middle Susitna River comprised less than one percent of the total Susitna Basin escapement (Jennings 1985).

The pink salmon escapement to Talkeetna Station averaged 5,900 fish annually during odd-years (1981, 1983). Even-year escapements to Talkeetna Station were 177,900 fish in 1982 and 10,950 fish in 1984 (Barrett et al. 1984, 1985). The pink salmon escapement to Curry Station averaged 3,300 fish during odd years and 87,000 during even years (Barrett et al. 1984, 1985).

Similar to the sockeye and coho escapements, a portion of the pink salmon escapement to Talkeetna and Curry stations is comprised of milling fish that return downstream to spawn. In 1984, about 85 percent of the pink salmon escapement to Talkeetna Station was unaccounted for on the spawning grounds and may have returned downstream to spawn (Barrett et al. 1985).

Habitat Utilization. In the middle Susitna River, most pink salmon spawn in tributaries. The most important spawning streams are Indian River, Portage

Creek, Fourth of July Creek and Lane Creek for both even and odd runs (Table IV-5). Most of the spawning activity in tributaries occurs in the second week of August and continues through the first week of September (Barrett et al. 1984, 1985).

Although the majority of pink salmon spawn in tributaries, sloughs are also used for spawning. Even-year pink salmon spawn in sloughs more than odd-year pink salmon. The three most important sloughs were 8A, 11, and 20. Sloughs that supported fewer spawning fish, were 3A, 3B, 5, 8, Bushrod, 8A, Moose, 9, 9B, and 21. The spawning areas within sloughs 8A, 9, 11, 20, and 21 had tributary-like characteristics such as shallow riffles and gravel/rubble/cobble substrates. Most of the spawning activity in the sloughs occurred during the month of August and the first week of September (ADF&G 1981, 1982, Barrett et al. 1984, 1985).

<u>Habitat Requirements</u>. Habitat requirements for spawning pink salmon in the middle Susitna River. Suitability criteria developed from the Terror and Kizhuyak rivers (Wilson et al. 1981) were modified by biologists familiar with pink salmon in the Susitna River (Figures IV-16 and IV-17). The most preferred water depths were 1.0 to 2.3 ft. The preferred water velocities ranged from 1 to 2 fps, and preferred substrates ranged from 1 to 3 inches in diameter. These preferred depths, water velocities, and substrates are well within the ranges noted for pink salmon from other parts of Alaska and Washington (Collings 1974, Graybill et al. 1979, Wilson et al. 1981, Estes and Kepler 1981).

<u>Habitat Availability</u>. (will be provided later) (Figure IV-18 will be provided later)

<u>Juveniles</u>

The life history pattern for pink salmon fry is to outmigrate to the ocean soon after emergence. Outmigration usually occurs during spring break-up (end of May and early June) accompanied by ice and high discharge levels.

There has been no estimation of the size of the fry population in the middle Susitna River. Outmigrant traps collected six fry in 1982, 245 fry in 1983

Table IV-5. Pink salmon peak index counts in the middle Susitna River, 1981-1984.

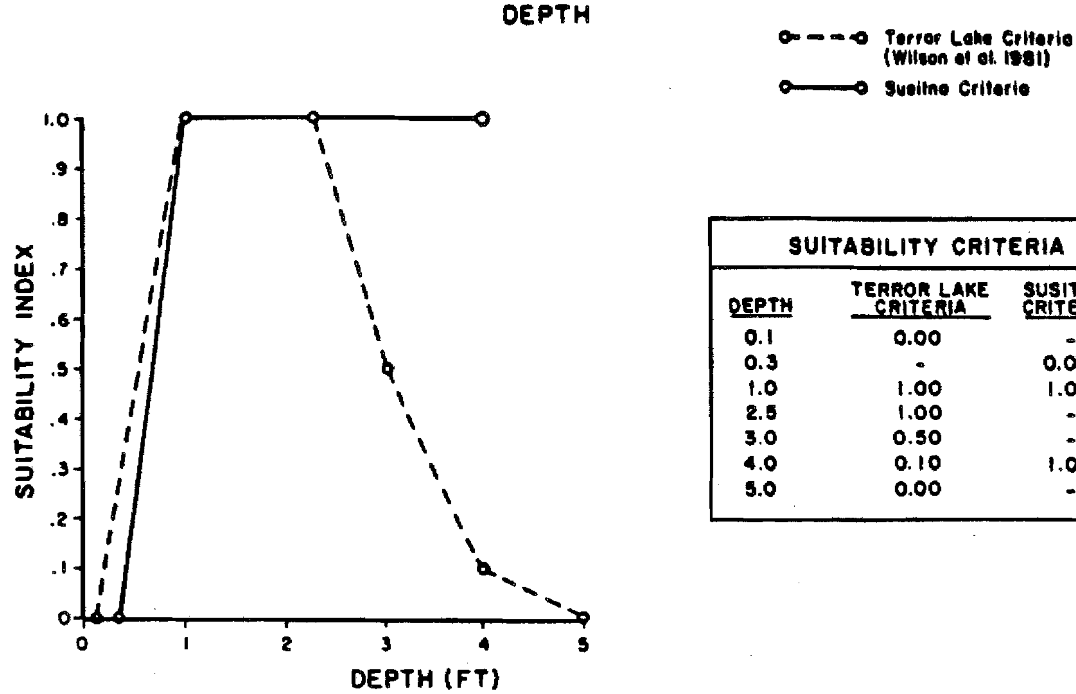
Stream	River Mile	1981	1982	1983	1984	Odd-Year Average	Even-Year Average
Whiskers Creek	101.4	1	138	0	293	1	216
Chase Creek	106.9	38	107	6	438	22	273
Slash Creek	111.2	0	0	0	3	0	2
Gash Creek	111.6	0	0	0	6	0	3
Lane Creek	113.6	291	640	28	1,184	160	912
Clyde Creek	113.8	0	0	0	34	0	17
Maggot Creek	115.6	0	0	0	107	0	54
Lower McKenzie Cr.	116.2	0	23	17	585	9	304
McKenzie Creek	116.7	0	17	0	11	0	14
Little Portage Cr.	117.7	0	140	7	162	4	151
Fromunda Creek	119.3	0	0	0	40	0	20
Downunda Creek	119.4	0	0	0	6	0	3
Deadhorse Creek	120.8	0	0	0	337	0	169
Tulip Creek	120.9	0	0	0	8	0	4
Fifth of July Cr.	123.7	2	113	9	411	6	262
Skull Creek	124.7	8	12	1	121	5	67
Sherman Creek	130.8	6	24	0	48	3	36
Fourth of July Cr.	131.1	29	702	78	1,842	54	1,272
Gold Creek	136.7	0	11	7	82	4	47
Indian River	138.6	2	738	886	9,066	444	4,902
Jack Long Creek	144.5	1	21	5	14	3	18
Portage Creek	148.9	0	169	285	2,707	143	1,438
Total		378	2,855	1,329	17,505	854[1]	10,180[2]

Source: Barrett et al. 1984, 1985

[1] Odd-year average of totals

[2] Even-year average of totals

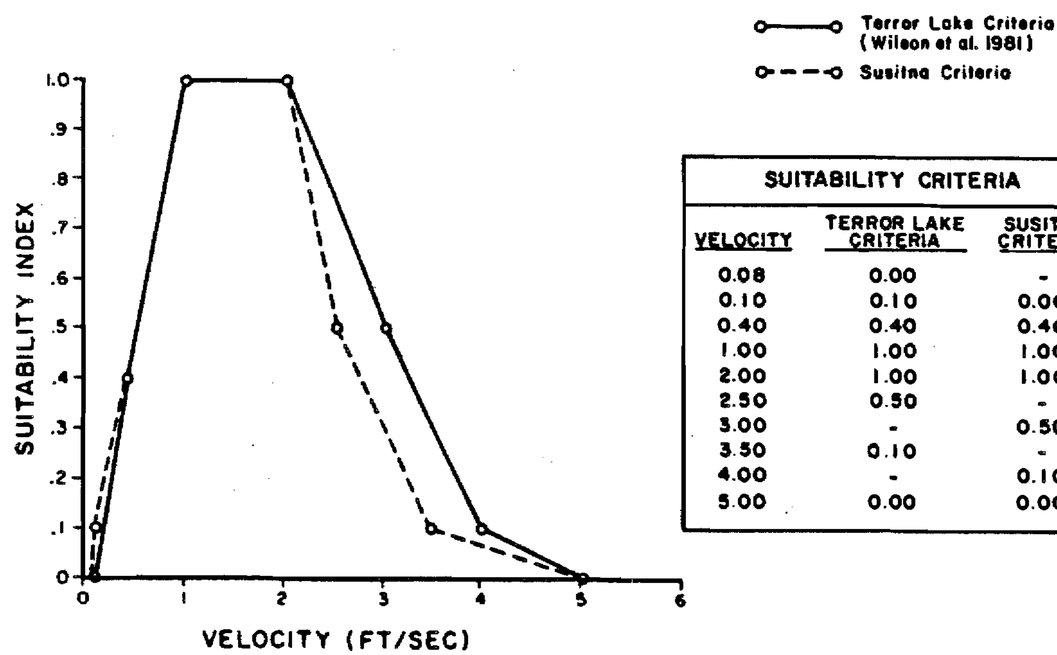
PINK SALMON
SUITABILITY CRITERIA CURVE
DEPTH



SUITABILITY CRITERIA

DEPTH	TERROR LAKE CRITERIA	SUSITNA CRITERIA
0.1	0.00	-
0.3	-	0.00
1.0	1.00	1.00
2.5	1.00	-
3.0	0.50	-
4.0	0.10	1.00
5.0	0.00	-

VELOCITY

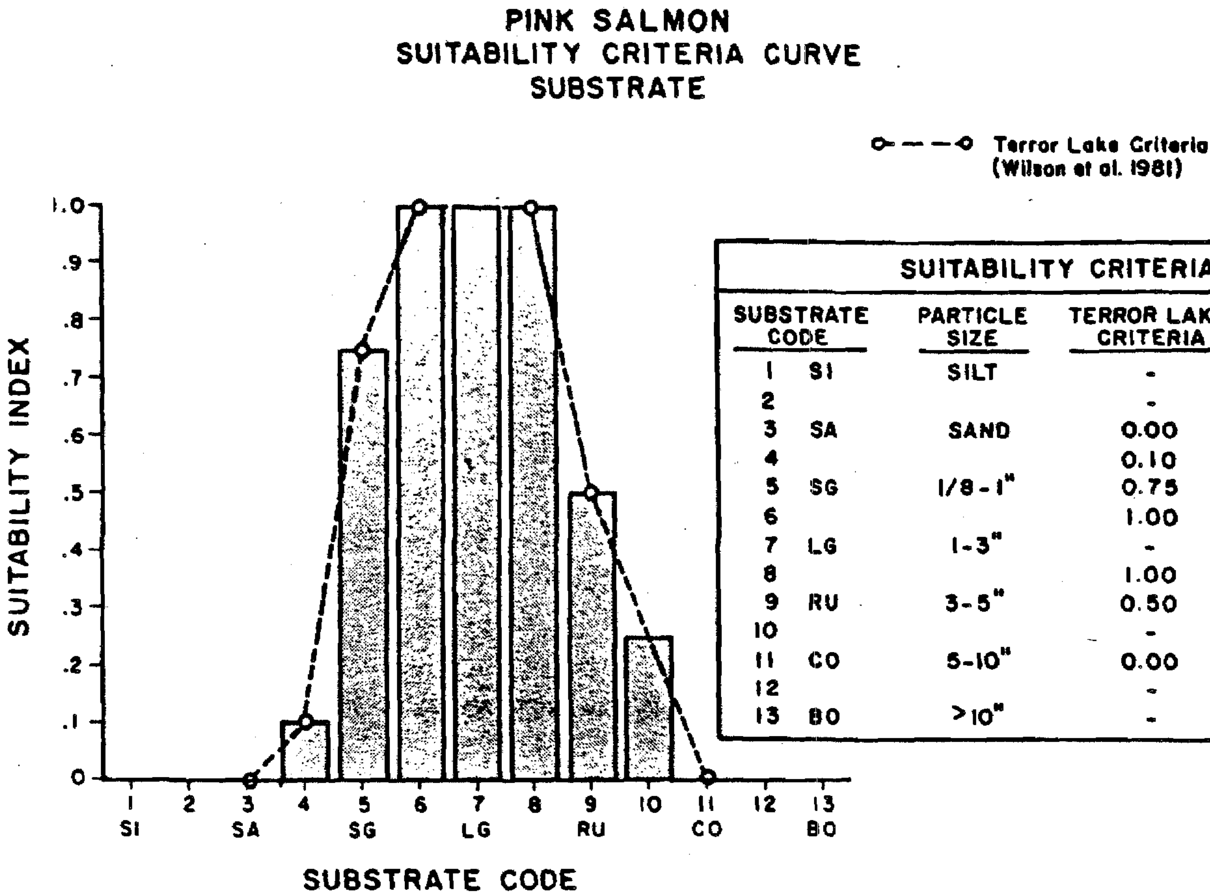


SUITABILITY CRITERIA

VELOCITY	TERROR LAKE CRITERIA	SUSITNA CRITERIA
0.08	0.00	-
0.10	0.10	0.00
0.40	0.40	0.40
1.00	1.00	1.00
2.00	1.00	1.00
2.50	0.50	-
3.00	-	0.50
3.50	0.10	-
4.00	-	0.10
5.00	0.00	0.00

Figure IV-16. Depth and velocity habitat requirements for spawning coho in the middle Susitna River.

Source: Vincent-Lang et al. 1984a.



SUITABILITY CRITERIA

SUBSTRATE CODE		PARTICLE SIZE	TERROR LAKE CRITERIA	SUSITNA CRITERIA
1	SI	SILT	-	0.00
2			-	0.00
3	SA	SAND	0.00	0.00
4			0.10	0.10
5	SG	1/8 - 1"	0.75	0.75
6			1.00	1.00
7	LG	1-3"	-	1.00
8			1.00	1.00
9	RU	3-5"	0.50	0.50
10			-	0.25
11	CO	5-10"	0.00	0.00
12			-	0.00
13	BO	>10"	-	0.00

Figure IV-17. Substrate utilization by spawning pink salmon in the middle Susitna River.

Source: Vincent-Lang et al. 1984a.

(will be provided later)

Figure IV-18. Habitat availability for spawning pink salmon based on area response of important habitat types.

and 68 fry in 1984 (ADF&G 1983, Schmidt et al. 1984, 1985). The number of even-year pink adults is thought to be about 10 times greater than the odd-year escapement based on the spawning escapement. Therefore, the outmigration of fry is larger during odd years.

Habitat Utilization. (will be provided later)

Habitat Requirements. Pink salmon fry outmigrate to the ocean soon after emergence and little, if any, freshwater rearing occurs. Discharge is thought to influence outmigration. Higher catches of pink fry have been directly correlated with higher discharges (Schmidt et al. 1984). The peak of the outmigration of pink salmon fry occurred during June in 1983 and 1984 (Schmidt et al. 1984, 1985).

ADD REQUIREMENTS RELATED TO OUTMIGRATION

Habitat Availability. The outmigration of pink salmon fry almost immediately after emergence results in little habitat utilization. Thus, surface area response curves are not applicable to the evaluation of the pink salmon fry.

Rainbow Trout

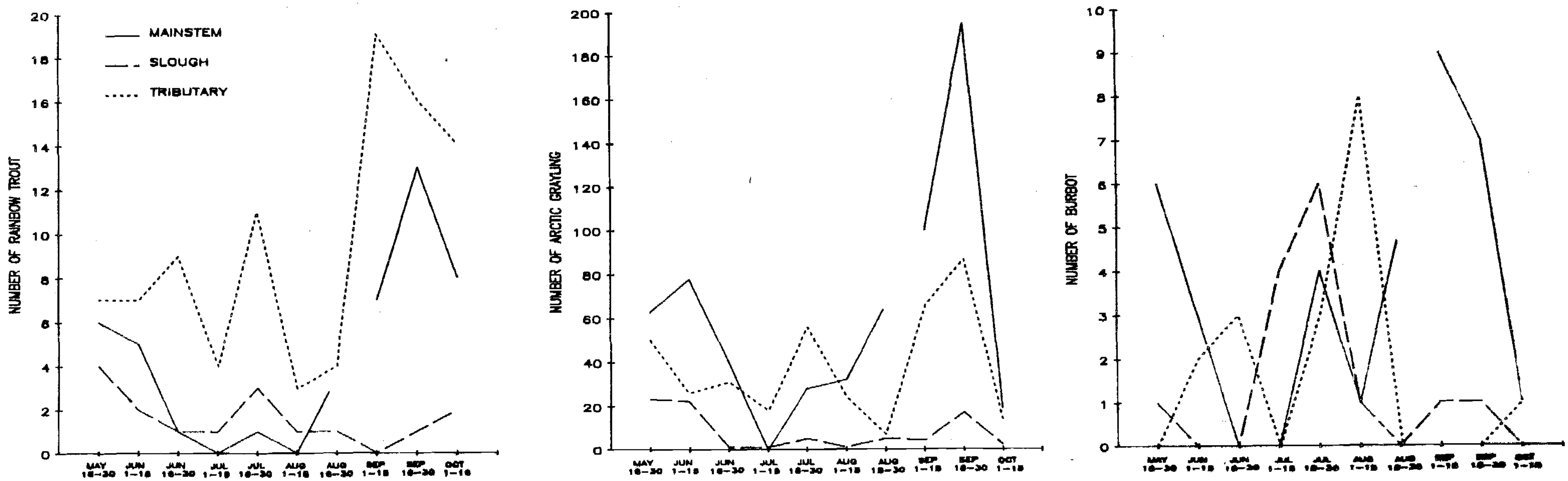
Adults

The size of the adult population of rainbow trout in the middle Susitna River was approximated as 4,000 fish using 1981-1983 data (Schmidt et al. 1984). (Sundet and Wenger 1984). Within this reach of river, recaptures of tagged fish have been sufficient to estimate the population size of rainbow trout in only one tributary, Fourth of July Creek where Sundet and Wenger (1984) reported a population of approximately 100 rainbow trout. In 1983, approximately 10 rainbow trout were estimated to reside in Fourth of July Creek (between TRM 0.0 and 0.8, below the falls). The size of the population in the middle Susitna River is relatively small. The main reason for the low population is probably due to the lack of spawning areas (Schmidt et al. 1984). Also, survival rates are relatively low especially in the wintertime due to a lack of suitable overwintering habitat. The sport fishing pressure at tributary mouths in the fall also contributes to the low population of rainbow trout (ADF&G 1983c, Schmidt et al. 1984).

Habitat Utilization. The distribution of adult rainbow trout were grouped into major categories according to season and life history activity. These categories were spawning, rearing, transition, and overwintering (Sundet and Pecheck 1985). The distribution of rainbow trout in 1983 and 1984 was very similar (Schmidt et al. 1984, 1985). Rainbow trout occupy either the tributaries or mainstem during May through October 1983 (Figure IV-19).

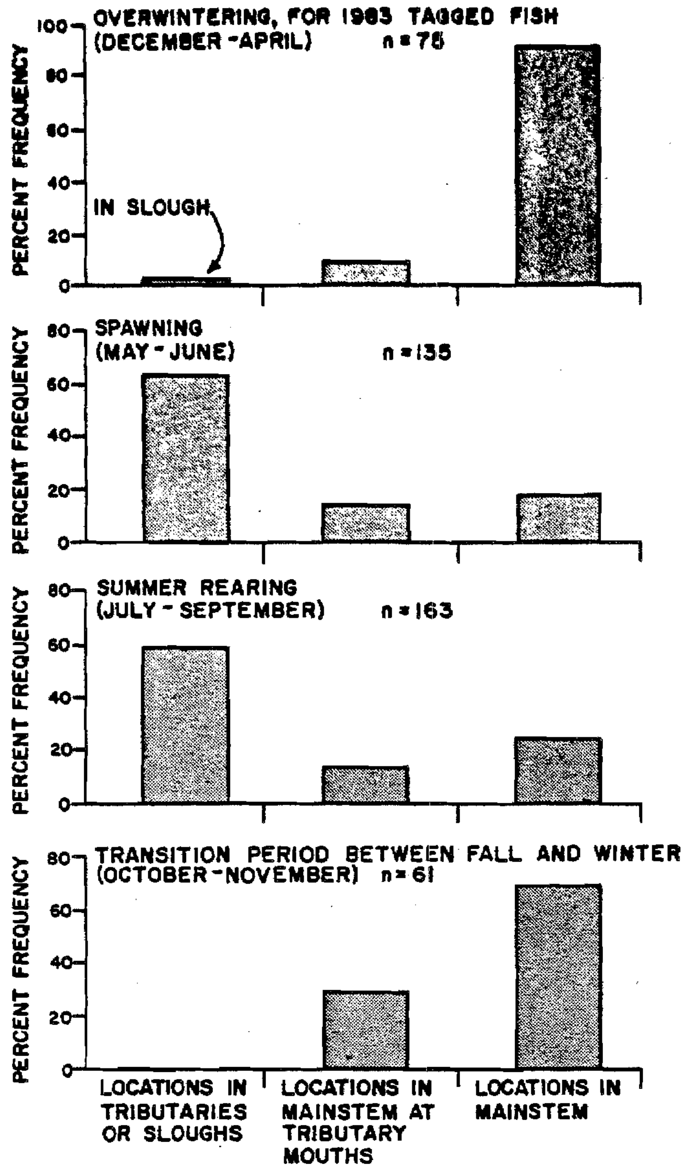
Spawning occurs primarily in tributaries during May and June (Figure IV-20). Spawning sites occur in Whiskers Creek, Lane Creek, and Fourth of July Creek. The highest catches were in Fourth of July Creek (Sundet and Wenger 1984). Less important spawning sites, in terms of abundance, included Indian River and Portage Creek.

Rainbow trout spawning in the middle Susitna River apparently occurs primarily in tributaries with connecting lakes. These tributary lake systems are within the Portage Creek drainage at TRM 2.3 and 5.21 and in the Fourth of July Creek drainage at TRM 0.7. There is little evidence of spawning in Indian River



Source: Suchanek et al. 1985

Figure IV-19. Boat electrofishing catch of rainbow trout, Arctic grayling, and burbot in major habitat types in the middle Susitna River, 1983.



Source: Sundet and Pechek 1985.

Figure IV-20. Frequency distribution of radio-tagged rainbow trout locations in the Susitna River during 1984.

although several lakes occur within Indian River drainage. It was suggested that few fish spawn in Indian River because its location borders the northern limits of the rainbow trout range and fish passage to lakes in the drainage may be too difficult (Sundet and Pechek, 1985). The timing of spawning in both portage Creek and Fourth of July Creek was in early to mid June (Sundet and Pechek 1985).

Adult rainbow trout rearing occurs July through September primarily in natal tributaries or sloughs (Figure IV-20) (Sundet and Pechek 1985). The highest catches of rainbow trout were in late July with relatively high catches also occurring during early and late September.

Different movement patterns were noted within the rearing areas. In Fourth of July Creek, most of the fish stayed between TRM 0.4 and 1.8, while the rest of the adults moved to the mouth, nearby sloughs, or into Indian River. In Portage Creek, rainbow trout moved upstream after spawning. Many of the rainbow trout that moved into tributaries to spawn, remained in the same tributary throughout the summer. Rainbow trout were found rearing in sloughs 9, 8A, A, and Moose Slough during July and September (Sundet and Pecheck 1985). Lakes in the Portage Creek and Fourth of July Creek drainages are thought to be important rearing areas for adults (Schmidt et al. 1985).

The transition period of rainbow trout movements from rearing to overwintering occurs from October to November (Figure IV-10). Rainbow trout left the mouths of tributaries and moved to the mainstem habitats. Documented mainstem sites during the transition period included RM 137.3, 138.3, 147.1, 148.0, and 150.1. Monitoring of rainbow trout movement showed that all the rainbow trout had outmigrated by October 6 and then moved slightly downstream (0.1 to 4.0 miles) before holding in overwintering areas (ADF&G 1983c, 1983f, Sundet and Wenger 1984). Thus, by December most rainbow trout had moved to overwintering areas (Sundet and Wegner 1984).

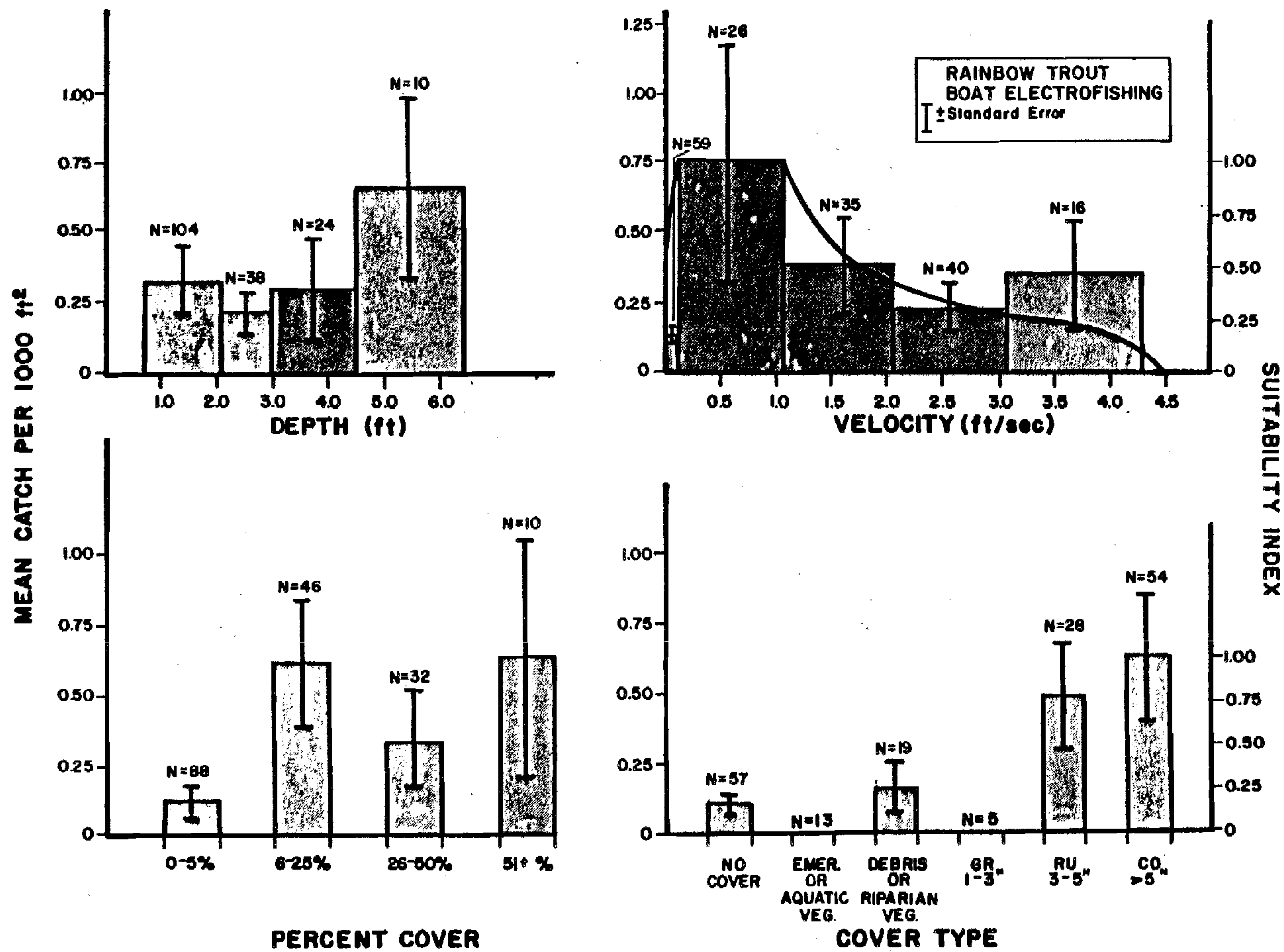
Overwintering rainbow trout were found primarily in the mainstem Susitna River from December through April (Figure IV-20). Documented mainstem areas included RM 100.7, 101.1, 111.4, 114.5, 114.8, 116.5, 131.1, 137.3, 138.3, 147.0-148.0 and 150.1. It is not known why rainbow trout utilize the mainstem during winter. During the winter of 1981-1982, several tagged rainbow trout were found holding near the tributaries Portage Creek and Fourth of July Creek where they were tagged (Schmidt et al. 1984).

Habitat Requirements. Spawning habitat measurements were taken in Portage Creek, east bank of Portage Creek, Fourth of July Creek, and a tributary of Fourth of July Creek (TRM 0.7) (Schmidt et al. 1985). Habitat characteristics included depths ranging from 1.4 to 4.5 ft, velocities ranging from 0.2 to 2.5 fps, and substrate sizes ranging primarily from small gravel to large cobble.

Temperature probably influences the migration of rainbow trout to spawning areas. The movement of adult fish into the tributaries in late May occurred at water temperatures of 6.7°C to 8.5°C. It is suspected that spawning probably occurs in lake outlets where water temperatures are warmer. Water temperatures of the outlets of several lakes within the Fourth of July Creek and Portage Creek drainages were 12°C in June (Sundet and Pechek 1985).

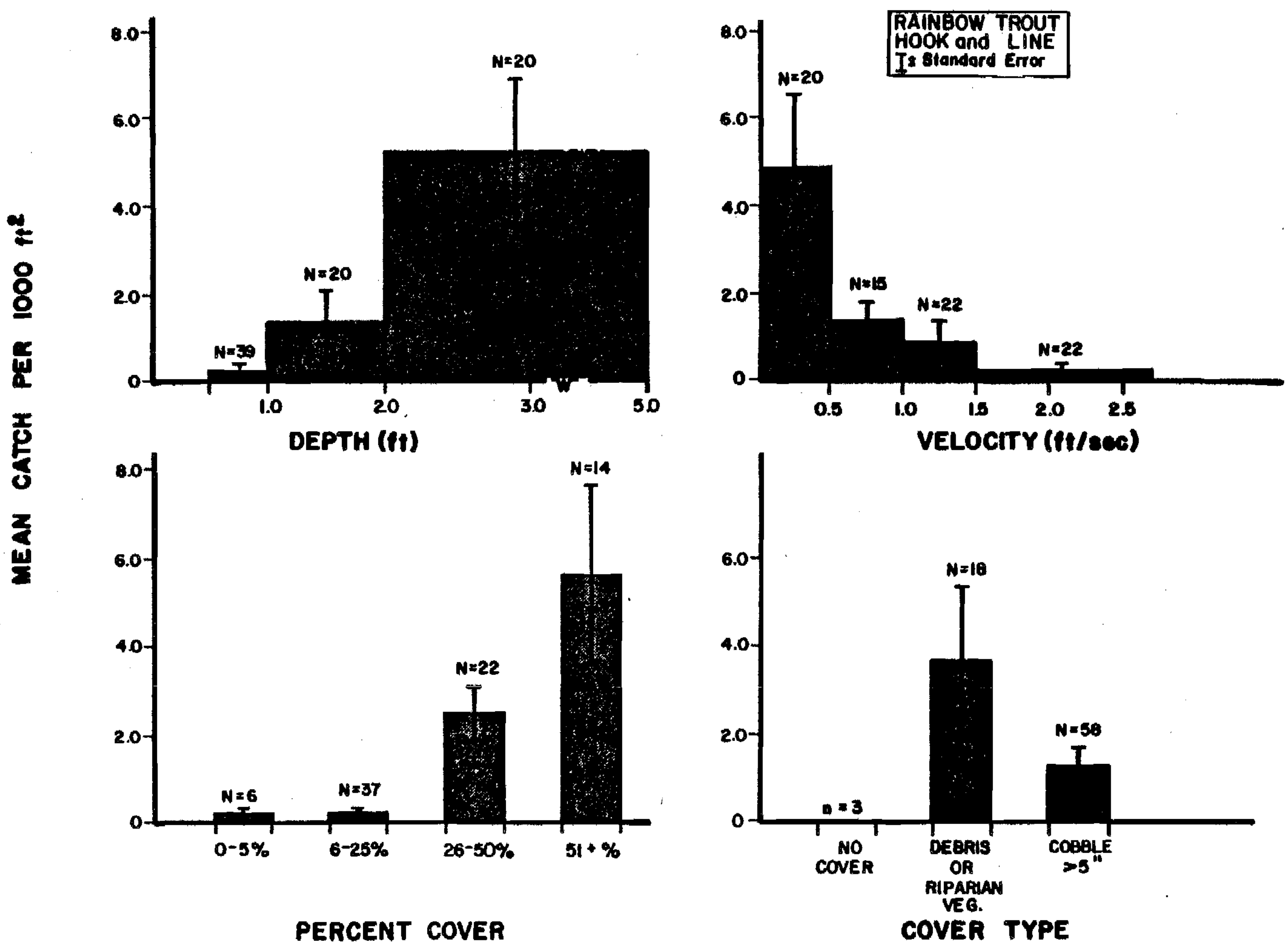
Rainbow trout suitability criteria for rearing adults were developed using depth, velocity, cover type, and percent cover (Figures IV-21 and IV-22). Typical habitats included the following characteristics (Suchanek et al. 1984). Fish caught by electrofishing preferred water depths of 4.5 to 6.5 ft and water velocities less than 1.5 fps. Preferred cover types were rocks with diameters greater than 3 inches followed by debris and overhanging riparian vegetation. Rainbow trout caught with hook and line were found in depths greater than 2 ft and in velocities less than 0.5 fps. Rainbow trout used debris, banks, and vegetation more for cover than the larger substrates. Adult rainbow trout were also found to avoid turbid water (Suchanek et al. 1984).

Rainbow trout suitability indices (for depth, velocity, and substrate) in the middle Susitna River were similar to suitability indices described by Raleigh et al. (1984). Water depths ranged from 0 to 10 ft with preferred depths between 0.8 and 1.6 ft. Water velocities ranged from 0.0 to 3.00 fps with preferred velocities at 0.00 fps. Substrate types ranged from detritus to boulders with preferred substrates 2.5 to 9.8 inches in diameter.



Source: Suchanek et al. 1985

Figure IV-21. Depth, velocity, and cover habitat requirements for rainbow trout captured by electrofishing in the middle Susitna River.



Source: Suchanek et al. 1985

Figure IV-22. Depth, velocity, and cover habitat requirements for rainbow trout captured by hook and line in the middle Susitna River.

Winter habitat measurements were scarce due to the difficulty of sampling. Habitat characteristics associated with the mainstem overwintering sites included: depths ranging from 1.0 to 10.0 ft, velocities of 0.0 to 2.5 fps, and substrate composed predominantly of rubble and cobble (3 to 10 inches in diameter). Water temperatures ranged from 0 to 0.1^{o}C. The rainbow trout were probably associated with groundwater upwelling as conductivity ranged from 212 to 256 umhos/cm. Most of these mainstem areas had open water leads (Schmidt et al. 1985, AFD&G 1983c).

Rainbow trout movements were strongly influenced by the timing and location of a particular food source. Salmon eggs, when available, are a major food source for rainbow trout. In July, rainbow trout moved to areas of chinook spawning in Indian River and Portage Creek. Later in August they moved to areas of pink and chum spawning (Barrett et al. 1984, Sundet and Wegner 1984). The rainbow trout were found in shallower water when feeding on salmon eggs and deeper water when feeding on insects (Suchanek et al. 1984).

Habitat Availability. (will be provided later)

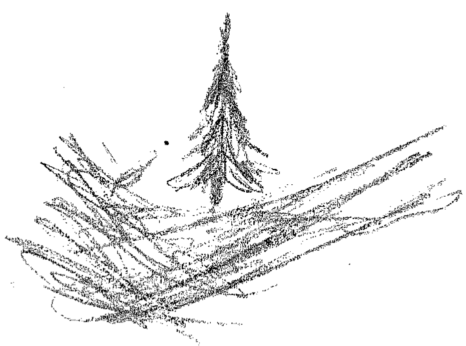
Juveniles

Catches of juvenile rainbow trout from 1981 to 1983 have been low. Sundet and Wegner (1984) suggested that either reproduction was limiting or survival was low (ADF&G 1981, 1983a). However, during 1984, 336 juvenile rainbow trout were captured in lakes connected to Fourth of July Creek and Portage Creek, indicating that reproduction and survival appears to be higher in tributary lake systems.

Habitat Utilization. Juvenile rainbow trout likely rear mainly in lakes connected to the tributaries or in the upper reaches of Portage Creek and Fourth of July Creek (Sundet and Pecheck 1985). One of the few tributaries that was found to support a juvenile rainbow trout population was Fourth of July Creek. As mentioned above, Fourth of July Creek appears to provide better rainbow trout habitat because of lakes within the drainage (Sundet and Wenger 1984). There is also a limited amount of rearing in mainstem and slough habitats of the Susitna River (ADF&G 1983a, Schmidt et al. 1984).

Habitat Requirements. Suitability indices for juvenile rainbow trout in the middle Susitna River have not been developed. However, suitability indices have been developed by Raliegh et al. (1984). Results of the analyses performed by Raliegh et al. indicate the juvenile rainbow trout utilize water depths of 0.2 to 10 ft with preferred depths between 2.0 and 10.0 ft. Water velocities ranged from 1.0 to 3.0 fps with preferred velocities from 0.00 to 0.49, and substrate types ranged from detritus to boulders with preferred substrates around 9 inches in diameter.

Habitat Availability. (will be provided later)



Arctic Grayling

Adults

The abundance of Arctic grayling in the middle Susitna River was simliar in 1982 and 1983 (Sundet and Pechek 1985). The Arctic grayling is estimated to be the third most abundant resident fish in the middle river (not counting sticklebacks or sculpins). Only longnose sucker and round whitefish are more abundant. In 1982, the population was estimated to be between 4,783 and 28,192 fish and in 1983, the population was estimated to be between 4,070 and 15,152 fish. Population estimates in 1981 and 1984 were not made (Sundet and Pecheck 1985).

Habitat Utilization. Grayling exhibit strong seasonal migration patterns. Grayling moved from the mainstem of the middle Susitna River into the tributaries to spawn. This migration occurred during May and early June, before and immediately after the breakup of river ice (ADF&G 1983a, 1981, Sundet and Wenger 1984). The tributaries used for spawning during 1981 to 1984 include Indian River, Portage Creek, Whiskers Creek, Lane Creek and Fourth of July Creek. After spawning fish may remain in spawning areas or migrate further up the tributary to summer feeding areas.

The timing of spawning varies in different parts of the middle river. Grayling in tributaries below RM 125 spawned about 7-10 days earlier in May than fish above RM 125. This may have been due to warmer water temperatures in tributaries below RM 125 (Sundet and Pechek 1985).

During summer, grayling are abundant in tributaries. Tributaries of importance include those listed for spawning in 1981 to 1984. In addition, Jack Long Creek has been utilized by grayling, but not extensively (Sundet and Wenger 1984, Sundet and Pechek 1985). Grayling have been captured at the following mainstem areas: RM 137.3 to 138.3, RM 147 to 148 and RM 150.1. The mainstem at RM 150.1 has had the most abundant mainstem catches.

In August and September, fish move out of the tributaries and into the mainstem for overwintering during October to April. Almost all grayling move out of the tributaries into the mainstem by the end of September in 1983 (Sundet and Wenger 1984).

There is little known about the winter distribution of grayling in the mainstem. Besides mainstem overwintering, Portage Creek is thought to provide winter habitat. Portage Creek is characterized by many deep (20 ft) pools to harbor fish. Recent recapture data showed that overwintering may occur in the mainstem between RM 146.0 and RM 148.0, at RM 150.1, and downriver from summer tributaries (Sundet and Pechek 1985).

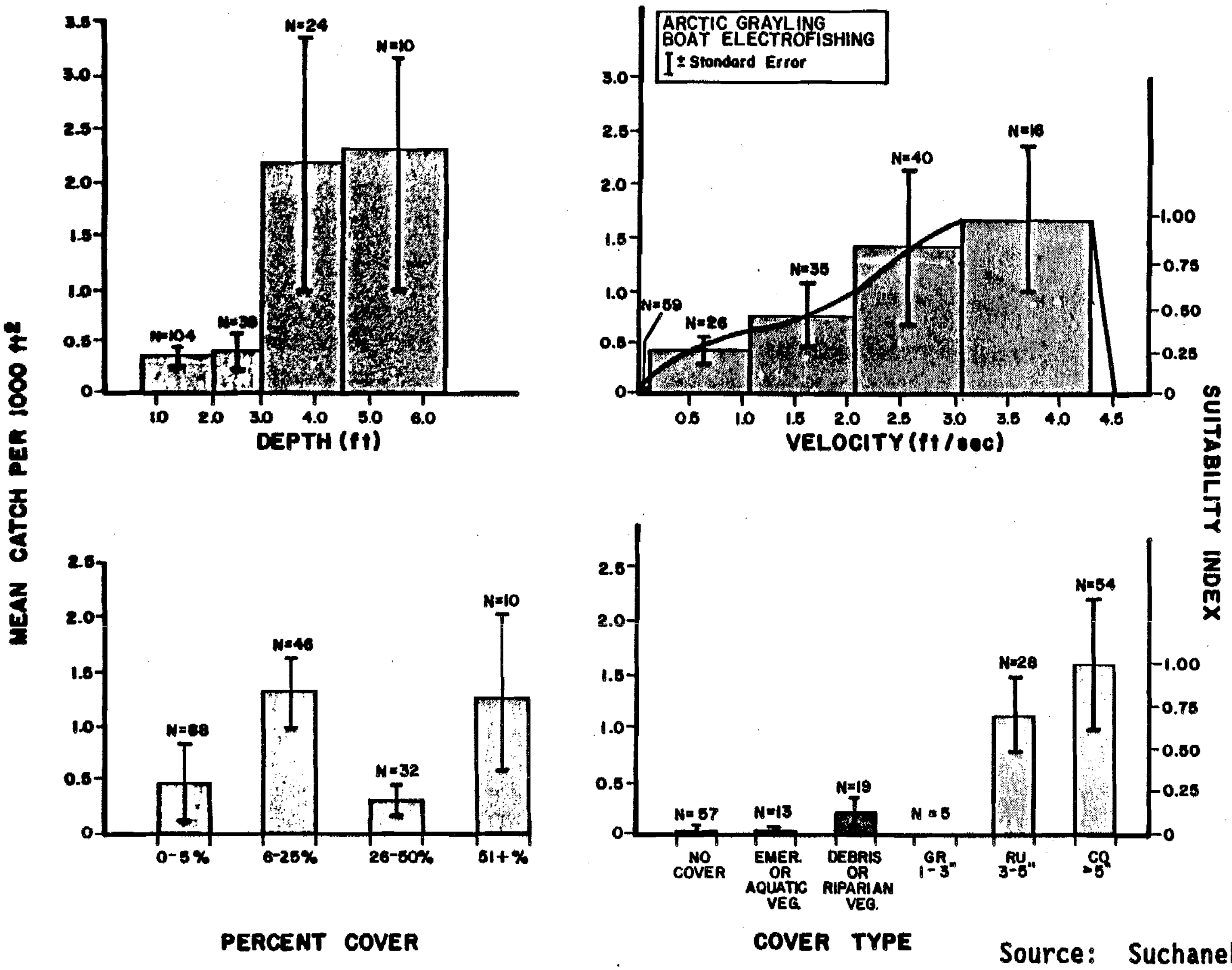
Habitat Requirements. There is little specific information on grayling spawning habitat in the middle Susitna River. In Krueger's (1981) summary of spawning habitat, fish spawned in areas with water depths varying from 0.18 to 3 ft, surface current velocities of 0.8 to 3.9 fps, and in unimbedded small gravels.

In general adults were found mainly in tributaries or mainstem areas throughout the year (Suchanek et al. 1984). Grayling utilized water depths ranging from 0.0 to 6.5 ft water velocities ranging from 0 to 4.3 fps, and substrate sizes ranging from 3 to 5 in. in diameter (Figure IV-23). Turbid areas were avoided (Suchanek et al. 1984).

Winter habitat requirements of Arctic grayling in the middle Susitna River have not been measured. However, winter habitat measurements taken near a radio-tagged grayling in the lower river included a water depth of 2.3 ft, a water velocity of 0.3 fps and a substrate size of 1 to 5 inches in diameter.

Habitat preferences for grayling in the Susitna River are similar to other studies. Hunter (1973) found grayling utilized water depths greater than 0.4 ft and substrate sizes between 0.1 to 6.0 inches in diameter. DenBeste and McCart (1984) found grayling preferred water depths of 1.9 ft, water velocities of 0.0 fps, and substrates less than 0.1 inches in diameter.

Habitat Availability. (will be provided later)



Source: Suchanek et al. 1985

Figure IV-23. Depth, velocity, and cover habitat requirements for Arctic grayling captured by electrofishing in the middle Susitna River.

Juveniles

Few juvenile Arctic grayling have been captured in the middle Susitna River. In 1983, 21 juveniles were captured, 20 were captured in mainstem side channels and one was captured in a tributary (Suchanek et al. 1984).

Habitat Utilization. Juvenile Arctic grayling exhibit a migration pattern similar to adult Arctic grayling. In the summer juveniles remained in tributaries or moved to tributary mouths until September. Juveniles (age class 2 to 4) were also captured in the mainstem during the summer. These fish may have been displaced by older, larger fish defending more favorable tributary habitat. Juveniles have also been found in the mixing zones of sloughs, tributaries or mainstem waters (ADF&G 1983a).

Beginning in September, the juveniles moved into the mainstem of the middle river to overwinter (ADF&G 1983a, Schmidt et al. 1984). Juvenile rainbow trout either move from the spawning area with the adult rainbow trout or shortly thereafter. Decreased water temperatures, discharge, and food availability probably influence the timing of migration (Krueger 1981). Specific overwintering areas for juvenile Arctic grayling have not been identified.

Habitat Requirements. Juvenile Arctic grayling showed habitat preferences for depths of 1.9 ft, water velocities of 0.0 fps and substrates less than 0.08 inches in diameter (Krueger 1981). Juvenile arctic grayling (<200 mm) may have microhabitat preferences similar to chinook salmon fry (Suchanek et al. 1984). In the upper Chena River, near Fairbanks, Alaska, juvenile Arctic grayling habitat preferences were similar to Susitna River juveniles. Arctic grayling juveniles were most abundant in water depths of 1.0 to 1.5 ft, in water velocities of 0.0 fps, and in silty substrate areas (Lee 1985).

Juvenile grayling are opportunistic feeders. Younger juveniles feed on smaller food items such as zooplankton and the older juveniles feed on immature insects (Krueger 1981). The juveniles probably hold in areas of lower current velocities then move to faster and deeper areas for increased food availability and cover.

A suitability index was developed for Arctic grayling using turbidity. Arctic grayling tended to avoid turbid water (Suchanek et al. 1984). Turbidity becomes more important when juvenile Arctic grayling are displaced to mainstem areas by the older Arctic grayling. In the mainstem, turbidity substitutes as cover for Arctic grayling (Suchanek et al. 1984).

Habitat Availability. (will be provided later)

Burbot

Adults

Burbot are found in the middle Susitna River, but are not abundant (Suchanek et al. 1984, Sundet and Wegner 1984, Sundet and Pechek 1985). In 1984, 163 burbot were captured in the middle river. A population estimate of 15 burbot (confidence interval 13 to 24) was made for the site at RM 138.9-140.0 in 1983 (Schmidt et al. 1984). The small number of burbot in the middle Susitna River have been attributed to several factors including the scarcity of food and rearing habitat.

Habitat Utilization. The burbot lives a sedentary life, except for movement to and from the spawning areas (Morrow 1980). Most movement is thought to take place in December, when the burbot migrate to the spawning grounds and in March when the burbot leave the grounds (Morrow 1980). The spawning locations of burbot spawning areas in the middle river are believed to be located in mouths of sloughs and tributaries, and in deep backwater areas influenced by groundwater upwelling (Sundet and Wenger 1984, ADF&G 1983e). During 1983, burbot were found in mainstem, sloughs, and tributary mouths from May to October (Suchanek et al. 1984). During 1984, 78 percent of the burbot were captured in mainstem Susitna sites at RM 102.5, and 147.0-148.0, and at a side channel site at RM 139.6.

Habitat Requirements. Burbot spawn in the winter from November to February (ADF&G 1981b, 1983a). Burbot spawning occurs under the ice, in water temperatures between 0.6 to 1.7°C, in water depths of 1 to 4 ft, and on substrates of sand or gravel (Morrow 1980). The water temperatures observed at the Susitna River mainstem spawning areas below RM 98.6 were between 0 and 0.7°C (Meyer et al. 1984).

Some habitat preferences of burbot in the middle Susitna River have been observed. Burbot occupy the turbid waters of the mainstem most of the year. Burbot usually avoid clearwater (Sundet and Wenger 1984, Mecum 1984). Catch data (1981-1983) showed burbot preferring low velocity waters of less than

1.5 fps, shallow water depths around 2.5 ft, and a rubble or cobble substrate (ADF&G 1981b, ADF&G 1983a, ADF&G 1983e, Suchanek et al. 1984). In the Tanana River, burbot were seldom caught in water depths less than 1.5 ft (Mecum 1984). Habitat measurements were taken in the middle Susitna River during December 1983 near a radio-tagged burbot located at RM 131.1. The site had a depth of 4 ft, a velocity of 1 to 2 fps, and a water temperature of 0.2°C.

The food preferences of Susitna burbot have not been determined (Sundet and Wenger 1984). There have been a few burbot captured near salmon spawning sites that ingested salmon eggs. However, ingestion of eggs was thought to be low. Morrow (1980) states that burbot have a strong preference for fish rather than eggs or insects.

Habitat Availability. The amount of available habitat for spawning may be a limiting factor to the middle Susitna River burbot population (Sundet and Pechek 1985).

Juveniles

There have been few juvenile burbot captured in the middle Susitna River. In 1983, only 18 juvenile burbot were captured at the juvenile anadromous habitat sites in the middle Susitna River. And in 1982, only 22 juvenile burbot were captured in the mainstem of the middle Susitna River.

Habitat Utilization. It is suspected that juveniles rear in the mainstem, tributary mouths, slough mouths and clear water sloughs (ADF&G 1981, 1983a) and seek areas of upwelling (ADF&G 1983b). Burbot juveniles were captured near Slough 9 in 1982 (ADF&G 1983a).

Habitat Requirements. (will be provided later)

Habitat Availability. (will be provided later)

Dolly Varden

Adults

Dolly Varden catches throughout the Susitna River have been low (Schmidt et al. 1984, Sundet and Pecheck 1985). In 1983, 89 percent of the 47 Dolly Varden caught in the Susitna River were upstream of Talkeetna.

Habitat Utilization. There is a Dolly Varden migration pattern similar to Arctic grayling. Dolly Varden migrate from summer rearing and spawning areas in tributaries to overwintering areas in the mainstem. Catch data suggested that most Dolly Varden moved into the tributaries before late June (ADF&G 1983a, Schmidt et al. 1984). The highest catches in the middle Susitna River have occurred in Lane Creek, Indian River, and Portage Creek (Schmidt et al. 1984, 1985). The fish were then thought to remain in the tributaries until mid-September to October (Sundet and Wenger 1984, Sundet and Pecheck 1985). In the fall after spawning, there was a migration back to the mainstem.

There was a population of dwarf Dolly Varden found in the upper reaches of several tributaries. These fish are thought to remain throughout the year in tributaries such as Indian River and Portage Creek (ADF&G 1983).

Habitat Requirements. Habitat requirements for Dolly Varden in the middle Susitna River have not been quantified. However, habitat requirements are available for Dolly Varden from other studies done in Alaska (Blackett and Armstrong 1965, Wilson et al. 1981). Dolly Varden in southeast Alaska spawned in depths from 0.1 to 3.8 ft; and in riffle/run and pool reaches in water velocities of 1.0 to 3.8 fps. The gravel was usually small at 0.02 to 2.00 in. in diameter (Blackett and Armstrong 1965). Habitat suitability curves done for spawning Dolly Varden in the Terror Lake drainage on Kodiak Island showed similar preferences with water depths between 0.8 to 4.2 ft, water velocities of 0.9 to 2.5 fps, and substrate sizes ranging from 0.08 to 2.5 in. in diameter (Wilson et al. 1981).

Distribution of adult Dolly Varden has been directly linked with food sources. Thus, Dolly Varden are found near salmon spawning areas when salmon eggs and fry are available (Blackett and Armstrong 1965). Dolly Varden are also known to feed on invertebrates such as Chaeoborus, chironomids, and Daphnia (Hume and Northcote 1985).

Habitat Availability. (will be provided later)

Juveniles

There have been so few juvenile Dolly Varden captured in the middle Susitna River that estimation of relative abundance has not been possible.

Habitat Utilization. Habitat utilization of juvenile Dolly Varden in the middle Susitna River are unknown. It is thought that the juveniles rear in the upper reaches of tributaries during the summer and then migrate to the mainstem in the fall to overwinter (Schmidt et al. 1984).

Habitat Requirements. General descriptions of juvenile Dolly Varden habitat on Kodiak Island and southeast Alaska are available. After emergence, juveniles occupied shallow areas in tributaries with low water velocities and varying sizes of substrates (Blackett 1968, Armstrong and Elliot 1972). These slower velocity areas were utilized until the fish grew large enough to move into faster currents to feed on drifting invertebrates. Juvenile Dolly Varden in Kodiak also seemed to prefer the slower velocity waters and the warmer waters of eddies, pools, side channels, and sloughs (Wilson et al. 1981). Suitability criteria in the Terror Lake drainage showed that juveniles preferred depths of 0.1 to 1.0 ft, and water velocities of 0.0-0.2 fps. No preference for substrate sizes was observed.

Temperature is thought to influence migration (Krueger 1981). Migration to overwintering areas occurred at temperatures between 7 and 4^{o}C. Winter water temperatures are usually around 1^{o}C (Elliot and Reed 1974, 1975). When water temperatures rose above 2^{o}C, Dolly Varden fry came out of the gravel and swam about the stream. Cover such as debris, large substrates, and a stable winter flow are probably important to winter survival (Elliot and Reed 1974, Elliot

1975). Migration from the overwintering sites to summer rearing occurred when temperatures rose from $1^{\circ}C$ to 4 or $5^{\circ}C$.

Food preferences of juveniles varied with the season. From April to June immature insects were preferred, while from July until November salmon eggs and small salmon were preferred (Krueger 1981).

<u>Habitat Availability</u>. (will be provided later)

V. SUMMARY

Will be provided later.

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