FISHERY RESEARCH BULLETIN 88-05

Migratory Rate and Behavior of Salmon in Upper Cook Inlet, Alaska, 1983-1984

by

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May 1988

State of Alaska Steve Cowper, Governor

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ACKNOWLEDGMENTS

The completion of this project required the help of numerous people who gave of their time and energy. Foremost among these individuals was the field tagging crew, which consisted of Pat Shields, Mike Villegas, Daniel Kingsley, Thea Thomas, Scott Banke, and Virginia Petanovitch. In addition, the owners of the seine vessels, Doug Blossom and Dan Calhoun, went out of their way to meet project expectations. The crew and skippers who manned the vessels had a high tolerance level throughout the project and the author is thankful for their skill and help.

Initial data summaries were prepared by Randall Davis and Mark Clark as well as my daughter, Michelle. Numerous hours were spent recording the raw data from fishermen's returns into a meaningful format. The success of the project in obtaining a high return rate of tagged fish is due to the cooperation of the Cook Inlet Aquaculture Association and specifically Tom Walker and Tom Mears for publishing return notices and promoting the project. Special thanks goes to Sandi Seagren and Jim Browning for typing and drafting figures for the report. Finally, recognition is due for the fine job Paul Ruesch, Chuck Meacham and Ken Florey did in supporting the project and helping to secure the operational funds.

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ABSTRACT

During 1983 and 1984 approximately 5,800 adult salmon (*Oncorhynchus*) were tagged with Floy spaghetti tags in Upper Cook Inlet, Alaska. A tag return rate of 30.4% was realized from all tagging operations and recovery efforts. The mixed stock and mixed species nature of Upper Cook Inlet fisheries was further defined, but no additional geographical separation of manageable stocks or species was identified. No tagged salmon were recovered outside of Cook Inlet. Salmon migratory behavior was hypothesized to relate to home stream influence because primary migratory pathways identified corresponded to surface current patterns and resultant proximity of freshwater sources. A delay in migration of sockeye salmon (*O. nerka*) was also hypothesized because measured migratory rates of sockeye salmon decreased from 38 to 41 km/day for fish tagged outside Cook Inlet to less than 20 km/day for fish tagged within Upper Cook Inlet. An estimate of commercial exploitation rates was made for chum salmon in 1983. In addition, during 1984 the feasibility of capturing and sonic tagging chinook salmon (*O. tshawytscha*) was demonstrated.

KEY WORDS: Upper Cook Inlet; salmon; tagging; migratory behavior; migratory rate

INTRODUCTION

Background

Since the initiation of a commercial fishery in Upper Cook Inlet, Alaska (Figure 1) in the late 1800's, management biologists and fishermen have discussed the behavior, migratory rates, and abundance of the various salmon stocks within the Inlet. All five species of salmon are harvested in Cook Inlet and the run timing of most stocks coincide (Figure 2), creating a mixed stock fishery. Because of this phenomenon, management biologists are faced with a continuing dilemma of how to harvest the surplus of some stocks while allowing sufficient adult salmon of weaker stocks to escape the fishery to spawn. The geographical size of Upper Cook Inlet (2,600 km^2) combine with significant oceanographic features to further complicate and limit management options.

Upper Cook Inlet is presently divided into two districts, Central and Northern, for the purpose of commercial fisheries management (Figure 1). The Central District is divided into six subdistricts and the Northern District is split into two subdistricts (Figure 1). With the exception of the Chinitna Bay Subdistrict of the Central District where purse seines are allowed to fish, gill nets are the only legal salmon fishing gear in the Upper Inlet. Set gill nets and drift gill nets are allowed by regulation in the Central District, and only set gill netting is allowed in the Northern District. Approximately 600 drift gill net permits fish the Central District, and between 550 and 600 set gill net permits are fished annually throughout the Inlet. The fishing season generally extends from the end of June until mid-August. Examination of commercial harvest data collected since 1954 (Figures 3 and 4) revealed that recent returns of salmon to Upper Cook Inlet are at record or near record levels.

In addition to a commercial fishery, Upper Cook Inlet is the focus of a sport fishing effort in which over a million angler days per year are expended. Since 1977, this effort has comprised between 54% and 59% of the total sport fishing angler days for the state (Hilsinger 1987). The type of fish sought are adult salmon with the annual catch ranging between 198,000 and 348,000 fish since 1977. This intense effort has resulted in major allocation disputes between commercial and sport fishermen. Chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) stocks bound for the Kenai River (Figure 1) or Northern District streams are the subjects of dispute.

The increasing complexity of the Upper Cook Inlet fisheries has placed additional pressure on research and management personnel to provide commercial fishery harvest options relative to regulatory and biological requirements. In this context, the Alaska Department of Fish and Game (ADF&G) has expended considerable effort since 1966 to develop systematic and coordinated programs to manage Upper Cook Inlet sockeye salmon (*O. nerka*) stocks on a stock-specific basis. For example, the total return of sockeye salmon entering Upper Cook Inlet is estimated by entry pattern analysis (Waltemyer 1987). As sockeye salmon are harvested within the Inlet, the various stocks are differentially separated through stock separation scale pattern analysis techniques as to their river of origin (Cross et al. 1986).

In addition, the number of spawning sockeye salmon are estimated by hydroacoustic enumeration of adults entering the major river systems of the Inlet (Tarbox et al. 1983). These data provide an estimate of how well management actions are achieving the desired harvest, and how well escapement goals are being met. Although these programs have significantly improved overall management capabilities, the need for additional information on migratory rates and behavior of sockeye salmon stocks within the Inlet remains.

The existing information on other salmon species in Upper Cook Inlet takes a variety of forms. Harvest data by statistical area are available for the period 1966 to present. In most cases the number of spawning adults and the exploitation rate of the commercial fishery have not been estimated. In addition, knowledge of the migratory behavior of these species within the Inlet is lacking. In essence, the development of management programs for these species has not progressed at the same rate as for sockeye salmon.

Recognizing these deficiencies, ADF&G embarked on a program in 1983 to develop a management regime for all salmon species based on stock-specific data. This program consisted of the following sub-programs: (1) summarization of existing catch and escapement data by statistical area. This was accomplished through development of computer programs for data retrieval and analysis of run timing, run strength, and age/length data; (2) estimation of the total return of chum salmon *(O. keta)*, coho salmon, and pink salmon *(O. gorbuscha)* stocks inseason through expansion of the test fish programs; (3) monitoring of escapement into selected streams and development of counting techniques for the Susitna River system (Figure 1); (4) sampling of all salmon species in the commercial catch and escapement for age, length, and weight data; (5) further definition of migratory rates and behavior of salmon within the fishing districts of Upper Cook Inlet; and (6) estimation of commercial exploitation rates on chum salmon, coho salmon, and pink salmon.

This report presents the results and discussion of data from a 2-year investigation of salmon behavior collected by tagging individual fish. The specific objectives of the study were to: (1) assess spatial and temporal migratory behavior of salmon entering the Central District; (2) estimate the exploitation rate of the commercial fishery for chum salmon, coho salmon, and pink salmon; and (3) determine the feasibility of capturing and sonic tagging chinook salmon migrating along the western shore of the Kenai Peninsula.

Review of Previous Studies

In 1922 the United States Department of Commerce, Bureau of Fisheries initiated extensive salmon tagging studies in Alaska. The first reported investigations in Cook Inlet occurred in 1929 under the general direction of Willis H. Rich and were reported by Thompson (1930). The overall objective of the program was to determine the direction of salmon migration from the entrances of Cook Inlet. Four tagging locations were selected in 1929; Flat Island, Nubble Point, Cape Starichkof, and Nikishka Bay. A total of 788 sockeye salmon, 831 pink salmon, 224 chum salmon, and 48 coho salmon were tagged between 14 June and 24 July. The return of tags from sockeye salmon tagged at Flat Island indicated a northerly migration to streams located south of Anchor Point. Sockeye salmon recovered from the Nubble Point effort revealed that 21.6% of the returns were from Upper Cook Inlet spawning areas. Of 202 sockeye salmon tagged at Cape Starichkof on 22 July 1929, most recoveries came from northern locations along the western shore of the Kenai Peninsula. There were, however, 20 tags (27% of recoveries) returned from Kachemak Bay. In addition, pink salmon recoveries indicated that the principal migration for this species was southeast into Kachemak Bay. On 21 July, 245 sockeye salmon were tagged at Nikishka Bay in an attempt to resolve whether sockeye salmon captured on the east shore of Cook Inlet north of the East Forelands were bound exclusively for Northern District streams. Thompson (1930) noted that "it is quite apparent that most of these fish were bound for the spawning grounds south of East Foreland, and 46.5% of the recoveries were made in the immediate vicinity of the Kenai and Kasilof Rivers." No information on migratory rates was presented from the 1929 tagging effort.

Following a 20-year hiatus, the United States Fish and Wildlife Service, Bureau of Commercial Fisheries contracted with the Fisheries Research Institute at the University of Washington to renew salmon tagging efforts in Cook Inlet. These studies were reported by Tyler and Noerenberg (undated) and covered the tagging years 1949, 1954, 1955, 1957 and 1958. The objectives of this effort remained essentially the same as the 1929 studies with the directional movement of salmon and degree of separation of stocks a primary objective. In addition, the rate of movement and proportion of tagged fish returned were examined. It should be noted the ability to count sockeye salmon in the glacial rivers of Upper Cook Inlet was not developed until the late 1960's; therefore, an estimation of the exploitation rate of the commercial fishery was of considerable interest during this period. The 1949 tagging effort was severely limited in scope, consisting of tagging only 397 sockeye salmon captured on Chisik Island and 8 km south of Cape Kasilof. Tag returns were entirely from the commercial fishery and represented 42% of the tagged population.

In 1954 the geographical area of tagging was extended to the mid-Inlet area east of Chisik Island and the vicinity of Kalgin Island during July. A total of 478 and 905 sockeye salmon were tagged at each location, respectively. Tag return rates were approximately 41% and 42% for each area with most returns from the east shore of Upper Cook Inlet. No tags were returned from areas outside Cook Inlet. Based on the commercial fishery returns the average distance traveled prior to capture was 48.5 km, and time at liberty was 6.4 days for sockeye salmon released at Kalgin Island. A similar migratory rate was noted for Chisik Island releases.

Kalifonsky and Salamatof Beaches were the focus of tagging efforts in 1955 with 1,198 sockeye salmon released. An additional 120 fish were tagged at Kalgin and Chisik Island but returns were too few to be meaningful. No recoveries from fish tagged on Kalifonsky and Salamatof Beaches were reported by the drift gill net fleet, however; a return rate of 31% was recorded from set net sites and traps. The average number of days before recapture was two to three depending on gear type.

The major tagging effort took place in 1957 and 1958 when approximately 3,802 sockeye salmon, 758 chum salmon, 2,244 pink salmon and 612 coho salmon were tagged. The fish were tagged at a variety of locations throughout Cook Inlet, including mid-Inlet releases from a chartered seine vessel. The majority of fish tagged, however, was captured in commercial traps. Results of these investigations revealed salmon tagged north of Anchor Point showed essentially northward movement from the point of release. An exception to this pattern was observed at certain times for Chisik Island releases. In 1957, 26% of the returns from late-June releases were reported from along the Alaska Peninsula. Releases from south of Anchor Point resulted in "substantial" returns from areas outside Cook Inlet.

Tag returns for sockeye salmon released along the eastern shore of Cook Inlet and Kalgin Island averaged 36%, which was approximately 9% higher than returns for sockeye salmon tagged at other locations. The importance of the Kenai and Kasilof Rivers as major sockeye salmon producing streams was verified because sockeye salmon tagged along the east shore of Cook Inlet were found to be bound primarily for these streams. Rate of migration was estimated to be 3.2 to 8.0 km/day for sockeye salmon tagged at Kalgin Island and the eastside beaches while the migratory rate for fish tagged at Chisik Island and southern Cook Inlet below Anchor Point averaged 17.6 to 36.9 km/day. No migratory rate data were presented on salmon species other than sockeye salmon.

Data on pink salmon tagged north of Anchor Point suggested that the Susitna River was a major producer of this species. Pink salmon tag returns from fish tagged at Ninilchik Beach indicated at least two stocks passed this location. Tag returns from early July were primarily from the Susitna River, while late July returns were from the Kenai/Kasilof Rivers.

Conclusions on chum salmon and coho salmon were limited to suggestions that the major producer of these species for fish tagged north of Anchor Point were Northern District streams, mainly the Susitna River.

METHODS

The tagging of salmon to study migratory behavior and patterns is a standard tool used by numerous investigators in both coastal and high seas experiments (Hartt 1966). However, the success of a project requires: (1) effective capture gear and vessel; (2) minimization of handling stress during tagging; (3) an effective tag type; (4) recapture success including public awareness if user group returns are part of the recapture programs; and (5) selection of analysis procedures.

During 1983 and 1984 the major salmon tagging operations were conducted in the Central District of Upper Cook Inlet in what is commonly referred to as the mid-Inlet area (also referred to as offshore in this paper). Unlike previous investigations where pile traps were available as a capture method the available gear types were limited to purse seine or gill net techniques. Hartt (1963) discussed the relative effectiveness of gill nets and concluded that although they were an effective means of capturing salmon, they were not a practical gear for tagging salmon at sea. Therefore, a chartered 12.8-m purse seine vessel was selected to capture salmon for tagging. The purse seine used was 150 fathoms in length and 10 fathoms deep. In 1983, a total of 36 sets were made between 10 July and 31 July (Appendix A.1). In contrast, only 17 sets were made in 1984 between 2 July and 24 July (Appendix A.2) because poor weather hindered the operation.

In addition to the offshore work, an effort was made to capture chinook salmon near Anchor Point in 1984 (referred to as Anchor Point). The primary goal of this investigation, as previously noted, was to assess whether chinook salmon could be captured in this locality and tagged with either radio or sonic tags. The existence of an intense chinook salmon sport fishery in this area made this a logical site. However, the characteristics of the area required nearshore sets be made. Therefore, a 6.7 - m seine jitney was chartered and a shallow water purse seine deployed. Between 7 July and 17 July a total of 20 individual sets were made.

Handling stress was a major concern in all tagging operations, and care was taken to minimize this impact on salmon. Salmon captured offshore were retained in a loosely held seine until time of tagging at which point they were individually dipped from the seine with a fine mesh knotless longhandled dipnet. A foam lined tagging cradle was used to restrain the fish. Each fish was tagged with an individually numbered Floy spaghetti tag inserted through the cartilage immediately ventral and posterior to the dorsal fin (secured with an overhand knot). The fish was then returned to sea via a water slide consisting of a 20.3-cm diameter PVC pipe and water pump. At Anchor Point, fish were released directly to the water from the seine via hand. Chinook salmon were never removed from the water for tagging.

In addition to the spaghetti tags, three chinook salmon captured at Anchor Point were also tagged with a radio transmitter. The original intent of this project was to assess the feasibility of chinook salmon capture. A concurrent radio tagging project was taking place in the Kenai River (Hammarstrom et al. 1985), and three radio tags were made available from this project. While radio tags cannot be tracked in saltwater, the monitoring program in freshwater would provide some indication of initial entry and more importantly the tagging crews could assess tagging procedures for future investigations. The procedure for tagging consisted of placing the fish in a holding tank and adding tricane methanesulfonate (MS 222) until the fish could no longer maintain vertical stability. At this point, the fish was held ventral side up and its lower jaw held open. A glycerin coated radio transmitter was inserted through the esophagus into the anterior portion of the stomach using a veterinarian balling gun. The transmitter antenna was attached and the fish allowed to recover prior to release. Radio telemetry equipment and methods within the Kenai River are fully discussed by Hammarstrom (1985).

Recapture of tagged fish was predicated on the assumption the commercial and sport fisheries in the Inlet would be the primary recovery mechanisms. Therefore, an extensive public awareness program was initiated to increase the potential for a significant return rate. Posters and handouts defining the program were distributed to all the major salmon processors in Cook Inlet. In addition, a full page description of the program, a tag recovery form and informational articles were included in the publication "Smolts". This newsletter is published and mailed by Cook Inlet Aquaculture Association to all salmon fishing permit holders in Cook Inlet and other interested parties (circulation of 4,000 in May and July 1983 was expanded to 101,000 in October 1983). In addition to these written notices, a number of verbal presentations on the importance of returning tags were made at various meetings of fishermen's groups. Finally, as a further incentive, eight annual awards were made by means of a drawing from all tags returned. The awards consisted of one tag at $1,000.00, two tags at $500.00 each, and five tags at $100.00 each. Eligibility for the drawing required the spaghetti tag be returned to ADF&G. This requirement was necessary to avoid false reporting of data or numbers.

In addition to the fisheries, tag recoveries were made at ADF&G stream escapement evaluation programs. These programs consisted of weirs on tributary streams in the Kasilof River system, various salmon enumeration sites in the Susitna River, a weir on Fish Creek, and weirs at Hidden Creek, Quartz Creek, and Russian River within the Kenai River drainage.

In an effort to assess the impact of handling on tagged fish, a condition factor was assigned to approximately every eighth fish tagged. This factor was subjective, as the professional biologist on board the tagging vessel was required to make a visual determination of condition. The factors consisted of a numerical rating of one to four, with one being a fish in poor condition. This was defined as a fish exhibiting obvious stress because of long holding time prior to tagging, minor external injury in the net, fatigue upon release, etc. In contrast, a numerical rating of four was assigned to a fish showing no obvious stress or injury, active upon release, and tagged relatively quickly. Fish in extremely poor condition were not tagged. A chi-square goodness of fit test (Zar 1974) was run to compare the recaptured fish condition factor frequency distribution to the expected distribution from the tagging operation.

Data summarization was completed for each species by tallying return information in a variety of forms. Recovery and tagging locations (defined as an individual set of the purse seine) were plotted on base maps with days to recovery noted (all base maps are presented in Tarbox 1987). Measurements of distance from point of tagging to point of recovery were made assuming straight line travel, thus distance reported herein represents a minimum value in the calculations. Data were further summarized by recovery gear type and, in the commercial fishery, the fishing district where captured. Migratory rates were calculated for each tag returned, and a mean and variance calculated for returns to known locations. It should be noted on occasion the amount of data on an individual tag return was incomplete relative to gear type, location, or capture date. In these cases the author contacted the fisherman, if possible, to clarify the data set. However, this was often inconclusive and therefore only those pieces of information known to be valid were used in the analysis. This resulted in differential sample sizes for the various components of the study.

In an effort to assess the migratory rate of Cook Inlet bound fish from areas outside Cook Inlet, data on tagged sockeye salmon tagged at Kayak Island, Alaska (M. McCurdy, ADF&G, Cordova, personal communication) and Cape Igvak, Alaska (ADF&G, undated) and recovered in Cook Inlet were summarized. Distance traveled again represented a minimum value (straight line distance). Additional information on Cook Inlet stocks was generated by recomputation of Tyler and Noerenberg (undated) data on migratory rates. Tyler and Noerenberg reported mean days out to recovery and mean miles traveled. Unfortunately, individual returns were not available; therefore, as a rough approximation of migratory rate, a simple division of these two values was made. McCurdy also provided the raw tagging data for sockeye salmon recoveries from Prince William Sound commercial fisheries and various stream systems. While individual commercial fishing locations were not available, the statistical fishing area was noted. Therefore, assuming a straight line distance to the statistical district (minimum value), migratory rates of Prince William Sound sockeye salmon tagged at Kayak Island, Alaska, were calculated for comparison to results of this investigation.

RESULTS

A total of 5,800 salmon were tagged during this investigation with a tag return rate of 30.4% (1,764 fish). During the tagging operation, the diversity of salmon species within individual purse seine sets was very evident. A total of 30.6% of the sets in 1983 contained four salmon species; 27.8% contained three species. In the offshore tagging of 1984, a total of 71% of the sets had more than three species. Nearshore at Anchor Point the mixed species phenomena was reduced with 45% of the sets containing two salmon species and 40% with three species. Only one set had four species.
The mixed stock nature of the Upper Cook Inlet salmon fishery was demonstrated on numerous occasions for all species. For example, on 3 July 1984 a total of 218 sockeye salmon were tagged near the Central District southern boundary. Recoveries from this single set were made in five major river systems and distributed among 9 tributary systems. Similar patterns of mixed sockeye salmon stocks were observed on most sets involving the tagging of significant numbers of fish (Tarbox 1987 presents raw data for each set).

As previously noted, a concern was expressed that the tagging procedure would result in significant mortality for a segment of the tagged population and, therefore, compromise the analysis of the data. However, comparison of the frequency of tag returns to expected returns from the tagging procedure indicated the null hypothesis of no difference be accepted (p .05, Appendix A.3).

Sockeye Salmon

A total of 836, 2,394, and 968 sockeye salmon were tagged offshore in 1983 and 1984 and at Anchor Point in 1984, respectively. Total tag return rates were 41.6%, 24.8%, and 58.6% for these same areas, respectively (Appendix A.4, A.5,and A.6).

Recovery of sockeye salmon tagged offshore was primarily from the Central District drift gill net fleet and set gill nets. In 1983 the commercial fishery recovered approximately 38.8% of the fish tagged, with the Central District drift gill net fleet and set gill nets contributing 150 and 166 tagged fish, respectively. Only six tagged fish were recovered by Northern District set gill nets (Appendix A.7). Stream recoveries were few with only 19 tagged fish returned from the various recovery programs. The Kenai and Kasilof River systems were the predominate contributors with 11 and five recoveries, respectively (Appendix A.8).

In 1984 a lower recovery rate and a change in the distribution of recoveries was evident for the offshore tagging operation. The commercial fishery recovered approximately 19% of the available tagged fish. The Central District drift gill net fleet captured 169 fish while the combined set gill net recoveries totaled 272. In contrast to 1983, Northern District set gill net recoveries were 30.1% of the set gill net total (Appendix A.9). Stream recoveries were also higher in 1984 with 131 fish reported from a variety of streams. The Kenai River (29), Kasilof River (24), Fish Creek (47), and Susitna River (21) were the major sources of the recoveries (Appendix A.8).

The frequency of different stocks in the individual purse seine sets, determined from the stream recovery data, revealed an interesting phenomenon in 1984. Russian River bound sockeye salmon were present in 47% of the sets, Kasilof River and Fish Creek fish were captured in 50% of the sets (Appendix A.8). Examination of subpopulations from Kasilof River/Tustumena Lake tributaries indicated Bear Creek fish were captured only in early July (2-6), while Glacier Flat Creek fish were captured until 14 July (Appendix A.8). Fish bound for the Russian River and Quartz Creek, within the Kenai River system, were present throughout the tagging period. Fish Creek sockeye salmon were also captured in sets through the end of the tagging period.
In contrast to the offshore tagging results, the Anchor Point program had a unique tag recovery pattern. Of the 968 sockeye salmon tagged, 42.5% were recovered in the Lower Cook Inlet commercial purse seine fishery. Only 14 recoveries were made by the Central District drift gill net fishery, and 110 recoveries were reported from the set gill net fisheries of the Upper Inlet (104 in the Central District, six in the Northern District; Appendix A.10). Stream recoveries totaled 23 and came primarily from the Kasilof River system (13). Kenai River (4), Susitna River (3), Fish Creek (2) and Wolverine Creek (1) comprised the remainder of the stream recoveries. Within the Kasilof River, the majority of the recoveries came from Glacier Flat Creek.

Migratory rates of sockeye salmon were relatively constant to specific locations during the study period. In both the 1983 and 1984 offshore tagging studies, sockeye salmon recaptured on Salamatof, Kalifonsky, Cohoe, and Ninilchik Beaches averaged between 13.4 and 17.3 km/day (Tables 1 and 2). Migratory rates calculated from stream recoveries at weirs on the Russian River and Quartz Creek, tributaries of the Kenai River drainage, ranged from 7.2 to 8.6 km/day. A similar pattern was observed for fish captured at Fish Creek with an average rate of 8.9 and 11.3 km/day for 1983 and 1984, respectively. In contrast, the highest average rates were recorded for fish recaptured in the Northern District (excluding Fish Creek). Average rates ranged between 18.9 and 23.2 km/day for fish captured in the commercial fishery, while fish captured in the Susitna River, at Sunshine Station, traveled at an average of 20.6 km/day. It should be noted the majority of fish recaptured in the Northern District were tagged on a single day (14 July 1984) near the eastern portion of the Central District (Appendix A.11).

Migratory rates of fish recaptured in Lower Cook Inlet followed a similar pattern to fish recaptured on the eastern side of Upper Cook Inlet. A total of 282 recoveries from the China Poot purse seine fishery averaged 14.7 km/day in 1984. However, recoveries from other areas of Lower Cook Inlet had calculated migratory rates which ranged from 7.1 to 26.7 km/day (Table 2) although sample sizes were limited for these localities.

Recomputation of Tyler and Noerenberg (undated) data indicated they observed similar migratory rates within Upper Cook Inlet. Sockeye salmon tagged by purse seine east of Chisik Island in 1954 migrated at a rate of 7.8 to 12.2 km/day (Appendix A.12). The slowest rate (less than 1.0 km/day) was recorded for fish tagged on Kalgin Island from trap catches and recaptured in the vicinity of tagging.

While overall average rates provided a relative comparison of migratory behavior, analysis of different tagging time periods in 1983 and 1984 revealed a changing pattern with the season. Only recaptured fish from the set gill net fisheries located on the western shore of the Kenai Peninsula and the drift gill net fishery provided enough samples for analysis. In 1983 fish tagged between 10 and 15 July migrated at an average rate of 6.9 to 8.4 km/day depending on tagging location (Table 3). In contrast, fish tagged between 16 and 20 July migrated at an average rate of 18.5 to 21.4 km/day. A decrease in average rate to 9.7 to 13.1 km/day was then measured for the period after 20 July. A similar analysis in 1984 revealed that fish tagged between 3 and 8 July migrated at 12.6 to 17.1 km/day to the set gill net fisheries. Between 12 and 15 July, a decrease in rate was noted with fish moving at an average rate of 8.4 to 13.4 km/day (Table 4); lack of recoveries because of a commercial fishery closure after 15 July precluded assessment of migration rates during this period. Recaptures from the drift gill net fleet did not follow the pattern noted for the set gill net recaptures. Instead, during the period of 12 to 15 July the rate of migration increased to 16.1 km/day (Table 4).

Analysis of tag recovery data for Cook Inlet sockeye salmon stocks tagged outside of Cook Inlet and recovered within the Inlet indicated a much faster migratory rate. For example, fish tagged at Cape Igvak, Alaska migrated at an average rate of 38.1 km/day (Table 5). Sockeye salmon tagged at Kayak Island, Alaska in 1985 returned to Cook Inlet at an average rate of 41.8 km/day (Table 6).

In contrast to Cook Inlet, sockeye salmon tagged at Kayak Island and recovered within Prince William Sound also appeared to travel at a higher average rate. Recoveries from a weir on the Coghill River (a known location) averaged 27.2 km/day (Appendix A.13). Recaptured fish from the commercial fisheries of Prince William Sound varied in the calculated average rate of between 26.5 to 59.4 km/day depending on fishing district (Table 6).

Chum Salmon

A total of 200 and 651 chum salmon were tagged offshore in 1983 and 1984, respectively (Appendix A.4, A.5). No chum salmon were captured at the Anchor Point tagging site. In addition, 227 chum salmon were tagged in Chinitna Bay, Alaska on 21 July 1983. The majority (91%) of chum salmon tagged in 1984 were tagged on 12 July (Appendix A.5).

The drift gill net fleet reported the recapture of 48.5% of the fish tagged in 1983 (excluding Chinitna Bay, Appendix A.7). In contrast, only 1.2% were recaptured by the drift gill net fleet in 1984 (Appendix A.9). The set gill net fisheries reported recaptures of only 4.0% and 0.5% in 1983 and 1984, respectively. Stream recoveries were essentially non-existent (total two) in 1983 increasing to 5.2% of tagged fish in 1984. Ninety-four percent of the stream recoveries came from the Susitna River drainage.

The tagging of 227 chum salmon in Chinitna Bay resulted in the recovery of only 14 fish. Tag recoveries were split between the Chinitna Bay set and drift gill net fisheries and the set net fisheries of Tuxedni Bay/Chisik Island.

The migratory rate of chum salmon tagged in Upper Cook Inlet was difficult to assess. Unlike sockeye salmon, where the recaptures were predominantly north of the tagging location or from a fixed geographic location, the recapture of chum salmon were from the open waters of Cook Inlet. In addition, the direction of migration was not necessarily toward a northerly location at time of recapture (i.e., retrograde migration). For example, in 1984, 58.5% of the recaptures were made south of the tagging location. Chum salmon migrated within the fishing districts at an average rate of 13.5 km/day in 1983 and 18.6 km/day in 1984 (Table 7). These rates were calculated independent of direction traveled. Analysis of Tyler and Noerenberg (undated) data collected in 1958 resulted in similar rates of migration for predominantly northern recaptures. A total of 251 chum salmon were tagged on 3 and 4 July 1958 in the mid-Inlet area off Anchor Point with over 80% of the 60 recoveries made north of the tagging location. Migratory rates of chum salmon calculated from these data averaged 9.2 to 10.7 km/day (Appendix A.14).

Calculations of migratory rates to specific stream locations were limited because of sample size. However, 15 fish recovered from Sunshine Station in the Susitna River drainage in 1984 averaged 15.4 km/day.

Coho Salmon

Only 252 coho salmon were tagged during the 2 years of investigation (112, 136, and four in 1983 and 1984 offshore and Anchor Point, respectively). Tag recoveries ranged from 17.6% for the 1984 offshore program (Appendix A.5) to 25% for the other two tagging operations (Appendix A.4 and A.6).

The differential tag recovery rate by the commercial fishery between 1983 and 1984 offshore program for sockeye salmon and chum salmon was also evident for coho salmon. In 1983 the total commercial tag return amounted to 21.4% with the drift gill net fleet reporting 13.3% and the set gill net fishery the remainder (Northern District had 25% of the set gill net recoveries, Central District 75%, Appendix A.7). In 1984 the commercial tag return decreased to 13.2% with the relative percent contribution to this figure by the drift gill net fleet reduced to 5.9%. The distribution of the set gill net returns also changed relative to 1983 with the Northern District contribution being 75% of the total set gill net returns.

The Anchor Point tagging program tagged only four coho salmon, and the single recovery was reported from the Lower Cook Inlet set gill net fishery.

Combining all recoveries from the commercial fisheries resulted in an average migratory rate of 9.1 and 15.8 km/day for 1983 and 1984 offshore, respectively (Table 7). Similar to chum salmon, 50% of the 1983 recoveries were from south of the tagging location. In 1984, however, 75% of the recoveries were from north of the tagging site. Again, these rates are comparable to those calculated from data collected in 1958 by Tyler and Noerenberg (undated). For fish tagged from purse seine catches offshore of Anchor Point in 1958, an average rate of 8.6 to 9.3 km/day was calculated (Appendix A.15). Fish tagged offshore of Cape Kasilof had an average rate of 7.0 to 8.4 km/day while fish released from Kalgin Island trap catches varied from <1 km/day to 48.3 km/day (a single fish; Appendix A.15).

Pink Salmon

A total of 58, 110, and 78 pink salmon were tagged during the 1983, 1984 offshore and 1984 Anchor Point operations, respectively (Appendix A.4, A.5 and A.6). Tag recapture percentages were low ranging from 5.2% to 16.7% for both commercial and stream recoveries combined.

The lack of recoveries by the commercial fishery makes any discussion of gear types and locations essentially meaningless. However, the one facet of the recoveries which is consistent with previous results is the predominance of recoveries in Lower Cook Inlet for fish tagged at Anchor Point. Of the 12 commercial fishery recoveries, nine were from the purse seine fishery of the Lower Inlet (Appendix A.10) with the majority from Tutka Bay.

Pink salmon average migratory rates appeared to be much higher at 31 to 43.2 km/day than for other species (Table 7). Stream recoveries also indicated a faster rate with two fish averaging 23.2 km/day to Sunshine Station on the Susitna River, and a single fish averaged 24.7 km/day to the Russian River and 34.2 km/day to Beaver Creek in the Kenai River system. However, sample sizes are relatively small and the data should be viewed accordingly.

Tyler and Noerenberg (undated) results, from purse seine tagging at Anchor Point, suggested migratory rates more consistent with other species at 5.9 to 9.0 km/day (Appendix A.16). However, a single fish tagged at the Kalgin Island trap on 23 July 1958 traveled at an average rate of 48.3 km/day.

Chinook Salmon

Twenty-six chinook salmon were tagged at Anchor Point between 7 and 17 July 1984 (Appendix A.6). Sixteen of these fish were tagged on 15 July. Six tags were recovered with five of these from the Kenai River and the remaining fish was taken in the set gill net fishery (Appendix A.10).

The migratory rate of chinook salmon to the Kenai River was highly variable with one fish migrating from the tagging site to the lower river in 4 days (23.4 km/day) and a second fish (radio tagged) not entering the river until 34 days later (2.3 km/day). Two fish averaged 5.7 km/day and a single fish moved at 13.3 km/day (Table 8). A radio tagged fish migrated at 5.6 km/day to river-kilometer 0.0 of the Kenai River and at a rate of 5.7 km/day between the mouth of the river and river-kilometer 119.2.

DISCUSSION

Migratory Pattern

It is hypothesized adult salmon migrating to their stream of origin from high seas rearing areas use a variety of techniques or cues to arrive on the spawning grounds. These may include solar orientation, lunar orientation, magnetic fields, currents, olfactory responses, visual cues, etc. (McKeown, 1984). The relative importance of one set of cues over another is strongly debated. However, it is generally recognized salmon respond to the distinctive odors of their home streams (home stream cues) in coastal areas (a complete discussion of the history of olfactory imprinting and homing in salmon is presented by Hasler and Scholz 1983). In this context, a brief overview of Cook Inlet freshwater sources and circulation patterns is warranted prior to a discussion of salmon migratory pathways.

The major freshwater sources into Upper Cook Inlet include the Susitna River, Kenai River, and Kasilof River. These rivers, as previously noted, are also the major salmon producing systems of the Upper Inlet. The circulation patterns within Cook Inlet are highly complex and are a function of tides, freshwater input, and surface winds. The tides within Cook Inlet are semi-diurnal with a mean tidal range of 4.2 m at the mouth of the Inlet to 9.0 m at the city of Anchorage (Rosenberg et al. 1967). The impact of coriolis effect is evident in the overall circulation pattern of the Inlet with oceanic waters entering the Inlet on the east side and turbid, fresh water exiting the Inlet on the western side. However, a complex surface pattern consisting of gyres, shear zones, and mixing areas typify Upper Cook Inlet; Figure 5 (ADF&G 1978) presents a summer circulation pattern. According to ADF&G (1978), seawater from the Alaska Current enters Cook Inlet through Kennedy Entrance. An eastern counterclockwise gyre is present in Kachemak Bay in addition to a northward surface current along the western shore of the Kenai Peninsula which moves surface waters toward Anchor Point. At Anchor Point, the northward movement of seawater is altered to a strong westerly direction and a counterclockwise gyre is evident in the central lower inlet. However, seawater also continues north and northwest of Anchor Point where it mixes with the southerly flow of turbid, low salinity water from the Upper Inlet. Mixed water is carried westward from this area. A southward flow of low salinity water (i.e., river influence) is evident in an area of convergence of the westward intruding seawater to produce what is known as the mid-channel rip (Figure 5). Additional frontal zones are present both east and west of the mid-channel rip and are known locally as the east and west rip, respectively. Convergence along the mid-channel rip is significant in the area between Anchor Point and Kasilof. As surface waters exit the Inlet they are diverted to the west of the mid-channel rip and eventually enter Shelikof Strait. Burbank (1977) presents further explanations of circulation patterns in Cook Inlet.

Evidence from a variety of programs conducted in Cook Inlet suggest home stream cues may play a primary role in the migratory behavior of returning adult salmon. Waltemyer (1983, 1987) has presented the results of test fishing and noted over 70% of the test fishing catch has occurred in the area of the mid-Inlet. Observations on the location of the drift gill net fleet during commercial fishing periods (P. Ruesch, ADF&G, Soldotna, personal communication) tends to verify the importance of the mid-channel rip as a major concentrator of salmon. During some fishing periods, the majority of the 600 drift gill net vessels have been observed within 1 km of this area. Drift gill net fleet tag recoveries reported during this investigation also tended to be concentrated in the area of the mid-channel with few recoveries from the eastern portion of the Inlet. Thus it appears salmon entering Upper Cook Inlet do so where low salinity water is most intense and continue their migration into the Upper Inlet along this gradient of freshwater influence.

This entry pattern of salmon is consistent with freshwater orientation responses observed in other studies. For example, Scholz et al. (1972), reported in Hasler and Scholz (1983), observed sonic-tagged chum salmon, in a 7.0 km saltwater bay in northern Honshu, Japan, swam into the bay only during ebb tides. When river water from the head of the bay flowed along the south shore they swam into the bay via that route. When river water moved out along the north shore, chum salmon entered along the north shore. Fish were located within 3 m of the surface where the influence of the fresh river water was the greatest.

Further evidence of a home stream response was suggested in this investigation from the tag recoveries from China Poot Bay in Lower Cook Inlet. As previously noted, approximately 42% of the sockeye salmon tagged in the nearshore area adjacent to Anchor Point migrated approximately 30 km south of the tagging site to their area of imprinting. China Poot bound sockeye salmon were also tagged in the mid-channel rip area on 4, 5, and 16 July in 1984. This migratory pattern is consistent with the results reported by Thompson (1930) who noted the principal migration of pink salmon tag recoveries, from tagging at Cape Starichkof, came from Kachemak Bay.

Evaluation of the surface current pattern by Burbank (1977) suggested surface waters move north out of Kachemak Bay along Anchor Point and are then diverted westward. Thus, China Poot bound fish responding to home stream cues should move eastward from the mid-channel rip toward Anchor Point and then southward toward China Poot. Interestingly, no tagged sockeye salmon were recovered from China Poot in 1983 when sockeye salmon were tagged farther north in Upper Cook Inlet (run strength to China Poot was approximately equal in 1983 and 1984). In addition, in 1984 the farthest north a tagging site with recoveries from China Poot Bay occurred was Ninilchik, an area where diversion of surface waters westward and mixing of Upper Inlet waters is strong.

A similar phenomenon of southward entry into the Kenai River system by sockeye salmon has been observed by biologists since the 1920's. Thompson (1930) reported the majority of fish tagged at Nikishka Bay were recovered south of the tagging site and most fish were bound for the Kenai and Kasilof Rivers. Ruesch (ADF&G, Soldotna, personal communication) and the author have observed large numbers of sockeye salmon moving south along Salamatof Beach, against the flooding tide, to enter the Kenai River. Again, the overall circulation pattern of the inlet suggests Kenai River water is mixed with inlet water and moves northward along Salamatof Beach. Rosenberg et al. (1967), in a limited study of tidal excursion in the vicinity of the Forelands, noted an important feature of the current pattern was the existence of a large eddy which develops on the north side of the East Forelands. Burbank (1974) as discussed by Berkland (1976) has indicated northward moving water from the inlet is diverted strongly westward in the area of the Forelands because of the basin geometry of this area. Thus the attraction water of the Kenai River follows a similar pattern to that observed for China Poot Bay water, a net northward movement with diversion to the west and exit via the mid-channel rip.

In summary, it is probable the ultimate factors which relate to the migratory pathways used by Cook Inlet salmon are intimately tied to the physical and chemical parameters of the water masses of the Inlet. The understanding of the observed migration and entry pattern of salmon into and through the inlet will require substantial investigation into these areas. While the overall circulation pattern is somewhat defined, the influence of variables on this pattern is not detailed. For example, the effects of wind on surface circulation has been hypothesized to be significant at times but a lack of offshore wind data precludes an assessment of these perturbations (ADF&G 1978).

Migratory Rate

Based on the results of tagging data from within Cook Inlet and for Cook Inlet stocks tagged outside the inlet, it appears a decrease in the rate or delay of migration occurs within the Central District. For example, sockeye salmon migrated at a rate two to three times faster from Prince William Sound (41.8 km/day) and Cape Igvak (38.1 km/day) to Cook Inlet than fish moving through the Inlet. This pattern of higher migratory rates further from the coastal environment is consistent with that observed for other geographical areas. For example, Hartt (1966) reported sockeye salmon migrating to the coastal waters of Bristol Bay from the high seas averaged approximately 45 km/day. A seasonal change in rate from the high seas was noted with fish tagged later in the season migrating at a faster rate than fish tagged earlier. French et al. (1976) reported maturing sockeye salmon migrated at between 46 and 56 km/day during their last 30 to 60 days at sea. Sockeye salmon tagged at Kayak Island migrated into Prince William Sound fishing districts at a minimum average rate of between 26 and 50 km/day. Stasko et al. (1976) observed ultrasonic tagged sockeye salmon swim at an average ground speed of 52 km/day in the coastal waters of Washington, approximately 70 km south of the Fraser River. Tyler and Noerenberg (undated) reported that for sockeye salmon tagged in Cook Inlet and recovered outside the Inlet, the migratory rates varied from 26.6 to 77 km/day.

A delay in migration has been observed for various salmon species as they approach their natal streams. O'Malley and Rich (1918) reported sockeye salmon near the mouth of the Fraser River reduced their average rate of travel prior to entry into the system. Gilhousen (1960), citing MacKay et al. (1944, 1945), indicated some sockeye salmon delay off the mouth of the Fraser

River between arrival at the river mouth and river entry. Gilhousen further noted Adams River sockeye salmon were characterized as having a slow wandering movement pattern within the influence of Fraser River discharge. The area of wandering was not close to the river mouth but offshore in deeper, clearer waters. As time of river entry approached, fish moved closer to the tidal flats and eventually entered the river in a peak. Delays ranged from a few days to several weeks with at least one race of sockeye salmon showing a delay in some years and not others. Anderson and Beacham (1983) reported on the migration of chum salmon stocks of the Johnstone Strait-Fraser River Area. They noted that, "...chum salmon entering upper Johnstone Strait show a decrease in their rate of travel from the Johnstone Strait area to that of the Strait of Georgia and a subsequent increase in the duration of delay." Seasonal average rates of travel decreased from 25.6 km/day in Johnstone Strait to 9.6 km/day in the central and northern section of the Strait of Georgia. They further noted, "...delayed migration near or within the marine areas adjacent to natal spawning grounds is a phenomenon common to all chum salmon stocks, including those of Washington State."

The mixed stock nature of Upper Cook Inlet sockeye salmon and other salmon species makes any statements about migratory rate differences by individual stock highly speculative. In 1983 the apparent increase in sockeye salmon migratory rate after 15 July (Table 3) may be the result of stock differences as opposed to an overall change in migratory behavior. Cross et al. (1983), using scale pattern analysis, allocated the sockeye salmon commercial harvest for the various set gill net fisheries. They reported for the fishing periods on stocks tagged prior to 10 July, the commercial harvest was approximately 38.8%, 54.7%, and 26.9% Kasilof sockeye salmon for Cohoe/Ninilchik, Kalifonsky, and Salamatof Beach, respectively. Kenai River bound sockeye salmon were approximately 41.1%, 33%, and 73% for the same beaches, respectively. In contrast, during the commercial periods when fish tagged from 16-20 July were in these areas, the relative contribution of Kenai River fish increased to 87%, 74%, and 66% for Cohoe/Ninilchik, Kalifonsky, and Salamatof Beach, respectively.

Therefore, the observed pattern may have resulted from rate differences between stocks as stock composition shifted over time, or have been a rate change common to both stocks. One point of reference is that Salamatof Beach stock composition remained predominantly Kenai River sockeye salmon during all three sampling periods (Table 3).

Recoveries of tagged sockeye salmon in the Northern District in 1984 provided the only insight on migratory rates of stocks moving toward this area. An absence of recoveries in 1983 precluded any meaningful discussion for that period. In 1984, the majority of sockeye salmon recovered in the Northern District were tagged on 14 July. The Northern District set gill net fishery fished for four consecutive days starting on 16 July (Ruesch 1986), providing an excellent opportunity for recoveries. The majority of the sockeye salmon tag recoveries occurred on 18 July, four days after tagging (Appendix A.11). The distribution of tag recoveries relative to days out, adjusting for fishing time, suggest most fish had left the Northern District set gill net fishery by the fifth day. A migratory rate of 23.7 km/day (n=47) was computed for fish tagged in this specific set. In comparison, Northern District recoveries, for sockeye salmon tagged between 2 and 6 July, although limited in number (n=13), migrated at an average rate of 17.5 km/day (excludes one fish that had a calculated rate of 88 km/day). Again the mixed stock nature of the fishery makes individual river system comparisons impossible.

In summary, Cook Inlet sockeye salmon appear to reduce their migratory rate as they enter Upper Cook Inlet. The factors responsible for this behavior are not understood and therefore require further investigation. Recovery data for chum salmon, pink salmon, and coho salmon are inconclusive relative to this topic as the number of tagged fish recovered was limited. However, the extended period of chum salmon in the Central District (up to 8 days) and higher exploitation of this species would tend to suggest that a similar behavior pattern may occur.

Stock Composition

One of the major goals of the tagging program was to assess if individual purse seine sets provided any indication of temporal or spatial segregation of stocks in the Inlet. Based on the seine results, it is clear individual sockeye salmon stocks are mixed throughout the tagging areas, even within relatively small areas, providing little hope of geographic separation relative to commercial fisheries management strategies. For example, the individual set on 14 July 1984 (Appendix A.11) was composed of sockeye salmon bound for all three major rivers plus Fish Creek.

Unlike the results of Tyler and Noerenberg (undated) who observed migration of fish tagged in Cook Inlet out of the area, this investigation had no reported recoveries from other areas. The location of tagging may have had a significant impact on the observed results. Tyler and Noerenberg tagged a number of fish in Lower Cook Inlet and returns from a number of the areas outside the inlet were from these tagging sites. Tagging in 1983 and 1984 in Upper Cook Inlet may have allowed these stocks to separate and, therefore, the integrity of Upper Cook Inlet stocks was more secure. However, Tyler and Noerenberg did report that in late June of 1957, 25.7% of the sockeye salmon tagged on Chisik Island were recovered along the Alaska Peninsula outside Cook Inlet as far west as the Shumagin Islands. This was not evident in tagging from other periods.

Because of the recent large sockeye salmon returns to the Kenai and Kasilof Rivers, the proportion of Susitna River and other Northern District stocks in the eastside set gill net fishery was examined. Fishing time and effort directed at harvesting Kenai and Kasilof River sockeye salmon stocks has increased significantly over historical levels (P. Ruesch, ADF&G, Soldotna, personal communication). Cross et al. (1986, in press) estimated, using scale pattern analysis, the proportion of Susitna River stocks at between 5% and 25%. In an effort to independently look at this issue, tag returns from the 1984 Anchor Point tagging effort were examined along with an evaluation of Tyler and Noerenberg (undated) data.

A total of 23 sockeye salmon tagged at Anchor Point were recovered from Upper Cook Inlet stream systems. Of these, approximately 22% were recovered from Northern District streams. In evaluating these data, the relative effort spent in each system for tag recovery and the exploitation rate of the commercial fishery on individual stocks is relevant. Relative to recovery effort, the number of fish examined in the Northern District for tags approximated the number examined in the Central District. However, the exploitation rate for the various stocks differed. In 1984 Cross et al. (in press) estimated the exploitation rate of Kenai, Kasilof, and Susitna Rivers ranged from 63% to 72%. Fish Creek, in contrast, was only exploited at 33%. Even with these differences, the estimate of 22% is probably a reasonable estimate from the limited tagging effort.

A second source of independent data is the work of Tyler and Noerenberg (undated) who tagged sockeye salmon from commercial fish traps on all three eastside beaches. In 1955 approximately 20% of the commercial gill net returns for fish tagged on Kalifonsky Beach were recovered in the Northern District. Stream recoveries from the Northern District contributed 11% to the total stream returns. Similar data were generated in 1955 for Salamatof Beach. Fish tagged on 24 and 25 July were recovered predominantly in the Northern District (60%). Forty-six percent of the stream recoveries came from Northern District systems with Knik Arm streams contributing 92% of the Northern District returns. In 1958 the Northern District set gill net returns were only 6% (tagging period of 2 through 23 July). Approximately 19% of the fish tagged on Salamatof Beach were headed for Northern District stream systems. In contrast to Salamatof and Kalifonsky Beach, no set gill net recoveries from the Northern District were recorded for sockeye salmon tagged in 1957 at three trap sites near Clam Gulch.

From the above data it appears the Northern District component of the eastside set gill net fishery is highly variable, but not inconsistent with that estimated from scale pattern analysis.

Recovery Success

The presence of an extensive sockeye salmon counting system in select river systems in both 1983 and 1984 (weirs) and the Upper Cook Inlet stock separation program (Cross et al. 1986, in press) provided the opportunity to compare tag capture versus tag return rates based on a known exploitation rate. In 1983 the number of sockeye salmon returning to Upper Cook Inlet was estimated at 6,489,000 fish with an overall exploitation level of 78% by the commercial fishery (Cross et al. 1986). Total escapement was estimated at 1,383,700 fish with approximately 420,000 fish (30%) examined at weir and fishwheel sites for tags. In 1984 the total sockeye salmon return was 3.4 million fish of which 2.1 million fish (62%) were commercially harvested (Cross et al., in press). The sockeye salmon escapement in 1984 was estimated at 1,278,000 fish, of which approximately 39.6% were passed through weirs or fishwheels.

Assuming the tagging operation was random relative to the various stocks and tagging mortality was minimal, then the recovery of tagged sockeye salmon from the commercial fishery should have approximated the overall exploitation rates presented above. Only 38.8% in 1983 and 18.8% in 1984 of total fish tagged were recovered from the commercial fishery, instead of 78% and 62%. Thus, it appears that in 1983 only one out of every two tagged fish captured was returned and only one of three tagged fish captured was returned in 1984.

Stream recovery data suggested an even poorer recovery success for this aspect of the program. In 1983 and 1984 the stream recoveries were 35 and 32%, respectively, of the total tagged fish expected to enter monitored streams (the expected stream recoveries were determined by subtracting the expected commercial harvest of tagged fish from the total fish tagged and multiplying by the percent of escapement monitored). The reason for the poor return is unknown, but any of a number of variables could lead to this result. Foremost is the lack of recovery of tagged fish as they pass through a weir. While field crews were instructed to look for tags, the process of passing relatively large volumes of fish in short periods may have limited their ability to identify and recover tagged fish. In addition, the assumption relative to exploitation rates and tagging mortality may be oversimplified.

Exploitation Rate of Chum Salmon

Results of the chum salmon tagging effort in 1983 suggested that mid-inlet chum salmon stocks were exploited at a fairly high rate. The tag return from the commercial fishery was 52.5% which was the highest of any salmon species tagged (Appendix A.7). Unlike 1984 when most of the chum salmon tagged were from one set, in 1983 chum salmon were tagged in 71% of the mid-inlet sets. This occurred over the entire season, and the maximum number of fish tagged per set was 24 (Appendix A.4). The return of tagged fish for each day of tagging ranged from 0% to 100% (only one fish tagged on these days which comprised 3 days total). The remaining 9 days had tag returns ranging from 21% to 87.5% with a pattern of higher returns as the season progressed.

Examination of the distribution of the tag recoveries (Tarbox 1987) indicated tagged chum salmon remained in the Central District for up to 8 days or more even when tagged at the northern boundary of the Central District (the Central District drift gill net fleet was responsible for approximately 94% of the chum salmon harvest in 1983). Therefore, a longer residence time in the Central District and corresponding increased exposure to the drift gill net fishery could explain the higher tag return for chum salmon than for other species. Under-reporting of tags by the commercial fishery for chum salmon is also probable. Therefore, the overall exploitation rate is probably significanntly higher than the 52.5% tag return rate.

While the stress of tagging on chum salmon and thereby increasing exposure to the commercial fishery by retrograde migration is a possible explanation for the observed return rate, it is the authors' opinion this is unlikely. Independent studies, which estimated the number of chum salmon entering the Susitna River by mark/recapture techniques (ADF&G 1984), indicated the escapement of chum salmon into this system was at least 266,000 fish. Ruesch (1985) reported the 1983 Upper Cook Inlet chum salmon harvest was 1,115,000 fish, and the Susitna River drainage provided the majority of chum salmon for harvest. Ruesch (ADF&G, Soldotna, personal communication) further noted that escapement estimates for minor chum salmon streams were not available but escapement of an additional 100,000 fish into these streams would not be an unreasonable estimate. Therefore, assuming the total return of chum salmon to Upper Cook Inlet was 1.5 million fish, an exploitation rate of 75% would be realized.

Since the Central District drift gill net fleet is the primary harvester of chum salmon in Upper Cook Inlet, a central question is whether the drift gill net fleet could exploit a stock at 75% under existing management constraints. The intensive sockeye salmon studies conducted in Upper Cook Inlet provide a data base for a limited comparison. In 1983 Cross et al. (1986) reported that the drift gill net fleet harvested sockeye salmon stocks, and specifically Susitna River stocks, at approximately 50%. This exploitation rate for Susitna River sockeye salmon was repeated in 1984 and 1985 (Cross et al. in press). Thus, sockeye salmon stocks have not been exploited by the drift gill net fleet at a rate suggested for 1983 chum salmon stocks. However, the difference between 50 and 75% is certainly within a range which can be due to species behavioral differences in the Central District.

Feasibility of Chinook Salmon Tagging

The results of the Anchor Point effort have demonstrated chinook salmon can be successfully tagged in this nearshore area. However, the number of fish available for tagging was highly variable and, therefore, in some years few fish would be captured. In addition, recent evaluation of harvest data by Ruesch (ADF&G, Soldotna, personal communication) and Tarbox et al. (1987) indicated chinook salmon stocks may not be confined to the nearshore areas of the eastern Inlet. Therefore, tagged fish in this area may not be representative of the total Inlet return, but only a small segment of it.

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Table 1. Migratory rates of sockeye salmon tagged and recovered in Cook Inlet, Alaska in 1983.

District	Area	Mean Migratory Rate (km/day)	Standard Deviation	Sample Size
Northern	Fish Creek	8.9	2.9	3
Central	Salamatof Beach	16.9	12.8	69
	Kalifonsky Beach	14.0	11.0	40
	Cohoe Beach	13.4	13.5	30
	Ninilchik Beach	14.7	6.0	7
	Kenai River at Russian River weir	8.6	0.8	5
	Kenai River at Quartz Creek weir	13.0	12.0	2

Table 2. Migratory rates of sockeye salmon tagged and recovered in Cook Inlet, Alaska in 1984.

District	Area	Migratory Rate (km/day)	Standard Deviation	Sample Size
Northern	Beshta Bay	18.9	7.4	14
	Three Mile Beach	23.2	8.5	14
	Moose Point	28	16.6	26
	Fish Creek	11.3	5.1	48
	Susitna River at Sunshine	20.6	9.8	14
Central	Salamatof Beach	14.9	5.9	30
	Kalifonski Beach	14.4	8.9	49
	Cohoe Beach	14.2	11.9	38
	Ninilchik Beach	17.3	9.7	53
	Kenai River at Russian River weir	9.3	2.1	17
	Kenai River at Quartz Creek weir	7.2	1.1	10
Southern	China Poot	14.7	8.6	282
	Tutka Bay	7.8	6.8	4
	Eldred Passage	7.1	5.4	7
	Port Graham	26.7	16.2	4
	Halibut Cove	23.2	12.6	11

Table 3. Differential migratory rates of sockeye salmon tagged and recovered in Upper Cook Inlet, Alaska in 1983 (offshore).

	Salamatof Beach			Kalifonsky Beach			Cohoe Beach			Mid-Inlet[a]		
Tagging Period	Rate (km/day)	Standard Deviation	Sample Size	Rate (km/day)	Standard Deviation	Sample Size	Rate (km/day)	Standard Deviation	Sample Size	Rate (km/day)	Standard Deviation	Sample Size
10 July to 15 July	8.4	5.6	15	7.8	4.6	12	6.9	4.0	13	7.8	6.3	36
16 July to 20 July	21.4	13.5	44	18.5	12.4	22	20.3	16.1	15	19.5	31.0	72
After 20 July	9.7	6.6	10	9.9	6.0	6				13.1	12.6	34

[a] Drift gill net recoveries.

Table 4. Differential migratory rates of sockeye salmon tagged and recovered in Upper Cook Inlet, Alaska in 1984 (offshore tags only).

	Salamatof Beach			Kalifonsky Beach			Cohoe Beach			Mid-Inlet[a]		
Tagging Period	Rate (km/day)	Standard Deviation	Sample Size	Rate (km/day)	Standard Deviation	Sample Size	Rate (km/day)	Standard Deviation	Sample Size	Rate (km/day)	Standard Deviation	Sample Size
3 July to 8 July	17.1	4.5	14	15.3	5.6	21	12.6	4.0	17	9.5	5.8	113
12 July to 15 July	13.4	6.5	14	10.9	8.7	20	8.4	10.7	10	16.1	12.3	32

[a] Drift gill net recoveries

Table 5. Migratory rate of sockeye salmon tagged at Cape Igvak, Alaska and recovered in Upper Cook Inlet, Alaska in 1969 (ADF&G undated).

Date Tagged	Date Recovered	Days	Distance (km)[a]	Migratory Rate (km/day)
June 28	July 7	9	442	49.1
July 6	July 18	12	442	36.8
July 6	July 14	8	442	55.3
July 6	July 14	8	442	55.3
July 6	July 15	9	442	49.1
July 6	July 25	19	442	23.3
July 6	July 25	19	442	23.3
July 6	August 10	35	442	12.6
Mean		14.9	442	38.1

[a] Exact location of recoveries not reported. However, it is assumed that most recoveries came from the commercial fisheries since stream recovery location sites were limited in 1969. Therefore, a mid-inlet recovery location was assumed and a straight line distance path from Cape Igvak was followed.

Table 6. Migratory rate of sockeye salmon tagged at Kayak Island, Prince William Sound and recovered in Upper Cook Inlet, Alaska, 1985.

Tag Number	Date Tagged	Date Recovered	Distance Traveled (km)[a]	Migratory Rate (km/day)
13704	6/27	7/08	581	53
15077	6/28	7/12	581	42
15105	6/28	7/10	571	48
15155	6/29	7/19	581	29
15315	6/30	7/15	581	39
15332	7/04	7/16	581	48
15343	7/04	7/15	581	53
15389	7/04	7/25	739	35
15464	7/04	7/24	586	29
		Mean		41.8

[a] Migratory distance was calculated using the minimum water distance from tagging location to recovery location. Therefore, migratory rates represents a minimum estimate. Tagging dates were provided by McCurdy (ADF&G, Cordova, personal communication).

Table 7. Migratory rates of coho, pink, and chum salmon tagged and recovered in Cook Inlet, Alaska in 1983 and 1984 (offshore only).

Year	Species	Migratory Rate (km/day)	Standard Deviation	Sample Size
1983	Coho Salmon	9.1	7.5	24
	Chum Salmon	13.5	12.3	94
	Pink Salmon	43.2	3.5	3
1984	Coho Salmon	15.8	7.6	16
	Chum Salmon	18.6	12.3	8
	Pink Salmon	31.0	15.6	4[a]

[a] Includes two fish from Anchor Point tagging recovered on Ninilchik Beach.

Table 8. Data collected on chinook salmon tagged and recovered in Upper Cook Inlet, Alaska in 1984 (Anchor Point).

Date Tagged	Date Recovered	Location	Migratory Rate (km/day)
7/09[a]	7/25	Kenai River(10.0km)	5.6
	8/13	Kenai River(119.2km)	5.7 (5.7 in river)
7/10[a]	8/13	Kenai River(0.0km)	2.3
7/15	7/19	Kenai River(14.5km)	23.4
7/15	7/22	Kenai River(14.5km)	13.3
7/15	7/31	Kenai River(12.9km)	5.7
7/15	7/17	No location noted(set gillnet)	

[a] Radio tagged.

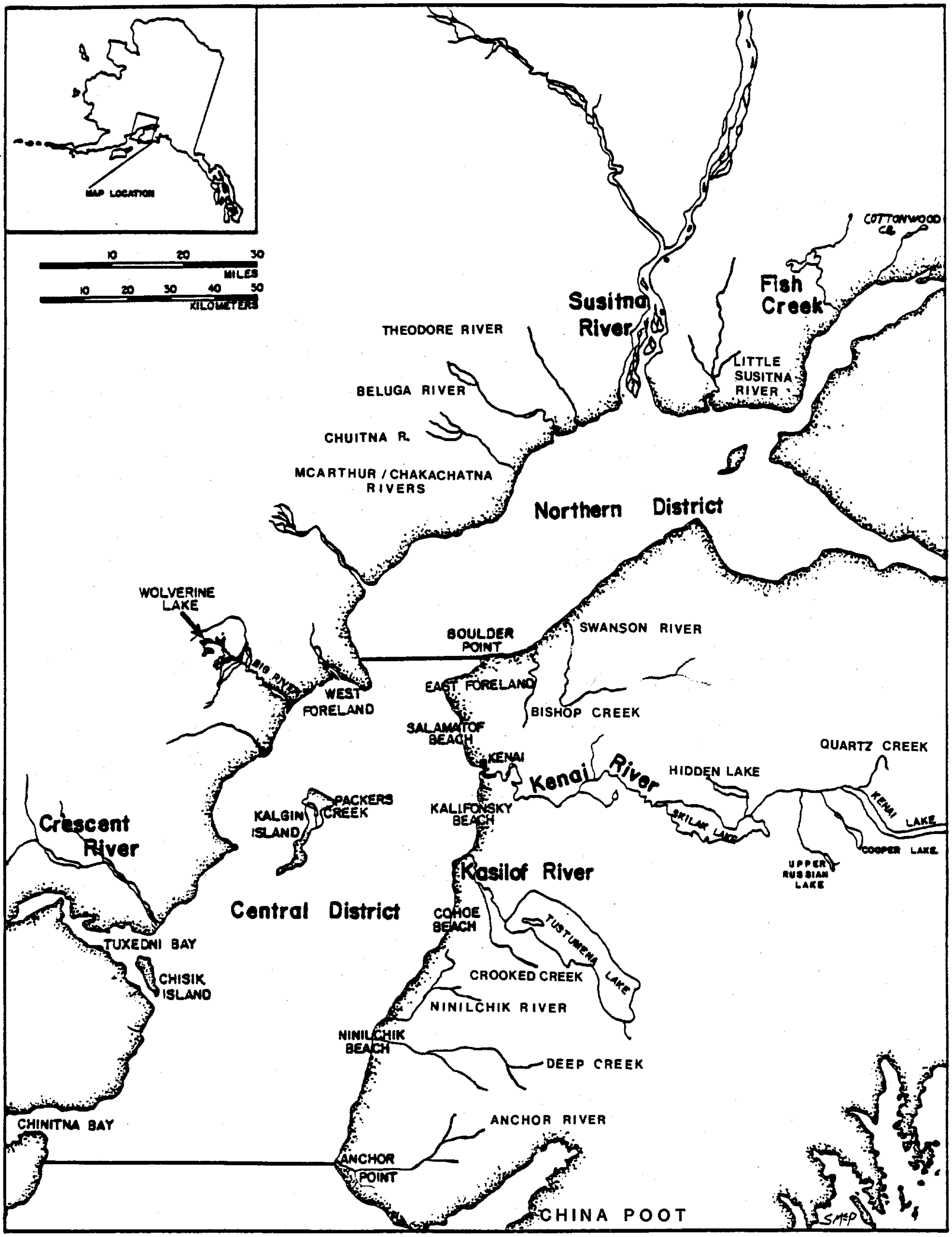


Figure 1. The Upper Cook Inlet area showing the locations of the Northern and Central Districts and the major sockeye salmon spawning drainages.

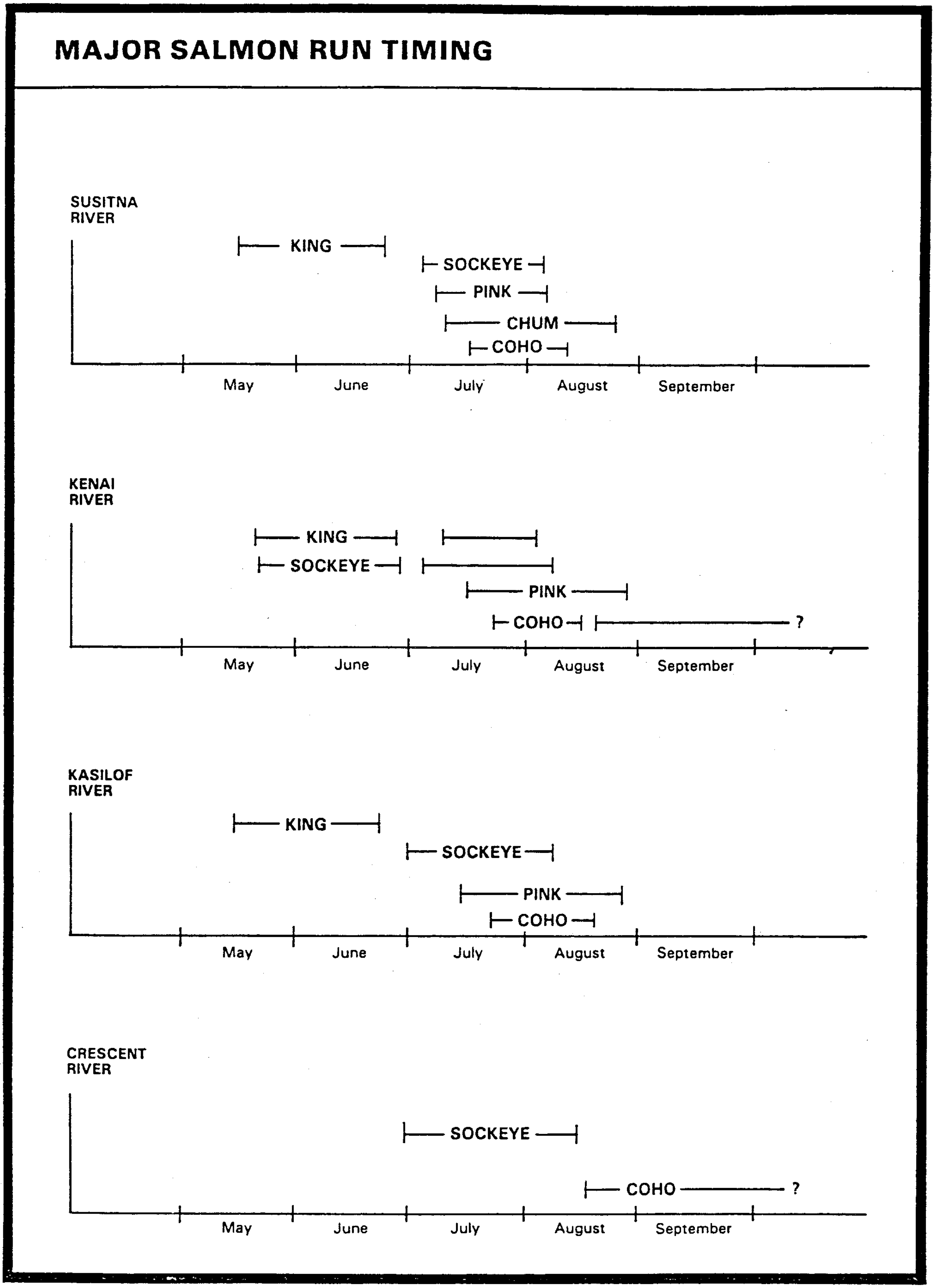


Figure 2. Run timing of the major salmon stocks within Cook Inlet, Alaska. Source: P. Ruesch, ADF&G, Soldotna, personal communication.

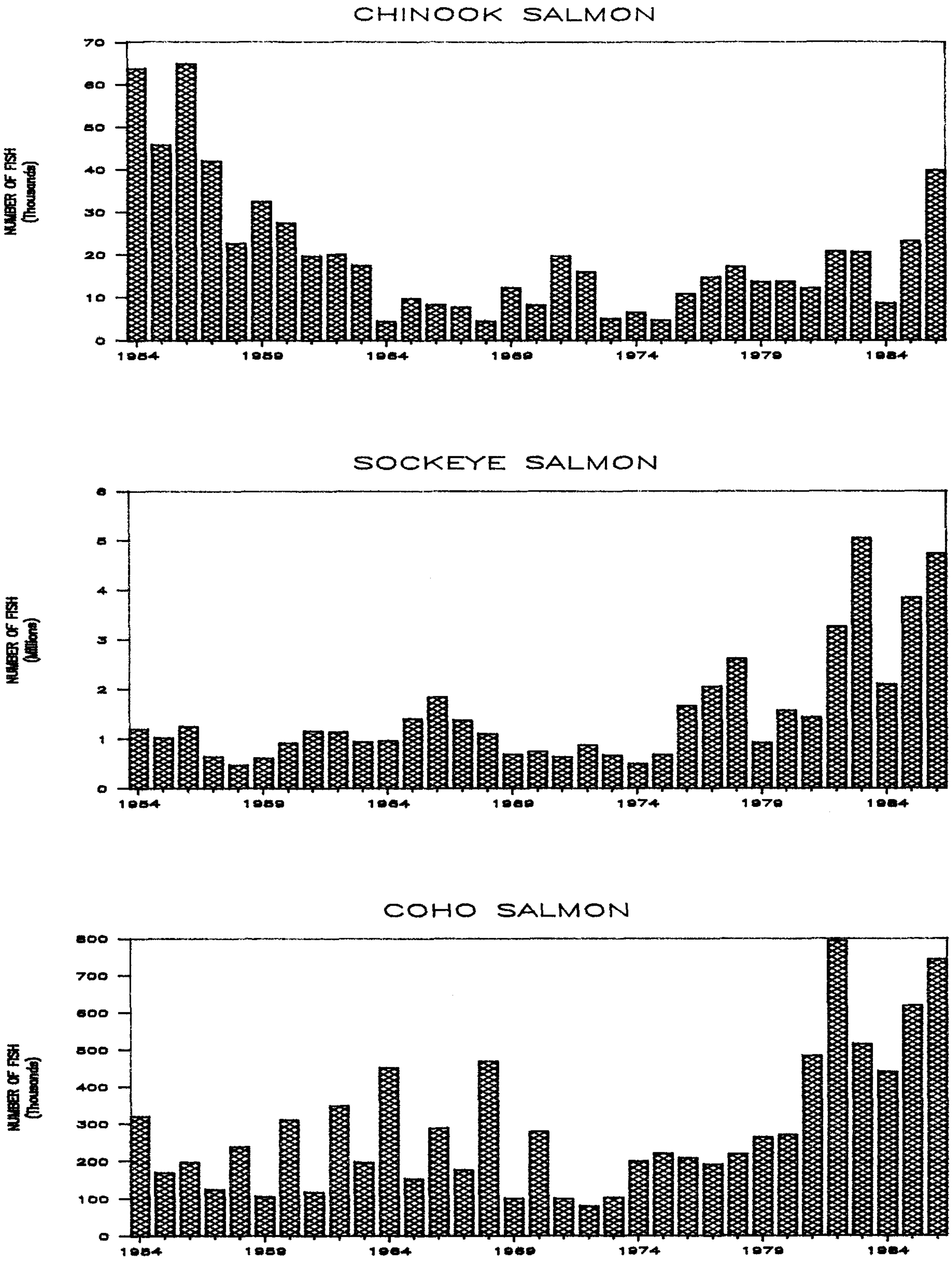


Figure 3. Number of chinook, sockeye, and coho salmon commercially harvested in Upper Cook Inlet, Alaska, 1954-1987. Source: P. Ruesch, ADF&G, Soldotna, personal communication.

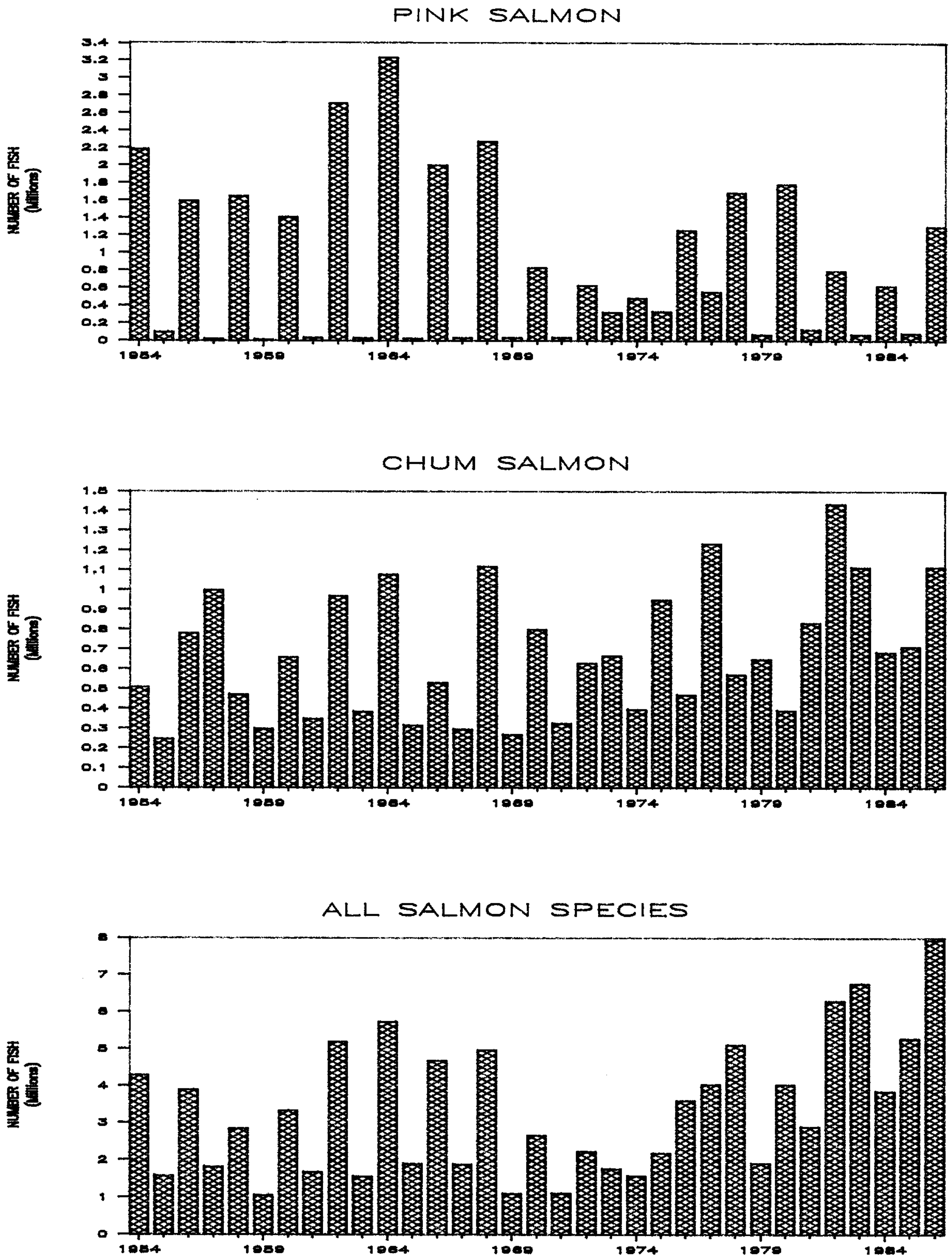


Figure 4. Number of pink and chum salmon and all salmon combined commercially harvested in Upper Cook Inlet, Alaska, 1954-1987. Source: P. Ruesch, ADF&G, Soldotna, personal communication.

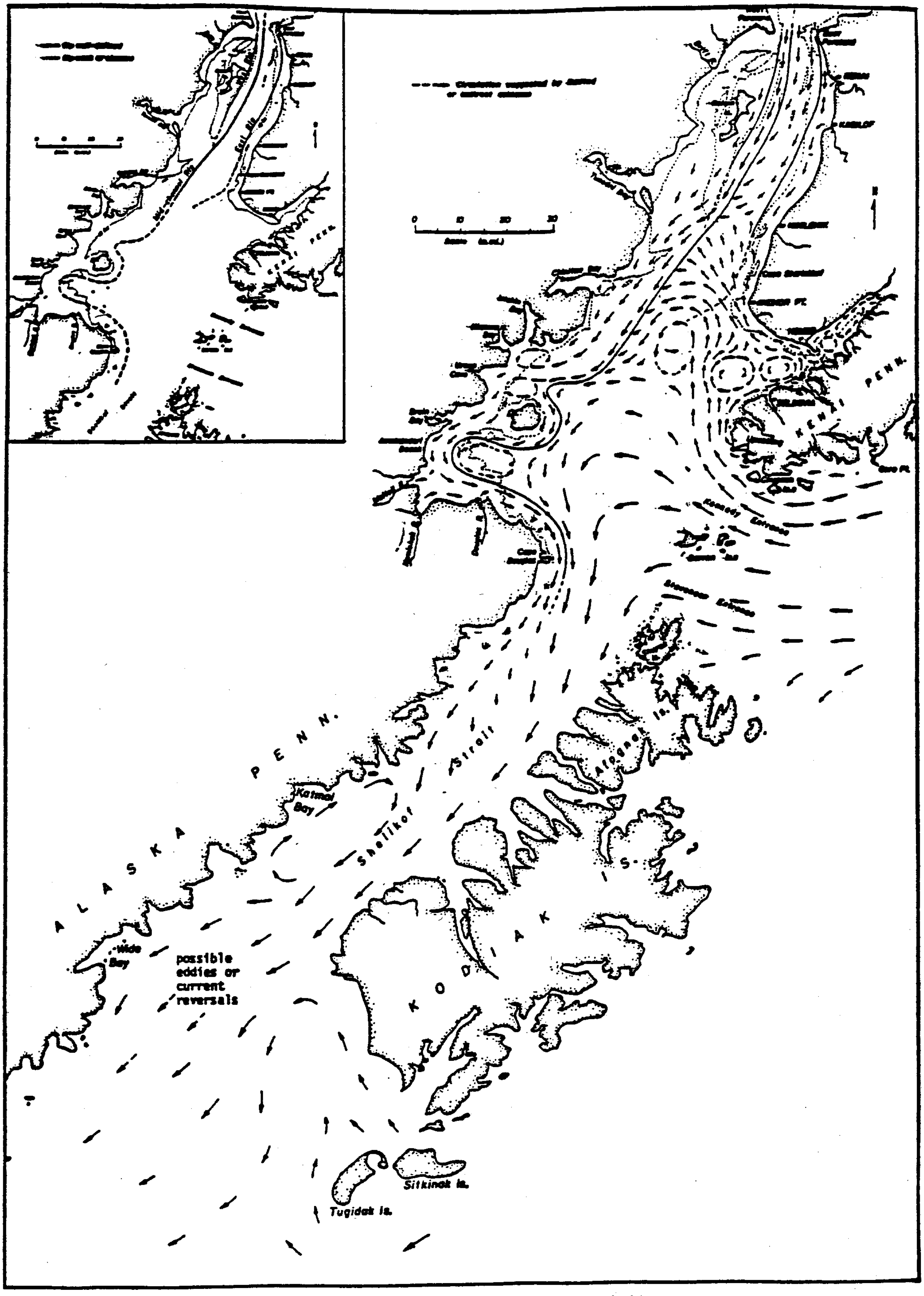
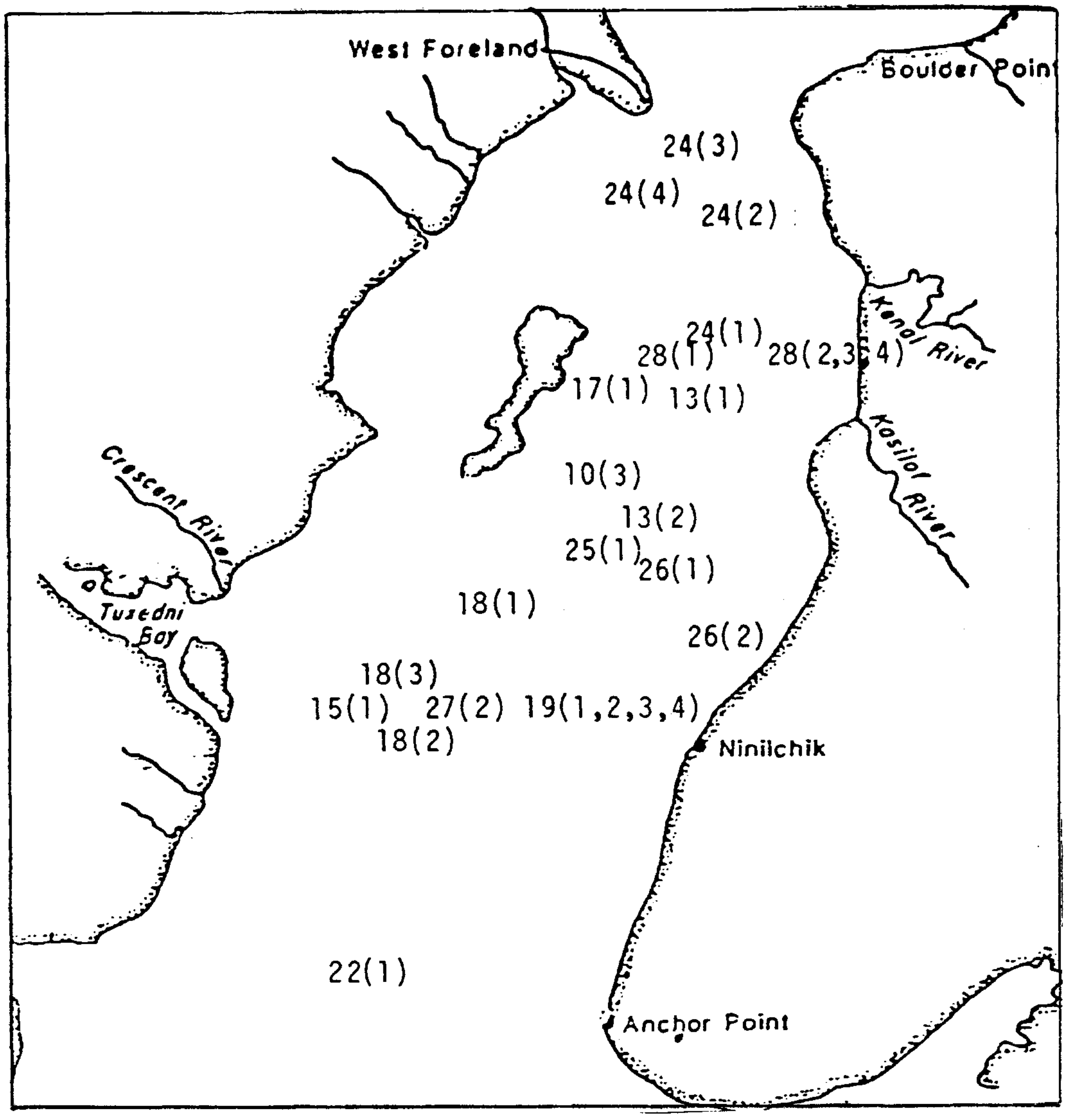
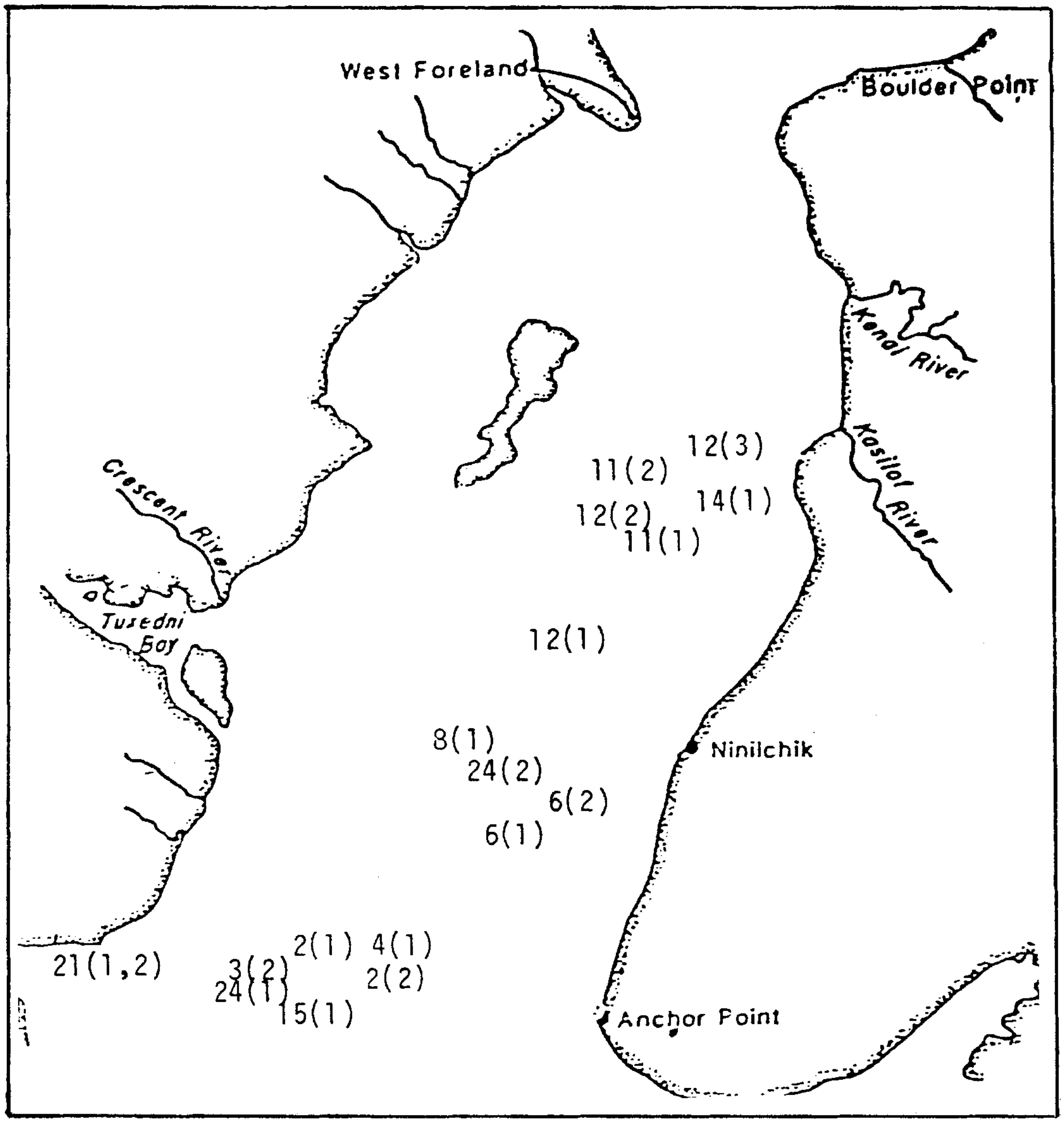


Figure 5. Surface circulation in Lower Cook Inlet and Shelikof Strait, based primarily on data collected during the spring, summer, and early fall seasons. Source: ADF&G, 1978.

APPENDICES



Appendix A.1. Tagging location and date of individual purse seine sets made in Upper Cook Inlet, Alaska, 1983. (NOTE: 18(1) - 18 refers to date; (1) refers to set number).



Appendix A.2. Tagging location and date of individual purse seine sets made in Upper Cook Inlet, Alaska, 1984. (NOTE: 11(2) - 11 refers to date; (2) refers to set number).

Appendix A.3. Analysis of condition factors assigned to tagged salmon in Upper Cook Inlet, Alaska 1983 and 1984 (offshore).

Date		Condition Factor (Percent of Fish) 1	2	3	4	Sample Size
7/3	Tagged	6.7	11.1	33.3	48.9	45
	Recovered	14.3	9.5	28.6	47.6	21
7/4	Tagged	4.4	14	42.1	39.5	114
	Recovered	8	12	28	52	25
7/6	Tagged	6.7	6.7	46.7	40	15
	Recovered	0	0	50	50	4
7/8	Tagged	0	40	40	20	5
	Recovered	0	0	100	0	1
7/12	Tagged	0.5	7.2	29	63.2	193
	Recovered	0	8.3	16.6	75	12
7/14	Tagged	0	1.1	18.9	79.8	179
	Recovered	0	0	16.2	83.7	37
7/15	Tagged	0	0	0	100	21
	Recovered	0	0	0	100	3
7/24	Tagged	0	0	0	100	10
	Recovered	0	0	0	100	2
Total 1984	Tagged	1.7	6.8	27.8	63.5	582
	Recovered	4.7	5.7	22.8	66.6	105
	Difference	+3.0	-1.1	-5.0	+3.1	
Total[a] 1983	Tagged	3.1	3.1	35.4	58.4	257
	Recovered	1.1	2.2	37	59.7	89
	Difference	-2.0	-0.9	+1.6	+1.3	

[a] By date analysis not completed in 1983 because of small sample size.
Condition factor: 1 = poor, 4 = good.

Appendix A.4. Summary of salmon species tagged and recovered in Upper Cook Inlet, Alaska during July, 1983 (offshore).

		Sockeye Salmon		Chum Salmon		Coho Salmon		Pink Salmon		Total Salmon	
Date	Set	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recapture
7/10	1	0	0	0	0	0	0	0	0	0	0
	2	1	0	0	0	3	0	0	0	4	0
	3	174	63	14	3	25	8	4	0	217	74
7/13	1	15	5	0	0	0	0	0	0	15	5
	2	18	5	16	4	2	2	0	0	36	11
7/15	1	45	21	1	0	2	0	1	0	49	21
7/17	1	8	4	10	4	0	0	1	0	19	8
7/18	1	64	36	14	10	19	4	16	0	113	50
	2	43	25	0	0	8	4	0	0	51	29
	3	4	3	8	4	0	0	2	0	14	7
7/19	1	79	32	7	1	3	0	5	1	94	34
	2	44	20	2	1	0	0	5	0	51	21
	3	41	23	0	0	0	0	1	0	42	23
	4	91	46	4	2	1	0	2	1	98	49
7/21	1	4	0	26	2	9	1	0	0	39	3
	2	1	0	201	12	5	2	0	0	207	14
7/22	1	5	2	0	0	0	0	1	0	6	2
7/24	1	31	12	1	1	1	0	3	0	36	13
	2	15	4	24	19	2	1	3	0	44	24
	3	13	5	20	15	0	0	0	0	33	20
	4	2	2	3	1	0	0	1	0	6	3
	5	0	0	1	0	0	0	0	0	1	0

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Appendix A.4. (p. 2 of 2)

		Sockeye Salmon		Chum Salmon		Coho Salmon		Pink Salmon		Total Salmon	
Date	Set	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured
7/25	1	6	1	1	0	0	0	2	0	9	1
7/26	1	8	4	7	7	1	0	1	0	17	11
	2	9	3	1	0	0	0	1	0	11	3
7/27	1	0	0	0	0	0	0	2	1	2	1
	2	5	2	3	2	0	0	0	0	8	4
	3	1	0	4	3	0	0	0	0	5	3
7/28	1	15	7	24	11	14	2	2	0	55	20
	2	31	9	20	11	8	3	3	0	62	23
	3	44	10	9	7	9	1	1	0	63	18
	4	10	4	5	3	0	0	0	0	15	7
7/30	1	3	0	0	0	0	0	0	0	3	0
7/31	1	3	0	1	1	0	0	0	0	4	1
	2	0	0	0	0	0	0	0	0	0	0
	3	3	0	0	0	0	0	1	0	4	0
Total		836	348	427	124	112	28	58	3	1433	503
Percent			41.6%		29.0%		25.0%		5.2		35.1%

Appendix A.5. Summary of salmon species tagged and recovered in Upper Cook Inlet, Alaska during July, 1984 (offshore program).

		Sockeye Salmon		Chum Salmon		Coho Salmon		Pink Salmon		Total Salmon	
Date	Set	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recapture
7/02	1	2	2	0	0	0	0	0	0	2	2
	2	52	13	0	0	1	0	1	0	54	13
7/03	1	0	0	0	0	0	0	0	0	0	0
	2	218	79	2	1	2	1	0	0	222	81
7/04	1	589	150	3	0	6	2	0	0	598	152
7/06	1	4	2	0	0	0	0	0	0	4	2
	2	73	28	2	1	0	0	0	0	75	29
7/08	1	47	16	8	0	3	1	4	0	62	17
7/11	1	1	0	0	0	0	0	0	0	1	0
	2	3	0	3	1	1	0	2	0	9	1
7/12	1	33	12	2	1	3	1	0	0	38	14
	2	32	10	26	3	2	1	0	0	60	14
	3	329	26	566	32	54	4	16	2	965	64
7/14	1	860	218	32	4	61	14	32	3	985	239
7/15	1	141	35	1	1	2	0	7	0	151	36
7/24	1	8	2	5	2	1	0	19	2	33	6
	2	2	1	1	0	0	0	29	3	32	4
TOTAL		2394	594	651	46	136	24	110	10	3291	674
PERCENT			24.8%		7.1%		17.6%		9.1%		20.5%

Appendix A.6. Summary of salmon species tagged and recovered in Upper Cook Inlet, Alaska during July, 1984 (Anchor Point).

		Sockeye Salmon		Chinook Salmon		Coho Salmon		Pink Salmon		Total Salmon	
Date	Set	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured
7/07	1	25	19	0	0	0	0	3	1	28	20
7/08	1	51	31	0	0	1	0	4	1	56	32
7/09	1	14	4	0	0	0	0	2	0	16	4
	2	54	29	1	1	0	0	5	2	60	32
	3	7	5	0	0	0	0	15	3	22	8
7/10	1	70	35	5	1	0	0	5	1	80	37
7/11	1	8	5	0	0	0	0	2	0	10	5
	2	8	7	0	0	0	0	0	0	8	7
	3	3	2	0	0	0	0	2	1	5	3
7/12	1	46	18	1	0	0	0	2	0	49	18
7/13	1	11	6	0	0	0	0	0	0	11	6
	2	13	7	0	0	0	0	3	0	16	7
7/14	1	60	29	0	0	1	0	6	1	67	30
7/15	1	37	20	0	0	1	0	11	2	49	22
	2	18	9	14	4	0	0	2	0	34	13
	3	85	42	2	0	1	1	7	1	95	44
7/16	1	197	129	1	0	0	0	0	0	198	129
	2	9	7	1	0	0	0	0	0	10	7
7/17	1	168	107	0	0	0	0	1	0	169	107
	2	84	56	1	0	0	0	8	0	93	56
TOTAL		968	567	26	6	4	1	78	13	1076	587
PERCENT			58.6%		23.1%		25.0%		16.7%		54.6%

Appendix A.7. Summary of the tag recoveries by location and gear type from tagged adult salmon released in Upper Cook Inlet, Alaska, 1983 (offshore).

Species	Fishing District	Number of Recaptpures by Gear Type			Number of Recaptures from River Systems	Number of Recaptures with no Location Reported[a]
		Purse Seine	Drift Gill Net	Set Gill Net		
Sockeye Salmon	Northern	0	0	6	3	7
	Central	0	150	166	16	
	Southern	0	0	0	0	
	Total	0	150	172	19	
	Percent[b]	0.00%	18.05%	20.70%	2.29%	0.84%
Chum Salmon	Northern	0	0	2	1	3
	Central	0	97	6	1	
	Southern	0	0	0	0	
	Total	0	97	8	2	
	Percent[b]	0.00%	48.50%	4.00%	1.00%	1.50%
Coho Salmon	Northern	0	0	2	1	3
	Central	0	13	6	0	
	Southern	0	0	0	0	
	Total	0	13	8	1	
	Percent[b]	0.00%	13.27%	8.16%	1.02%	3.06%
Pink Salmon	Northern	0	0	2	0	0
	Central	0	1	0	0	
	Southern	0	0	0	0	
	Total	0	1	2	0	
	Percent[b]	0.00%	1.72%	3.45%	0.00%	0.00%
All Species	Northern	0	0	12	5	13
	Central	0	261	178	17	
	Southern	0	0	0	0	
	Total	0	261	190	22	
	Percent[b]	0.00%	21.99%	16.01%	1.85%	1.10%

[a] Placed in Northern District row for representation only.

[b] Percent of total fish tagged, excludes Chinitna Bay tags in all calculations as these were isolated to a specific area.

Appendix A.8. Freshwater recoveries of sockeye salmon tagged in Upper Cook Inlet, Alaska in 1983 and 1984 (offshore).

Date	Kenai River			Kasilof River			Fish Creek	Susitna River	Other	Total
	Russian	Quartz	Mainstem	Bear	Glacier Flat	Other				
10July83	3	1	1	0	3	0	2	0	0	10
18July83	1	0	0	0	0	0	0	0	0	1
18July83	0	0	1	1	1	0	0	0	0	3
18July83	1	0	0	0	0	0	0	0	0	1
19July83	1	0	0	0	0	0	0	0	0	1
19July83	0	1	0	0	0	0	0	0	0	1
24July83	0	0	0	0	0	0	1	0	0	1
27July83	0	0	1	0	0	0	0	0	0	1
Total	6	2	3	1	4	0	3	0	0	19
02July84	0	0	0	1	0	0	2	0	1	4
03July84	2	1	0	4	2	3	6	1	1	20
04July84	4	0	2	3	1	3	1	1	1	16
06July84	1	0	0	2	0	0	0	0	0	3
08July84	0	0	0	0	0	0	0	1	0	1
12July84	3	0	0	0	1	0	1	1	0	6
12July84	1	0	0	0	0	1	2	0	1	5
12July84	0	1	0	0	1	0	4	2	2	10
14July84	4	8	0	0	2	0	30	15	4	63
15July84	1	0	0	0	0	0	0	0	0	1
24July84	1	0	0	0	0	0	0	0	0	1
24July84	0	0	0	0	0	0	1	0	0	1
Total	17	10	2	10	7	7	47	21	10	131

Appendix A.9. Summary of the tag recoveries by location and gear type from tagged adult salmon released in Upper Cook Inlet, Alaska, 1984 (offshore).

Species	Fishing District	Number of Recaptures by Gear Type			Number of Recaptures from River Systems	Number of Recaptures with no Location Reported[a]
		Purse Seine	Drift Gill Net	Set Gill Net		
Sockeye Salmon	Northern	0	0	82	77	13
	Central	0	169	190	54	
	Southern	9	0	0	0	
	Total	9	169	272	131	
	Percent[b]	0.38%	7.06%	11.36%	5.47%	0.54%
Chum Salmon	Northern	0	0	2	32	1
	Central	0	8	1	2	
	Southern	0	0	0	0	
	Total	0	8	3	34	
	Percent[b]	0.00%	1.23%	0.46%	5.22%	0.15%
Coho Salmon	Northern	0	0	7	5	0
	Central	0	8	3	1	
	Southern	0	0	0	0	
	Total	0	8	10	6	
	Percent[b]	0.00%	5.88%	7.35%	4.41%	0.00%
Pink Salmon	Northern	0	0	2	7	0
	Central	0	0	0	1	
	Southern	0	0	0	0	
	Total	0	0	2	8	
	Percent[b]	0.00%	0.00%	1.82%	7.27%	0.00%
All Species	Northern	0	0	93	121	14
	Central	0	185	194	58	
	Southern	9	0	0	0	
	Total	9	185	287	179	
	Percent[b]	0.27%	5.62%	8.72%	5.44%	0.43%

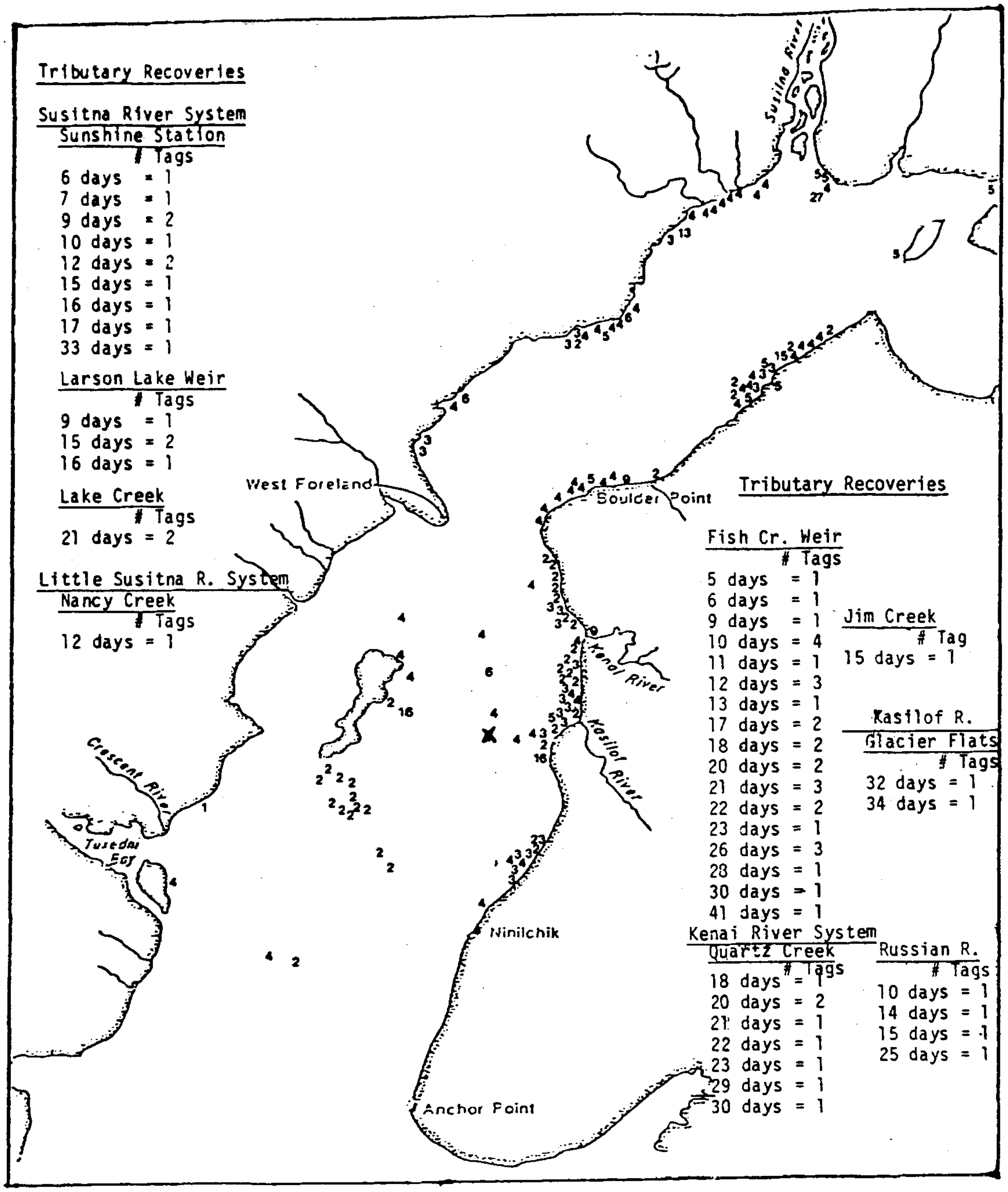
[a] Placed in Northern District row for representation only.

[b] Percent of total fish tagged.

Appendix A.10. Summary of the tag recoveries by location and gear type from tagged adult salmon released in Upper Cook Inlet, Alaska, 1984 (Anchor Point).

Species	Fishing District	Purse Seine	Number of Recaptures by Gear Type: Drift Gill Net	Set Gill Net	Number of Recaptures from River Systems	Number of Recaptures with no Location Reported[a]
Sockeye Salmon	Northern	0	0	6	0	8
	Central	0	14	104	23	
	Southern	411	0	1	0	
	Total	411	14	111	23	
	Percent[b]	42.46%	1.45%	11.47%	2.38%	0.83%
Chinook Salmon	Northern	0	0	0	0	0
	Central	0	0	1	5	
	Southern	0	0	0	0	
	Total	0	0	1	5	
	Percent[b]	0.00%	0.00%	3.85%	19.23%	0.00%
Coho Salmon	Northern	0	0	0	0	0
	Central	0	0	0	0	
	Southern	0	0	1	0	
	Total	0	0	1	0	
	Percent[b]	0.00%	0.00%	25.00%	0.00%	0.00%
Pink Salmon	Northern	0	0	1	1	0
	Central	0	0	2	0	
	Southern	9	0	0	0	
	Total	9	0	3	1	
	Percent[b]	11.54%	0.00%	3.85%	1.28%	0.00%
All Species	Northern	0	0	7	1	8
	Central	0	14	107	28	
	Southern	420	0	2	0	
	Total	420	14	116	29	
	Percent[b]	39.03%	1.30%	10.78%	2.70%	0.74%

[a] Placed in Northern District row for representation only.
[b] Percent of total fish tagged.



Appendix A.11. Location (X) of a single purse seine set on 14 July that resulted in the tagging and release of 860 sockeye salmon. Each number on the map represents the recovery of a single tag - the number indicates days passed since release on 14 July 1984.

Appendix A.12. Migratory rate of sockeye salmon tagged in Upper Cook Inlet, Alaska from 1949-1958 and reported on by Tyler and Noerenberg (undated).

Location of Tagging	Tagging Date	Migratory Rate (km/day)[a]	Sample Size
Chisik Island Trap	July 12, 1949	8.0	42
	July 24, 1955	9.3	16
	June 28, 1957	15.0	1
	June 29, 1957	13.6	18
	July 13, 1957	9.3	1
Chisik Island Seine	July 05, 1954	7.8	8
	July 07, 1954	10.3	70
	July 12, 1954	12.2	50
	July 13, 1954	9.7	45
Kalgin Island Seine	July 06, 1954	3.1	1
	July 09, 1954	5.1	60
	July 11, 1954	7.8	108
	July 13, 1954	4.6	12
	July 14, 1954	7.4	47
	July 16, 1954	7.0	8
	July 17, 1954	4.8	7
Kalgin Island Trap	July 17, 1955	18.8	17
	July 17, 1957	3.2	16

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Location of Tagging	Tagging Date	Migratory Rate (km/day)[a]	Sample Size
Kalgin Island Trap	July 02, 1958	1.0	7
	July 05, 1958	4.0	4
	July 06, 1958	1.9	22
	July 07, 1958	0.8	5
	July 12, 1958	5.9	28
	July 13, 1958	4.3	5
	July 14, 1958	2.4	36
	July 16, 1958	1.9	18
	July 17, 1958	1.2	39
	July 18, 1958	10.6	8
	July 19, 1958	4.0	20
	July 20, 1958	2.4	5
	July 23, 1958	9.7	8
	July 24, 1958	1.6	43

[a] Tyler and Noerenberg reported mean days out to capture and mean miles traveled and, therefore, the rates calculated in this table represent a simple division of these two parameters. Individual calculation for each tag return was not possible or variance calculations feasible.

Appendix A.13. Migratory rate of sockeye salmon tagged at Kayak Island, Alaska in 1985 and and recovered in Prince William Sound, Alaska.[a]

Tag No.	Tag Date	Recovery Location[b]	Recovery Date	Days Out	Migratory Distance (km)	Migratory Distance (km)	Rate (km/day)	Rate (km/day)
15071	6/28	22130000	7/01/85	3.0	148.0	167.0	49.3	55.7
13486	6/27	22130000	7/02/85	5.0	148.0	167.0	29.6	33.4
15754	7/07	22130000	7/17/85	10.0	148.0	167.0	14.8	16.7
15461	7/04	22130000	7/16/85	12.0	148.0	167.0	12.3	13.9
			Mean	7.5	148.0	167.0	26.5	29.9
			Variance	17.7	0.0	0.0	289.5	368.6
			SD	4.2	0.0	0.0	17.0	19.2
15097	6/28	22140000	7/01/85	3.0	167.0	200.0	55.7	66.7
15195	6/29	22140000	7/02/85	3.0	167.0	200.0	55.7	66.7
15092	6/28	22140000	7/02/85	4.0	167.0	200.0	41.8	50.0
15358	7/04	22140000	7/10/85	6.0	167.0	200.0	27.8	33.3
13573	6/27	22140000	7/01/85	4.0	167.0	200.0	41.8	50.0
13791	6/27	22140000	7/02/85	5.0	167.0	200.0	33.4	40.0
15169	6/29	22140000	7/01/85	2.0	167.0	200.0	83.5	100.0
15034	6/28	22140000	7/01/85	3.0	167.0	200.0	55.7	66.7
15253	6/30	22140000	7/02/85	2.0	167.0	200.0	83.5	100.0
13790	6/27	22140000	7/01/85	4.0	167.0	200.0	41.8	50.0
13535	6/27	22140000	7/01/85	4.0	167.0	200.0	41.8	50.0
13795	6/27	22140000	7/02/85	5.0	167.0	200.0	33.4	40.0
			Mean	3.8	167.0	200.0	49.6	59.4
			Variance	1.5	0.0	0.0	332.2	476.4
			SD	1.2	0.0	0.0	18.2	21.8
15094	6/28	22150000	7/02/85	4.0	187.0	206.0	46.8	51.5
13666	6/27	22150000	7/02/85	5.0	187.0	206.0	37.4	41.2
15283	6/30	22150000	7/11/85	11.0	187.0	206.0	17.0	18.7
15120	6/29	22150000	7/11/85	12.0	187.0	206.0	15.6	17.2
13772	6/27	22150000	7/02/85	5.0	187.0	206.0	37.4	41.2
15079	6/28	22150000	7/12/85	14.0	187.0	206.0	13.4	14.7
13641	6/27	22150000	7/11/85	14.0	187.0	206.0	13.4	14.7
15159	6/29	22150000	7/02/85	3.0	187.0	206.0	62.3	68.7
			Mean	8.5	187.0	206.0	30.4	33.5
			Variance	22.0	0.0	0.0	337.9	410.0
			SD	4.7	0.0	0.0	18.4	20.2

- Continued -

Tag No.	Tag Date	Recovery Location[b]	Recovery Date	Days Out	Migratory Distance (km)	Migratory Distance (km)	Rate (km/day)	Rate (km/day)
13706	6/27	22300000	7/05/85	8.0	212.0	264.0	26.5	33.0
15502	7/04	22300000	7/24/85	20.0	212.0	264.0	10.6	13.2
15162	6/29	22300000	7/09/85	10.0	212.0	264.0	21.2	26.4
15119	6/29	22300000	7/03/85	4.0	212.0	264.0	53.0	66.0
13150	6/22	22300000	7/08/85	16.0	212.0	264.0	13.3	16.5
15090	6/28	22300000	7/06/85	8.0	212.0	264.0	26.5	33.0
13595	6/27	22300000	7/11/85	14.0	212.0	264.0	15.1	18.9
15014	6/28	22300000	7/06/85	8.0	212.0	264.0	26.5	33.0
13661	6/27	22300000	7/05/85	8.0	212.0	264.0	26.5	33.0
13688	6/27	22300000	7/03/85	6.0	212.0	264.0	35.3	44.0
13550	6/27	22300000	7/03/85	6.0	212.0	264.0	35.3	44.0
15421	7/04	22300000	7/12/85	8.0	212.0	264.0	26.5	33.0
13750	6/27	22300000	7/03/85	6.0	212.0	264.0	35.3	44.0
15291	6/30	22300000	7/06/85	6.0	212.0	264.0	35.3	44.0
15705	7/07	22300000	7/12/85	5.0	212.0	264.0	42.4	52.8
15270	6/30	22300000	7/09/85	9.0	212.0	264.0	23.6	29.3
13213	6/22	22300000	7/23/85	31.0	212.0	264.0	6.8	8.5
13365	6/23	22300000	7/01/85	8.0	212.0	264.0	26.5	33.0
15706	7/07	22300000	7/15/85	8.0	212.0	264.0	26.5	33.0
			Mean	9.9	212.0	264.0	27.0	33.6
			Variance	41.5	0.0	0.0	124.6	193.3
			SD	6.4	0.0	0.0	11.2	13.9
13693	6/27	22330322	7/12/85	15.0	265.0		17.7	
13556	6/27	22330322	7/05/85	8.0	265.0		33.1	
15115	6/29	22330322	7/08/85	9.0	265.0		29.4	
15299	6/30	22330322	7/09/85	9.0	265.0		29.4	

- Continued -

Tag No.	Tag Date	Recovery Location[b]	Recovery Date	Days Out	Migratory Distance (km)	Migratory Distance (km)	Rate (km/day)	Rate (km/day)
15313	6/30	22330322	7/13/85	13.0	265.0		20.4	
13445	6/23	22330322	7/07/85	14.0	265.0		18.9	
13518	6/27	22330322	7/05/85	8.0	265.0		33.1	
13703	6/27	22330322	7/05/85	8.0	265.0		33.1	
15255	6/30	22330322	7/07/85	7.0	265.0		37.9	
15609	7/06	22330322	7/13/85	7.0	265.0		37.9	
15334	7/04	22330322	7/12/85	8.0	265.0		33.1	
13668	6/27	22330322	7/06/85	9.0	265.0		29.4	
15434	7/04	22330322	7/11/85	7.0	265.0		37.9	
13771	6/27	22330322	7/11/85	14.0	265.0		18.9	
15262	6/30	22330322	7/09/85	9.0	265.0		29.4	
13664	6/27	22330322	7/05/85	8.0	265.0		33.1	
13402	6/23	22330322	7/04/85	11.0	265.0		24.1	
13171	6/22	22330322	7/03/85	11.0	265.0		24.1	
15354	7/04	22330322	7/13/85	9.0	265.0		29.4	
15422	7/04	22330322	7/10/85	6.0	265.0		44.2	
13244	6/22	22330322	7/02/85	10.0	265.0		26.5	
15260	6/30	22330322	7/19/85	19.0	265.0		13.9	
15252	6/30	22330322	7/13/85	13.0	265.0		20.4	
15371	7/04	22330322	7/13/85	9.0	265.0		29.4	
13788	6/27	22330322	7/14/85	17.0	265.0		15.6	
13463	6/23	22330322	7/06/85	13.0	265.0		20.4	
15362	7/04	22330322	7/12/85	8.0	265.0		33.1	
13246	6/22	22330322	7/02/85	10.0	265.0		26.5	
15025	6/28	22330322	7/05/85	7.0	265.0		37.9	
13512	6/27	22330322	7/11/85	14.0	265.0		18.9	
13578	6/27	22330322	7/12/85	15.0	265.0		17.7	
13327	6/23	22330322	7/05/85	12.0	265.0		22.1	
15001	6/28	22330322	7/12/85	14.0	265.0		18.9	
15136	6/29	22330322	7/06/85	7.0	265.0		37.9	
15009	6/28	22330322	7/07/85	9.0	265.0		29.4	
13364	6/23	22330322	7/04/85	11.0	265.0		24.1	
15642	7/06	22330322	7/23/85	17.0	265.0		15.6	
15038	6/28	22330322	7/05/85	7.0	265.0		37.9	
15747	7/07	22330322	7/17/85	10.0	265.0		26.5	
15116	6/29	22330322	7/13/85	14.0	265.0		18.9	
			Mean	10.7	265.0		27.2	
			Variance	11.0	0.0		61.0	
			SD	3.3	0.0		7.8	

[a] Recovery location - ADF&G statistical area; for example, 22330322 is Coghill River weir.
[b] Source of data - Mike McCurdy (personal communication).

Appendix A.14. Migratory rate of chum salmon tagged in Upper Cook Inlet, Alaska in 1958 and reported by Tyler and Noerenberg (undated).

Location of Tagging	Date	Tagging Migratory Rate (km/day)	Sample Size
Anchor Point Seine	July 1	8.7	1
	July 2	1.9	2
	July 3	10.7	30
	July 4	9.2	28
Kalgin Island Seine	July 9	10.1	3
	July 10	6.2	2
Cape Kasilof Seine	July 11	8.7	2
	July 12	8.9	6
Chisik Island Trap	July 25	6.4	8
Kalgin Island Trap	July 18	31.7	1
	July 24	29.0	1

[a] Tyler and Noerenberg reported mean days out to capture and mean miles traveled and, therefore, the rates calculated in this table represent a simple division of these two parameters. Individual calculation for each tag return was not possible or variance calculations feasible.

Appendix A.15. Migratory rate of coho salmon tagged in Upper Cook Inlet, Alaska in 1958 and reported by Tyler and Noerenberg (undated).

Location of Tagging	Date	Tagging Migratory Rate (km/day)	Sample Size
Anchor Point Seine	July 3	8.6	5
	July 4	9.3	9
Ninilchik Seine	July 8	12.1	2
Cape Kasilof Seine	July 11	8.4	6
	July 12	7.0	4
Chisik Island Trap	July 27	5.8	8
	July 28	13.4	12
Kalgin Island Trap	July 2	0.4	1
	July 5	1.6	6
	July 6	0.4	22
	July 12	7.2	38
	July 13	5.7	13
	July 14	25.7	1
	July 16	4.6	6
	July 18	12.1	18
	July 19	5.9	6
	July 20	5.1	17
	July 23	2.6	17
	July 24	4.8	21

[a] Tyler and Noerenberg reported mean days out to capture and mean miles traveled and, therefore, the rates calculated in this table represent a simple division of these two parameters. Individual calculation for each tag return was not possible or variance calculations feasible.

Appendix A.16. Migratory rate of pink salmon tagged in Upper Cook Inlet, Alaska in 1958 and reported by Tyler and Noerenberg (undated).

Location of Tagging	Date	Migratory Rate (km/day)	Sample Size
Anchor Point Seine	July 1	5.9	6
	July 3	9.0	23
	July 4	8.7	22
	July 8	9.0	8
Kalgin Island Seine	July 10	8.5	22
Cape Kasilof Seine	July 11	13.5	10
Kalgin Island Trap	July 5	4.4	6
	July 6	4.6	10
	July 12	5.1	7
	July 13	2.3	3
	July 14	8.0	2
	July 17	3.0	3
	July 18	17.7	11
	July 19	23.3	2
	July 20	20.1	2
	July 23	48.3	1

[a] Tyler and Noerenberg reported mean days out to capture and mean miles traveled and, therefore, the rates calculated in this table represent a simple division of these two parameters. Individual calculation for each tag return was not possible or variance calculations feasible.