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ABSTRACT

Considerable controvery has developed in recent years over the magnitude and composition of catches of salmon in the South Peninsula June fisheries. To resolve this the stock compositions of the 1987 South Peninsula June fishery catches of sockeye *Oncorhynchus nerka* and chum *O. keta* salmon were estimated based on release and subsequent recovery of tagged fish in western Alaska, central Alaska, and Asian terminal fishing areas. Sockeye salmon (6,987) and chum salmon (6,323) were tagged and released to coincide temporally and spatially with the South Peninsula June fishery. As of September 1, 1989, 921 or 27.5% of the total releases of sockeye salmon tags and 843 or 13.3% of the total releases of chum salmon tags were recovered in terminal fisheries using a voluntary recovery program. Sockeye salmon recoveries came strictly from Alaskan fisheries. The chum salmon releases were more broadly distributed than sockeye releases, and recoveries from coastal fisheries included 37 from Japan (including hatcheries), 13 from USSR, 3 from Kotzebue Sound, and 1 from British Columbia. Recoveries were expanded to (1) total return, (2) for under-reporting of recoveries, (3) for direct tagging mortality, and (4) for delayed mortality, which includes natural mortality and tag shedding. The relative magnitude of the expanded recoveries for the respective stock provided an estimate of the stock composition of the South Peninsula June catches. The expansions to total return were based on the best available information on catches and escapements to terminal harvest areas. Expansions for under-reporting of tags were based on the reported fraction from a concurrent fishery sampling program for tag recoveries in western and central Alaska fisheries. Estimates of mortality and tag loss were made by fitting the expanded number of recoveries to numbers actually released in the Unimak and Shumagin areas. A Monte Carlo simulation model was used to estimate variance and 95% confidence intervals for the stock composition estimates.

Among the fish tagged, Bristol Bay sockeye stocks were predominant, i.e., 83.8% of the Unimak and 53.7% of the tagged Shumagin releases. The North Peninsula, South Peninsula, Chignik, and central Alaska (Kodiak, Cook Inlet, and Prince William Sound) stocks were collectively more prevalent in the Shumagin sockeye releases (46.3%) than in the Unimak releases (16%). The stock composition of the tagged chum salmon differed markedly from that of the sockeye salmon. There was a more diverse mixture of stocks, and no particular stock dominated. Tagged fish of Asian origin were significant and constituted 18% of the Unimak and 44.8% of the Shumagin releases. Tagged fish of Bristol Bay origin were the most abundant stock in the in the Unimak releases, accounting for 40.0% of the releases. Tagged fish of Japanese origin were the most abundant stock (36.5%) in the Shumagin releases. Of the Alaskan stocks, Bristol Bay (59%) and Kuskokwim (49.9%) stocks were most abundant in the collective Unimak and Shumagin releases. Applying the Monte Carlo simulation model, the relative contribution of Japanese and U.S.S.R. chum stocks were extremely sensitive to errors in Asian stock expansion factors. However these errors had almost no effect on the Alaskan chum contributions. There was little difference in mean date of release among recoveries of chum salmon in various western and central Alaska fisheries, indicating that almost total overlap in timing occurs for western and central Alaska chum salmon stocks in the area of the South Peninsula June fishery.

A model was developed to estimate the composition of the south Peninsula June fishery catches in other years. A set of stock specific vulnerability coefficients were estimated based on the 1987 tagging study. These coefficients together with the stock specific estimates of abundance of chum salmon in the various terminal areas of the North Pacific region for the year of interest can be used to estimate the composition of South Peninsula June fishery chum salmon catches for the respective year.

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INTRODUCTION

In Alaska, migrating sockeye salmon *Oncorhynchus nerka* and chum salmon *O. keta* are harvested during June in the area of South Unimak Island and Shumagin Island fisheries (or "South Peninsula June fisheries"). Originating in 1911, these two fisheries harvest chum salmon incidental to the more intensely managed sockeye salmon. Several tagging studies conducted since 1923, (Gilbert and Rich 1925; Thorsteinson and Merrell 1964; Aro et al. 1971; Aro 1972, 1974, 1977, 1980; Meyer 1983) have shown that a substantial fraction of the sockeye and chum salmon available to these fisheries were not of local origin. Tag recoveries indicated that these fisheries were intercepting (1) chum salmon primarily of western Alaska origin, although tags were recovered from widely dispersed areas throughout the Alaska Peninsula, Japan, the U.S.S.R., British Columbia, and Puget Sound (Brannian 1984); and (2) sockeye salmon primarily of Bristol Bay origin along with minor numbers bound for the North Alaska Peninsula.

Considerable controversy developed in recent years over the level of chum salmon catches in these fisheries. During the 1980–1987 period, chum salmon harvests in the South Unimak and Shumagin Islands fisheries averaged 566 thousand fish, including a record harvest of 1.1 million fish in 1982 followed by a harvest of 784 thousand in 1983. These large catches, well above the average harvests of 1970 to 1979 (306 thousand fish) and 1960 to 1969 (186 thousand fish), were tied to large sockeye salmon catch quotas in the South Peninsula fisheries, which were established in response to increased sockeye salmon returns to Bristol Bay. These sockeye salmon catch quotas were based on a fixed percentage of the forecasted harvest in the Bristol Bay inshore districts. Although the current management strategy appears adequate to maintain a consistent level of exploitation on Bristol Bay sockeye salmon, the strategy has not facilitated quota adjustments to reflect chum salmon abundance. Exploitation rates for chum salmon may have reached levels where the inshore returns of some stocks may be adversely impacted.

In recent years the inshore returns of several western Alaskan chum salmon runs, most notably the Yukon River fall run and Kotzebue Sound run, have been less than expected (Buklis and Barton 1984; Buklis 1987, personal communication), and their interception in the South Unimak and Shumagin Island fisheries is a suspected factor. Most western Alaskan chum salmon stocks are fully utilized in terminal commercial and subsistence fisheries. Therefore, in the face of increased exploitation in marine interception fisheries, it would be impossible to maintain harvests at current levels and still sustain chum salmon production. Because marine fisheries occur before terminal harvests each year, the long-term result of increased marine exploitation is an inevitable reduction in fish available for harvest in the respective terminal fisheries. This has provoked difficult allocation and conservation questions. However, it is impossible to quantify the impact of the South Peninsula June fishery interceptions on western Alaskan chum stocks and resolve these questions without adequate knowledge of the stock composition of the South Peninsula catch.

Unfortunately, several problems associated with previous studies have limited their relevancy to resolving current allocation and conservation disputes. The most important problem with previous studies is that tagging occurred in a broad area that included, but was not limited to, the present area of the fishery. Stock compositions may differ across time and space. For instance, the Shumagin Island catches may be composed of different stocks than the South Unimak catches. The historical tagging effort was insufficient to detect these differences. During the 1955–1966 period only 275 tag recoveries were made from 10,250 releases in the vicinity of the South Peninsula June fishery (Brannian 1984).

The complexities associated with the deployment and recovery of tags were such that contribution rates could not be quantified in the earlier tagging studies. Because most fisheries differ markedly in their intensity, the proportion of recoveries in various fisheries provide very biased estimates of stock composition. Even the presence of very small numbers of tags will be detected by a commercial fishery with high levels of exploitation, whereas a low intensity subsistence fishery conducted on stocks containing large numbers of tags might result in only a few recoveries. Without estimates of fishery exploitation rates on the contributing stocks and escapement sampling programs specifically designed to recover tags, neither the size nor the direction of this bias can be understood. Without knowledge of bias the flawed estimates cannot be corrected. In past tagging studies the commercial fisheries of western Alaska were the primary sources of tag recoveries. It is certain that the numbers of tag recoveries in these underdeveloped fisheries were low compared to the numbers that would have been recovered by contemporary western Alaskan fisheries.

Tagging studies in the vicinity of the South Peninsula June fishery were concluded in 1966 (Brannian 1984), but stock composition around the Pacific and Bering Sea rim has changed dramatically since that time: most notable is the huge increase in Japanese hatchery production. Gross changes in coast-wide relative abundance could alter our perception of which stocks are major contributors to the South Peninsula June fishery. Finally, no attempt has been made to examine annual stock composition over a period of years to determine the extent to which stock composition exhibits annual variation.

Scale pattern analysis (SPA), may provide a more cost-effective method of estimating stock composition. The feasibility of using SPA to identify major component stocks of the South Unimak and Shumagin Islands chum salmon harvest was demonstrated by Conrad (1984). Results of his study indicated that approximately 70% of the 1983 chum salmon harvest was of western Alaskan and Bristol Bay origin, followed in order of importance by Alaska Peninsula and Asian stocks. The major problem with that study was that the Asian standards were not collected in the proper fashion and therefore not adequately represented in the classification model. In addition, the accuracy of classification procedure used in SPA decreases as the number of stocks increases. Thus, the classification procedure permits only a limited number of stocks to be discriminated, and stocks must be aggregated over broad geographic areas. The method may not be suitable for identifying specific stocks such as Yukon fall chum salmon.

SPA methods would be feasible for separating Yukon fall chum salmon only if western Alaska chum stocks, other than the Yukon fall run, could be aggregated. To investigate this possibility, SPA was applied to 1987 samples from fall and summer chum salmon stocks within the Yukon River, (Wilcock 1987). There were only slight differences in scale patterns among these stocks. Based on these results, it is not feasible to use current SPA technology to discriminate between Yukon fall chum and other western Alaska chum stocks in South Peninsula catches.

To provide estimates of the stock composition of the 1987 South Peninsula June fishery catches, a comprehensive tagging study was conducted in 1987. The study was designed to correct the deficiencies of earlier tagging studies. In the 1987 study substantial

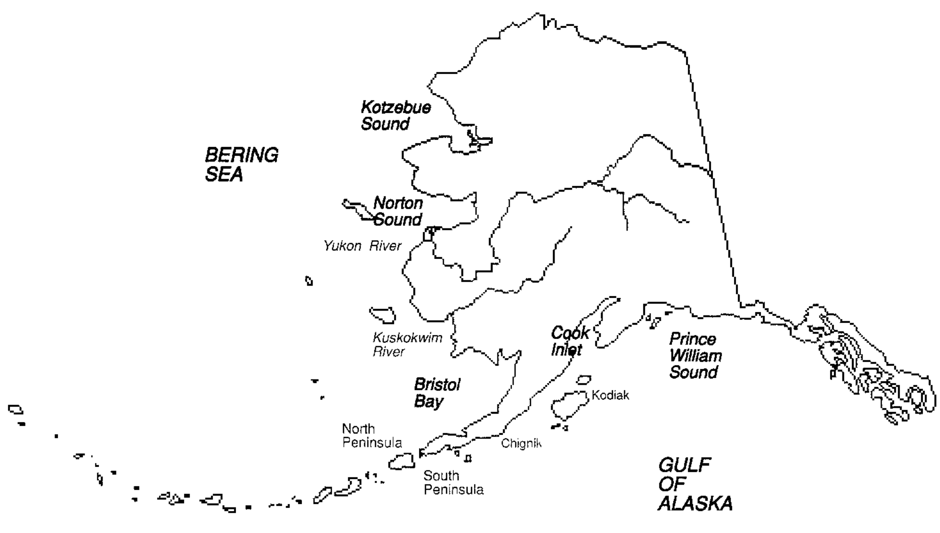

FIGURE 1.—Fishery unit definitions by which 1987 tag recoveries, catches and escapements were reported for western and central Alaska salmon fisheries.

numbers of tags were deployed in the area of the South Peninsula June fishery and comprehensive tag recovery efforts were conducted in all western and central Alaska fisheries.

In addition to stock composition estimates, the tagging study was to provide evidence for differential migratory timing among stocks in the South Peninsula fishery. There has been concern that certain stocks may be more vulnerable to the South Peninsula Fishery because their migratory timing is concurrent with the South Peninsula fishery. These include age-.2 Bristol Bay sockeye stocks, such as Kvichak River and the Wood River beach spawners, Ugashik sockeye salmon, and Yukon fall chum salmon. With the exception of Ugashik sockeye salmon, there have been some conservation concerns associated with the management of terminal fisheries on these stocks. The objective of the South Peninsula tagging study was to determine stock contributions to the South Peninsula June fisheries through tagging.

METHODS

A population of tagged fish was captured, marked, and released to coincide temporally and spatially with catches in the South Peninsula June fishery. Stock compositions were based on expanded recoveries in various fisheries conducted in the terminal harvest areas of the respective stock of origin. Recoveries were expanded to reflect the tagged fish in the unreported and noncatch, (i.e., escapement and mortality),

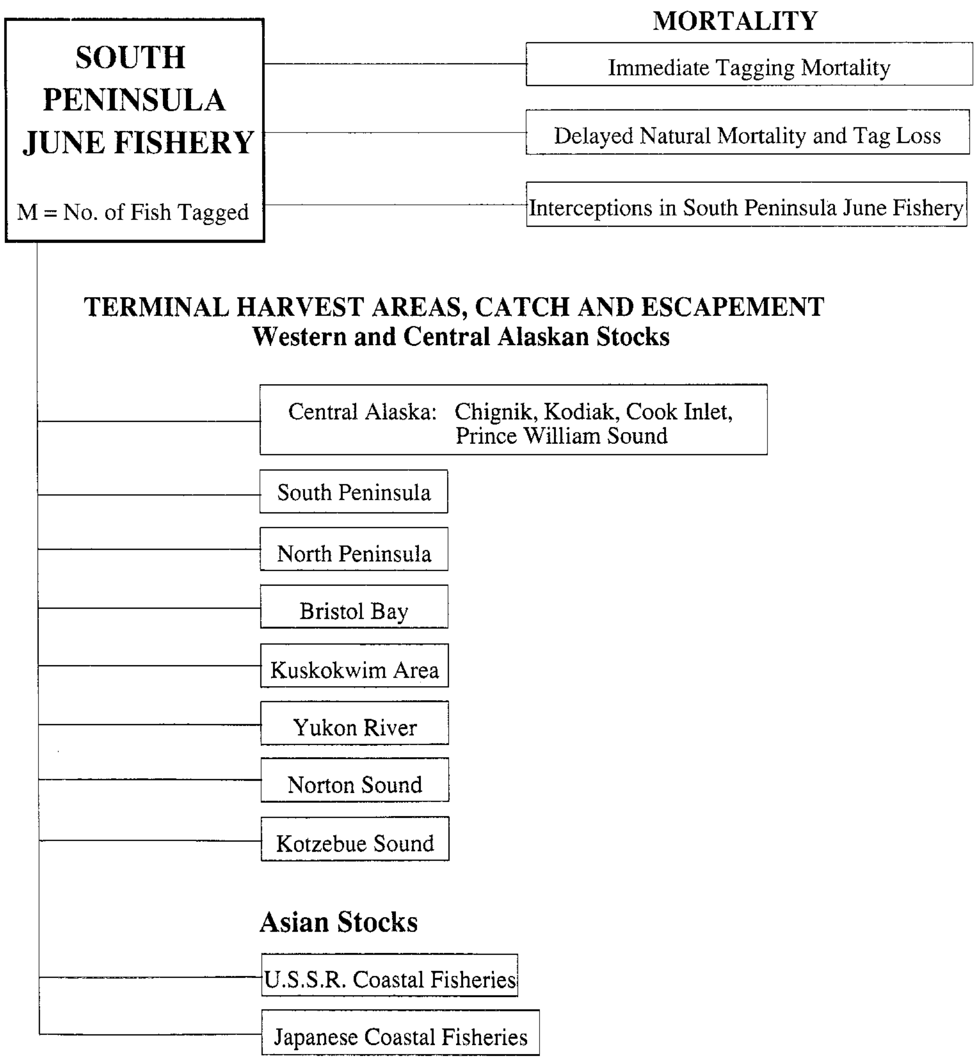

Figure 2.—Schematic of the possible fates of individual tagged chum salmon released in the area of the South Peninsula June fishery.

components of the population. The relative magnitude of the expanded recoveries for each stock provided an estimate of the stock composition of the South Peninsula June catches.

Tag recoveries were reported by statistical and substatistical catch reporting areas within each *fishery unit*. *Fishery units*, by which Alaska salmon catches and preseason forecasts are reported, generally correspond to stock identities (Eggers and Dean 1988). The fishery units in our study were based on the extent of tag recoveries. Chum salmon fishery units in Alaska include Kotzebue, Yukon Summer, Yukon Fall, Kuskokwim, Bristol Bay, North Peninsula, South Peninsula June, South Peninsula July, Chignik, Kodiak, Cook Inlet, Prince William Sound, and Southeast Alaska (Figure 1); units outside Alaska included Japanese coastal fisheries, U.S.S.R. coastal fisheries, and British Columbia coastal fisheries. Sockeye salmon fishery units included Kuskokwim, Bristol Bay, North Peninsula, South Peninsula June, South Peninsula July, Chignik, Kodiak, Cook Inlet, Prince William Sound, and Southeast Alaska. Fishery unit boundaries, maps of statistical and sub-statistical areas, and the specific assignments of these statistical and substatistical areas to fishery units is provided in Eggers et al. (1989).

The Yukon chum salmon recoveries were further classified into summer and fall chum salmon stocks based on both the area and time of capture (Appendix D.). These classifications followed the same procedures that have been used by area managers to classify the Yukon commercial and subsistence chum salmon catches. In addition, Alaska Peninsula sockeye and chum salmon recoveries were assigned to the June or July fishery based on the respective month of capture; all of the June and 80% of the July sockeye recoveries in the Southeast Mainland District were classified as Chignik origin. This classification also followed the procedures that have been used by area managers to classify commercial catches.

Theory

The possible fate of individual fish in the tagged population consisted of the following: (1) direct mortality due to capture and handling, (2) delayed mortality including natural mortality and tag shedding, (3) recapture in the South Peninsula June fishery, (4) occurrence in the returns to Alaska terminal harvest areas either as catch or as escapement, or (5) occurrence in the returns to terminal harvest areas outside Alaska. The most likely areas outside Alaska included Soviet coastal fisheries and Japanese coastal fisheries and hatchery returns. These possibilities for chum salmon are diagramed in Figure 2. Define the following:

C_i = catch in the *i*th stock terminal harvest area.

E_i = escapement of the *i*th stock.

E_{U_i} = expansion factor for exploitation.

E_{f_i} = expansion factor for under-reporting.

E_{M_i} = expansion factor for mortality and tag shedding.

f_i = reported fraction of tags in the catch in the *i*th terminal harvest area.

J = instantaneous rate of tag loss, including natural mortality and tag shedding.

K = direct or immediate tagging mortality rate (percentage).

M = total number of fish in the tagged population.

M_i = number of the fish in the tagged population that originate in the *i*th stock or terminal harvest area.

M_{spf} = number of tagged fish that were intercepted in the South Peninsula June fishery.

N_i = abundance of the *i*th stock ($C_i + E_i$).

n_i = number of fish examined in the *i*th terminal fishery sampling program.

P_i = proportion of *i*th stock in the tagged population.

r_i = number of recoveries of tagged fish in the catch (C_i).

t_i = travel time (days) from the release area to the fishery in the terminal harvest area.

U_i = rate of exploitation on the *i*th stock in the *i*th terminal harvest area.

Estimates of stock composition were made based on the reported recoveries from the catch of chum salmon in various terminal harvest areas. These reported recoveries were expanded to reflect the marked fish in the unreported and noncatch components of the population. The reported recoveries were expanded to reflect tagged fish in the unreported catch (E_{f_i}), the escapement (E_{U_i}), and mortality (E_{M_i}). Multiplying the reported recoveries by each of the above expansion factors provided the number of fish in the released population that originated in the respective fishery unit as follows:

$$M_i = r_i \cdot E_{f_i} \cdot E_{U_i} \cdot E_{M_i} \ . \tag{1}$$

A certain portion of the released population was intercepted in the South Peninsula June fishery. Note that M_{spf} was estimated as a special case of equation (1),

$$M_{spf} = r_{spf} \cdot E_{f_{spf}} \cdot E_{M_{spf}} \ , \tag{2}$$

where the expansion factor for catch is unity and r_{spf}, $E_{f_{spf}}$, $E_{M_{spf}}$ are the reported recoveries, the expansion factor for under-reporting, and the expansion factor for mortality, respectively, estimated for the South Peninsula June fishery.

Assuming that the interception rate for the South Peninsula June fishery was not stock specific, then the proportion of the ith stock in the tagged population is

$$P_i = \frac{M_i}{(M - M_{spf})} \ . \tag{3}$$

The released population consisted of fish that originated in a discrete number of fishery units. The collective expanded recoveries to terminal harvest areas and recoveries in the South Peninsula June Fisheries were assumed to be the size of the released population (M), such that

$$M = \sum M_i + M_{spf} \ . \tag{4}$$

Because salmon stocks in western and central Alaska and Asia are fully exploited at rates of at least 50%, the terminal fisheries provided an efficient means to sample for tagged fish, and we relied on voluntary return of tags recovered by fishermen. However, the fisheries were prosecuted in remote areas making it difficult for fishermen to return the tags, and we therefore believe that the number of tagged fish voluntarily returned to ADF&G was less than the actual number of tagged fish caught in fisheries. In addition, fishermen did not always provide complete information regarding the specific time and area for tagged fish recoveries.

Under-reporting of tagged fish occurred despite an advertising campaign and cash rewards for returned tags. To estimate the number of tagged fish in the ith stock catch, the under-reporting expansion factor (E_{f_i}) was applied to the voluntary recoveries (r_i), as follows:

$$E_{f_i} = \frac{1}{f_i} \ . \tag{5}$$

The fraction of tagged fish not reported (f_i) was estimated in a fishery sampling program in which we interviewed fishermen and sampled their catches (sampling goal was 10% of the catch) to obtain an estimate of the number of tagged fish they had caught. The reported fraction of tags in the catch was estimated by comparing the number of recoveries estimated in the fishery sampling program to the number of recoveries returned in the voluntary program.

The catch represented a portion of the total salmon run to the terminal fishing area; the remainder of the run consisted of escapement. Budget limitations prevented our sampling a large enough fraction of the escapement to reliably estimate the number of tagged fish in the escapement. However, estimates of the rate of exploitation were available for all the Alaskan terminal harvest areas. Because terminal harvests have been generally managed to spread the harvest equitably over the entire run and untagged fish were believed to have similar probabilities of capture, the proportion of tagged fish in the catch and escapement was assumed to be similar. Thus, voluntary recoveries were expanded to total return based on the observed exploitation rate (U_i) by the respective fishery, as follows:

$$E_{U_i} = \frac{1}{U_i} \ . \tag{6}$$

Mortality was assumed to occur on the released population during the ensuing time between capture by the tagging crews and recovery in the terminal harvest area. This mortality was due to (1) direct or immediate mortality resulting from the stress of capture and handling by the tagging crew and (2) delayed mortality resulting from natural causes (we also included tag shedding with delayed mortality). Direct tagging mortality occurred immediately and was specified by the fraction of the released population dying (i.e., the tagging mortality rate, K). The delayed mortality was the product of the instantaneous natural mortality rate (J) and the travel times between the release date and the terminal fishery (t_i). The recoveries were expanded for mortality based on the inverse of survival between the time of release and recovery in the terminal harvest area, as follows:

$$E_{M_i} = \frac{1}{[(1-K)\ \exp(-J\,t_i)]}\ . \qquad (7)$$

Estimates of stock composition (P_i) require estimates of several parameters implicit in equation (3), including reported fractions f_i , rates of exploitation (U_i), travel times (t_i), direct tagging mortality rate (K), and instantaneous rate of tag loss (J). Estimates of reported fractions were based on the fishery sampling program, and the rates of exploitation were those observed for Alaskan fisheries. Travel times were taken as the average observed for voluntary recoveries from the respective fishery.

The two remaining parameters, (K) and (J) were estimated by equating the observed total releases by area to the estimated total releases by area and then solving a 2 x 2 nonlinear system of equation as follows (superscripts U and S in (8) and (9) refer to Unimak and Shumagin releases) :

$$f_1(K,J) = M^U - [\,(\sum \hat{M}_i^U) + \hat{M}_{\text{spf}}^U\,] = 0\ , \qquad (8)$$

and

$$f_2(K,J) = M^S - [\,(\sum M_i^S) + M_{\text{spf}}^S] = 0\ . \qquad (9)$$

The reported fraction was not known for the Asian terminal fisheries. In absence of this information, the reported fraction for the Asian fisheries was assumed to be the average weighted by the number of recoveries observed in the sampling program for Alaskan fisheries. The rate of exploitation for the U.S.S.R. coastal fisheries was also not known. In absence of this information, the rate of exploitation for U.S.S.R. terminal fisheries was assumed to be 50%, which was the minimum observed for Alaskan fisheries. The Japanese coastal fishery operates on hatchery stocks of chum salmon. Because all runs (i.e., catch plus broodstock) are potentially examined for tagged fish, the rate of exploitation for the Japanese coastal fishery was taken to be 1 (Fisheries Agency of Japan 1988a).

A Monte Carlo simulation model was used to estimate variance and confidence intervals for stock composition estimates of the sockeye salmon and chum salmon releases. The model was also used to examine the sensitivity of the estimates of stock composition for the chum salmon releases to specific rates of exploitation and reported fractions assumed for the Asian stocks. The model assumed that the true mean stock proportions in the releases reflected those estimated based on this study and then generated, based on implicit stochastic processes, a set of observations. The simulated set of observations is then used to estimate new stock proportions. The simulation is repeated 500 times to give the sampling distribution for the stock composition estimates.

The Monte Carlo model incorporates two stochastic processes: (1) recoveries of tagged salmon reported by fishermen and (2) recoveries of tagged salmon found in the fishery sampling program. The random variable for the first process is the reported recoveries for the individual fisheries (r^*_i). The reported recoveries in the ith fishery is a Poisson random variable with a mean (λ_i) equal to the expected recoveries in the ith fishery as follows (quantities with the "hat" ^ were estimated based on the results of the tagging study):

$$\lambda_i = \frac{\hat{M}_i}{\hat{E}_{f_i} \cdot \hat{E}_{U_i} \cdot \hat{E}_{M_i}}\ . \qquad (10)$$

The random variable in the second process is the recovery (x^*_i) observed in the fishery sampling program for ith fishery, where x^*_i is a binomial random variable with parameters δ_i = the proportion of tagged fish in the ith fishery and n_i, = the sample size for the ith fishery sampling program. Thus:

$$\delta_i = \frac{\hat{M}_i\ U_i}{C_i}\ . \qquad (11)$$

The parameters which specify the underlying probability distribution used to generate the random variable observations in the Monte Carlo model were estimated based on the results of our study. Using the Monte Carlo model we calculated a set of stock composition estimates for the Unimak and Shumagin releases. Variances and confidence intervals for the stock composition of the releases were estimated from 500 computer runs simulating the results of the tagging study.

There were three basic steps in simulating the stock composition estimates. The first step was to generate the observations for the random variables (i.e., sets of r_i^* and x_i^*, the reported recoveries and observed recoveries in the fishery sampling programs, respectively. The second step was to estimate the parameters that were implicit in expansion of reported recoveries to total releases and depended on the random variables simulated. These included the reported fraction, immediate tagging mortality, and delayed tagging mortality and tag loss rate, (i.e., sets of f_i^*, K*, and J^*). Note that other parameters that do not depend on the simulated random variables, including the rate of exploitation (U_i), catch (C_i) and sample size (n_i), were constant among the computer runs. The third step was to estimate the stock composition (i.e., sets of M^*_i and P^*_i).

The model was used to generate stock composition estimates for various levels of errors in the estimated product of rate of exploitation (U_i) and reported fraction (R_i). The product ($U_i \cdot R_i$) was the fraction of the return for which recovered tags were returned to ADF&G, and the inverse of the product is the expansion factor for tags in the unreported and noncatch components of the return.

Let b_i be the ratio of the true to estimated fraction of return for which all tags present are recovered. Thus,

$$(U_i \cdot R_i)^{\text{true}} = b_i \cdot (U_i \cdot R_i)^{\text{estimated}}. \quad (12)$$

The manifestation of this error can easily be simulated in the Monte Carlo model by adjusting the appropriate λ_i used generate the reported recoveries, such that:

$$\lambda_i^{\text{true}} = b_i \cdot \lambda_i^{\text{estimated}}, \quad (13)$$

where λ_i^{true} is the Poisson mean used to generate the random observations and $\lambda_i^{\text{estimated}}$ is the value estimated based on the tagging study.

If $b_i < 1$, then the assumed expansion factors are too low, and therefore, the expanded recoveries are too high. Thus, the estimated contribution of the stock for which error occurs to the tag releases is too high. Conversely, if $b_i > 1$, then the assumed expansion factors are too high, and therefore, the expanded recoveries are too low. Thus, estimated contribution of the stock for which the error occurs to the tag releases is too low. However, this bias affects the estimates of all stocks to some extent. The Monte Carlo model was used to examine the relative effects of this bias on stock composition estimates.

The Tagging Operation

The capture, tagging, and release of fish was contracted to LGL Alaska Research and Associates, Anchorage. Detailed documentation of tagging methods, numbers of releases by species, area and date, and specific location and date of release by individual tag numbers are reported in Schmidt (1987).

Under the contract 7,000 sockeye and 13,500 chum salmon were to be tagged. The relative tagging effort was to reflect the historical fishing effort in the two areas (South Unimak and Shumagin Islands), and tags were to be applied in proportion to relative temporal abundance. A tagging strategy (Table 1 in Schmidt 1987) was devised to meet these requirements, based on analysis of historical performance of the South Peninsula June fishery.

The strategy consisted of allocating tagging effort to meet weekly guideline tagging goals by species and area. Purse seine vessels participating in the fishery were chartered to capture fish for tagging. They were used in an opportunistic manner, based on their availability during fishery closures and performance during the tagging operations. Tagging was conducted in the two South Peninsula fishing areas (Figure 3), the Shumagin Islands and the South Unimak areas. Field operations were based in Sand Point where daily tagging schedules and catch totals were maintained. Manpower aboard each tagging vessel consisted of the vessel's crew and skipper and one LGL research scientist or technician. LGL personnel provided tagging instruction to the crew, insured quality control, and recorded the tag release data.

During fishing operations the seine was typically set for 15 to 20 min. Occasionally set times or locations were modified to avoid large catches or rough seas. The pursing procedure was identical to that used in commercial fishing operations. The bag of the seine was held open with stand-off poles or plunger poles, and the fish were lifted onto the deck, usually two to four at a time with long-handled dip nets. Each salmon was then placed into an individual tagging box constructed of a rectangular plywood frame with a canvas cradle and tagged with an appropriately colored and individually numbered Floy spaghetti tag. Sockeye were tagged with yellow tags and chum salmon with red tags. Occasionally sockeye and chum salmon were tagged with the wrong color, but these were noted and documented in Schmidt (1987). Tags were inserted through the fleshy tissue behind and slightly below the posterior insertion point of the dorsal fin. The tags were then secured with either a double-overhand knot or a square knot. Fish were visually inspected to insure that no injured or weak fish were tagged. Rejected fish were enumerated and released without a tag.

Estimating Recoveries in Western and Central Alaska

Two methods were used to estimate the number of recoveries for various western and central Alaska terminal fisheries. The first was through voluntary return of tags along with information on species, date, and area of capture. The second was through a fishery sampling program in which a known fraction of the catches were sampled for tagged fish. The tags recovered from the sampled catches were expanded to the total catches based on the sampling fraction. These expansions were compared to the number of tags returned through the voluntary program to estimate reported fractions.

Voluntary Program

A large-scale publicity campaign was conducted during the 1987 fishing season in western and central Alaska. This campaign had three purposes: (1) to inform the fishing industry about the project, (2) to provide an opportunity for the industry to express their concerns and make suggestions prior to tagging, and (3) to provide fishermen with instructions for returning tags. Prior to the season, informational packets were prepared and distributed by the contractor, LGL Research Associates, to 1,069 industry groups and agencies (listed in Appendix A-1 in Schmidt 1987). The instructions stressed the importance of providing the specific location and date for the tagged fish captured.

During the season information packets were available in ADF&G area offices. Announcements requesting fishermen to return tags with the relevant information were also routinely made over public radio stations and in conjunction with the communication of emergency orders. Two $500 rewards by drawing were offered to fishermen as a further incentive to return tags. Preaddressed, postage-paid envelopes were also available and widely distributed to further simplify the task of returning tags.

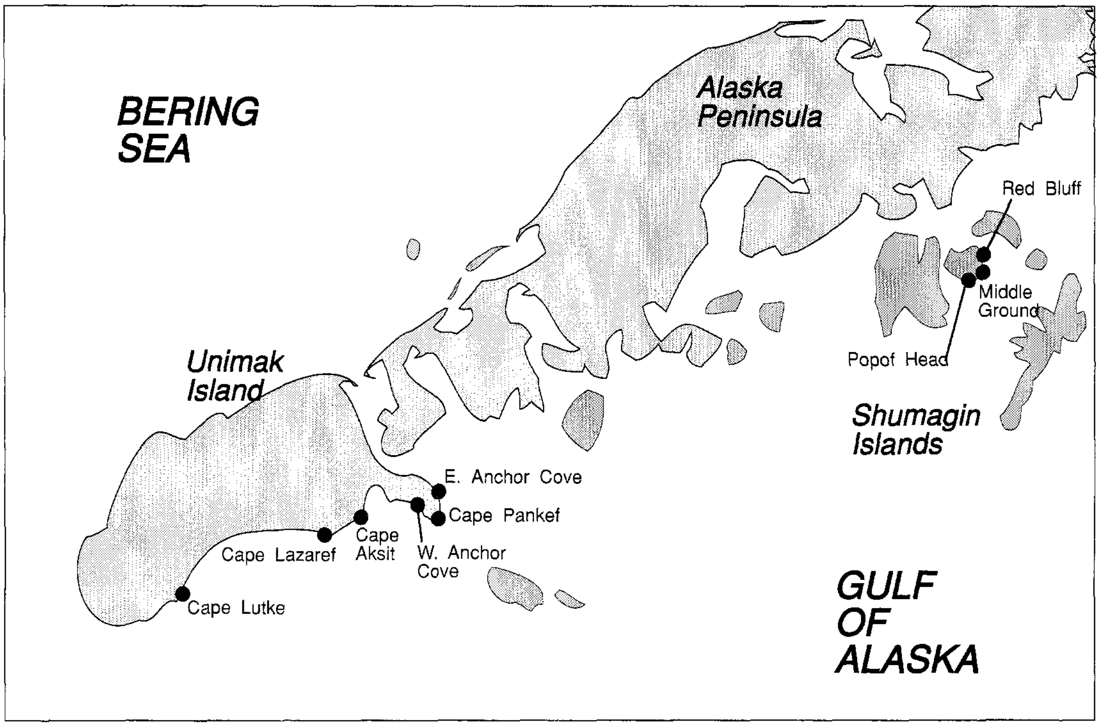

Figure 3.—Tagging locations in the Unimak and Shumagin Islands area used during South Peninsula tagging study, 1987.

Commercial fishermen, subsistence fishermen, sports fishermen and various processors returned tags by two means. The first was direct return through the mail to the address imprinted on the tag. The second was to return the tag to a local ADF&G offices which forwarded the tag information to the ADF&G Headquarters in Juneau. Upon arrival in Juneau, each tag was read and the tag number and other accompanying information were entered into a temporary data base.

After most of the recoveries had been returned, ADF&G and LGL personnel created a permanent tag recovery data base (Eggers et al. 1989). The date and location of release and the date and location of capture were fully documented for each tag, and the statistical and substatistical area of capture and the classification as a fishery or nonfishery recovery was verified from the actual tag and associated information. Recoveries without a verifiable recovery date and location were classified as not usable.

Fishery Sampling Program

Because western and central Alaska fisheries differed in remoteness, access of fishermen to the publicity campaign, and proximity of ADF&G area offices, we expected differences among the fisheries in the fraction of tags that would actually be recovered. A fishery sampling program for tagged fish was initiated in the terminal harvest areas of Kotzebue, Yukon River, Kuskokwim River, Bristol Bay, and the Alaska Peninsula to provide an independent estimate of the tag recoveries.

ADF&G technicians were stationed at processing and tender facilities and met fishermen as they delivered catches. An interview was conducted for each delivery. During the interview the technician recorded the fish ticket number, fisherman's name, permit number, number of fish in the delivery, and harvest location. The technician also collected any tags that were recovered For each tag recovered, the tag number, recovery date, recovery location, and fisherman's name and address were recorded. ADF&G technicians then examined the delivery for presence of tags that were overlooked by the fisherman. The target sampling level was 10% for each sampled fishery, a level based on similar tagging programs in the boundary-area fisheries of Southeast Alaska and British Columbia (Pella et al. 1988).

Small boats and skiffs dominated the Kotzebue, Yukon River and Kuskokwim River fisheries. Fish were individually handled during transfer from the fishing boat to the braille net at the processing facility, enabling ADF&G technicians to examine individual fish in each delivery for tags.

In the Bristol Bay and Alaska Peninsula fisheries, catches were transferred to processors and tenders from holds lined with braille nets. The entire net with the harvest was transferred to the processing facility, preventing direct examination of the catch for tags. Consequently, ADF&G technicians were stationed on tenders and interviewed all fishermen delivering to the respective tenders. The entire tender load was treated as a sample and examined for tagged fish. Examination of fish for tags from these tenders occurred at the chute leading from the unloading area into the processing facility and at the grading tables on the processing line. Date and location of fishing, number of fish by species that were delivered to the tender, and all tag recovery information were recorded.

Commercial harvest data (numbers of fish) that corresponded to fishing period and district sampled were obtained postseason. This data was used to determine the fraction of the catch that was sampled (S_i). The total number of tags in the fishery (r_i') was estimated based on the number of tags recovered in the sampling program (x_i) and sampling fraction, as follows:

$$r_i' = \frac{x_i}{S_i} . \qquad (14)$$

The fishery sampling program was designed to be reflective of recoveries from commercial harvests only. An attempt was made to sample all fishery openings and areas in an equitable manner. In some cases catches from several openings occurring at different times or areas were combined in tender loads. In these situations the catches were appropriately aggregated to insure that the sample was representative. In cases where this could not be assured samples were excluded from further analysis.

Estimating Catches and Escapements

Methods used to estimate catches and escapements for western and central Alaska sockeye and chum salmon fisheries are summarized in Appendix A.

Catches were estimated from receipts for catches delivered to processors (fish tickets). Catches were tabulated by statistical and substatistical areas and assigned to fishery units based on the respective assignment of statistical and substatistical areas to fishery units (Eggers et al. 1989).

Escapements were estimated from comprehensive aerial surveys of spawning streams, sonar and tower enumeration, test fishing, and from catches based on an assumed rate of exploitation. Counts of spawning salmon made in aerial surveys were always lower than actual escapements due to poor visibility, incomplete migration into the natal stream at the time of the survey, and fish postspawning mortalities. Either area-under-the-curve methods (Cousens et al. 1982; Johnson and Barrett 1987) or direct application of expansion factors were used to adjust aerial survey counts for the undercounting bias.

Abundance of Asian stocks of chum salmon was estimated based on returns to U.S.S.R. coastal fisheries, returns to Japanese coastal fisheries, and catches of chum salmon in Japanese high seas fisheries. The latter are almost entirely of Asian origin (Harris 1987). Estimates of returns to Japanese coastal fisheries and catches in U.S.S.R. coastal fisheries provided by the Japan Fisheries Agency (Yukimasa Ishida, Far Seas Fisheries Research Laboratory, personal communication). Returns to U.S.S.R. coastal fisheries were roughly estimated by expanding catches based on a 50% rate of exploitation. The catches of chum salmon in high seas fisheries were taken from Fisheries Agency of Japan (1988b).

RESULTS

Tag Releases

A total of 6,987 sockeye salmon were tagged—5,442 being released in the Unimak District and 1,545 in the Shumagin District. A total of 6,323 chum salmon were tagged, with 3,495 released in the Unimak District and 2,828 in the Shumagin Districts. Tagging occurred June 6 through July 2 on days when the South Peninsula June fishery was closed. Catches and numbers of tagged sockeye and chum salmon released are given by day for Unimak and Shumagin Districts combined and separately in Appendix B.1, B.2, and B.3.

The numbers of tagged chum salmon released was far less than the target goal of 13,500. Because the catches of sockeye in the Unimak District were relatively poor, there were few days when the fishery was closed and vessels were available for tagging. To compensate for the less than desired tagging effort early in the season, additional effort was conducted later in the season. However, the chum salmon tagging goal was not achieved even with the additional late tagging effort.

Because the commercial fishing effort in the Unimak District was high relative to recent years, it was not possible to time the release of tags to reflect the timing of the catches (Figures 4, 5, 6). For the combined Unimak and Shumagin Districts the mean date of the tag releases was 3.15 d later than the midpoint of the fishery for sockeye salmon and 4.4 d later for chum salmon (Appendix B.1; Figure 4). This difference also occurred separately for Unimak and Shumagin Districts (Appendices B.2, B.3; Figures 5, 6). The effect of the late timing of the releases on the estimates of stock composition for the South Peninsula catches will be discussed in the run timing section of this report.

Recoveries in Western Alaska, Central Alaska and Asian Salmon Fisheries

Voluntary Program

The voluntary tag recoveries from terminal commercial and subsistence fisheries were the primary information used for stock composition estimates and, thus, had to be correctly reassigned to a terminal fishery of recovery. The raw recoveries were classified as fishery or nonfishery recoveries and by fishery units and districts based on the statistical and substatistical area in which the tagged fish were reported to have been caught.

The raw recovery data base is presented by fishery unit for chum and sockeye salmon in Eggers et al. (1989). There was a total of 843 chum salmon recoveries, 820 of which were assigned to specific commercial or subsistence fishery units (Appendix C.1). There was a total of 1921 sockeye salmon recoveries, 1890 of which were assigned to specific commercial or subsistence fishery units (Appendix C.2). Because the

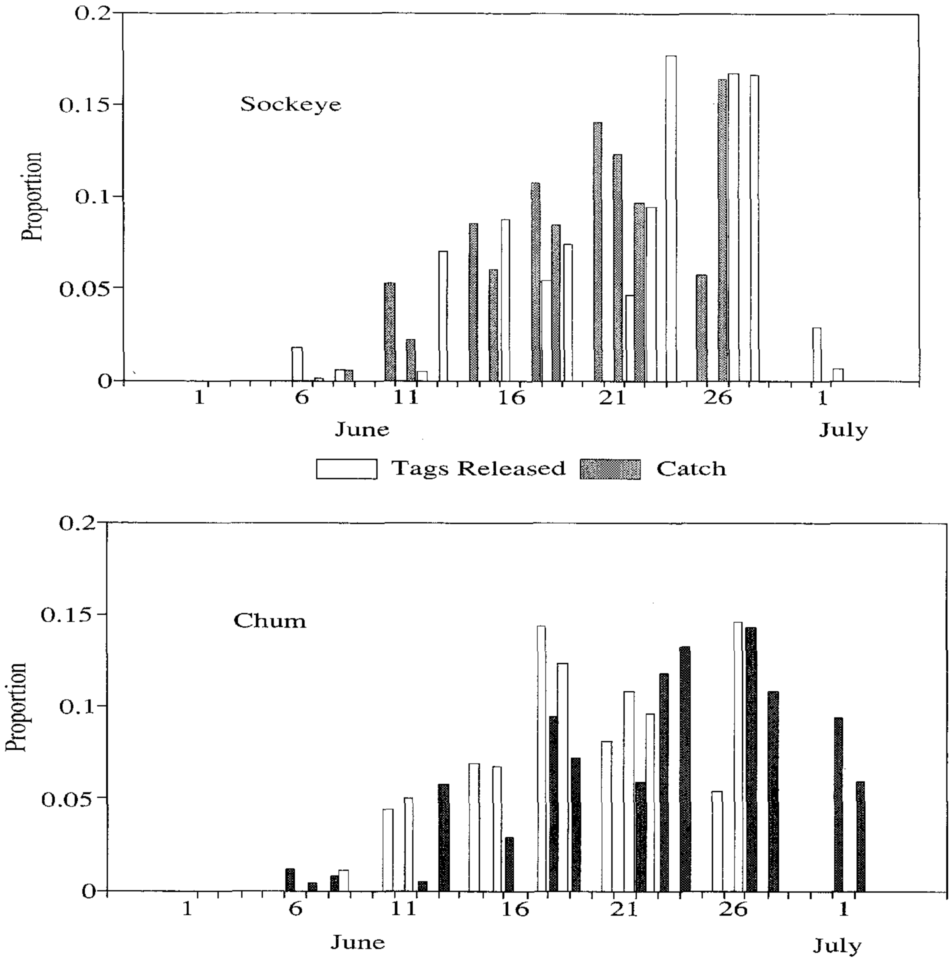

FIGURE 4.—Timing of 1987 tag releases and catches of sockeye and chum salmon in the combined Unimak and Shumagin district.

estimates of recoveries were made in the fishery sampling program by district within fishery unit, any recoveries without the district-of-recovery information were considered as an unreported tag.

Some recoveries from Bristol Bay and the Alaska Peninsula could not be assigned to specific districts and were designated as not usable (Appendices C.1 and C.2).

Fishery Sampling Program

Estimates of sockeye and chum salmon tag recoveries derived from the fishery sampling program in the Kotzebue Sound, Bristol Bay, North Peninsula, and South Peninsula fishery units reported below are documented in Eggers et al. 1989. Because conservation and allocation issues associated with the South Peninsula June fishery have been focused on the chum salmon stocks of the Yukon and Kuskokwim Rivers, the results of the fishery sampling program for those fishery units are presented in detail.

Yukon River. Harvests of Yukon River chum salmon stocks occurred in five commercial fishing districts. Subsistence harvests comparable in magnitude to the commercial harvests occurred throughout the Yukon drainage. Because of the remote and dispersed nature of Yukon River fishing effort, we conducted fishery sampling programs only in selected areas. A sampling program was conducted in the commercial summer chum salmon fishery in the lower river districts (Y1 and Y2), from June 15 to July 10 (Appendix E). Only three tagged salmon were found, and those tags were found in the final commercial fishing period. The estimate of summer chum recoveries in the total Y1 and Y2 catches was 25.

A commercial fishery did not occur on fall chum salmon in the lower river. Large numbers of Yukon

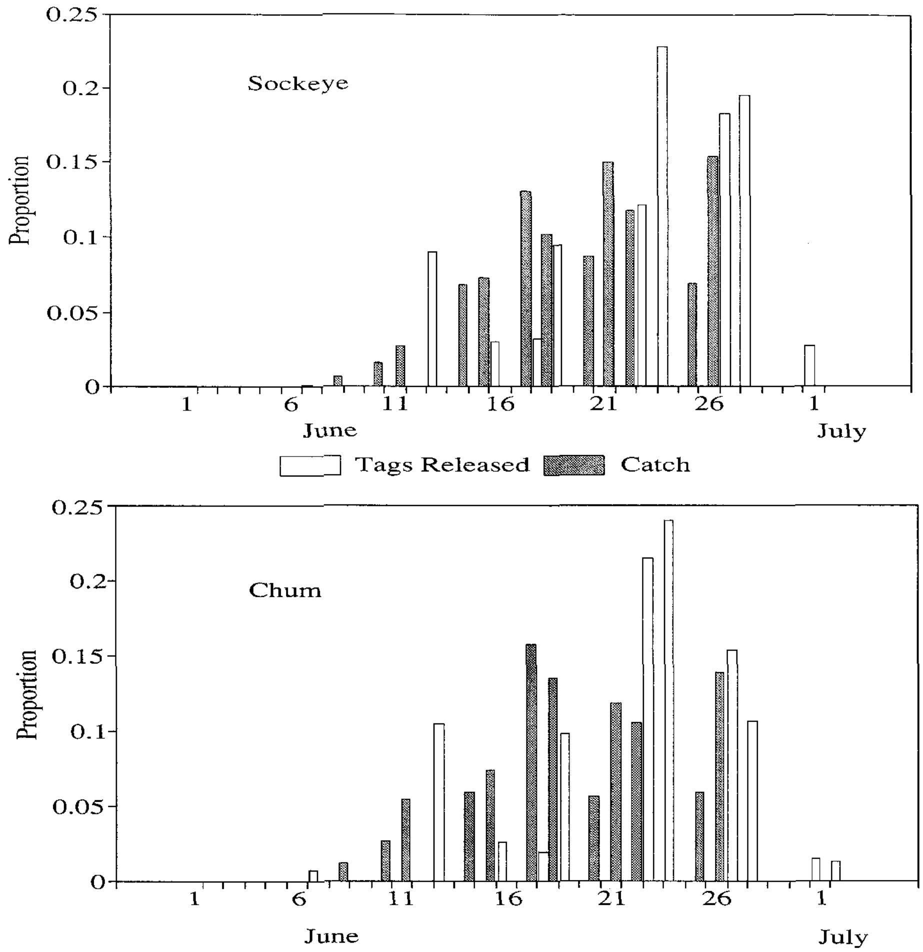

FIGURE 5.—Timing of 1987 tag releases and catches of sockeye and chum salmon in the Unimak district.

fall chum salmon were observed in a variety of biological samples, test or indicator fisheries, spawning ground surveys, and tagging programs by various governmental agencies. In addition, a subsistence survey was conducted in Districts Y1 and Y5 specifically to provide tagged fall chum salmon. Finally, Yukon fall chum salmon were counted and sampled for tags at the Fishing Branch weir. In this collective sampling effort, approximately 120 thousand fall chum salmon were examined for tags (Appendix F.). This effort represented an estimated 16.1% of Yukon fall chum salmon return. A single tag was sighted during the Fishing Branch weir operations but not recovered. Based on the 16.1% sampling fraction, six tagged fish were expected in the total Yukon fall chum return.

Kuskokwim River. A sampling program in District W1 was conducted from June 18 to July 22 (Appendix G.). A total of 57,000 chum salmon were examined for tags, representing approximately 8.3% of the Kuskokwim River commercial and subsistence harvest of chum salmon. Twenty-three tagged fish were found through sampling the commercial fishery catches, and based on the 8.3% sampling fraction, 260 tagged chum salmon were estimated to occur in the Kuskokwim catch.

Estimates of Reported Fraction. The pool of fish from which tagged fish could be found and voluntarily returned by fishermen included both the commercial and subsistence catches for Kuskokwim River fisheries and commercial catches for Bristol Bay and Alaska Peninsula fisheries. Estimates of tag recoveries made with the fishery sampling program were compared

TABLE 1.—Summary of results of ADF&G sampling program for sockeye and chum salmon tag recoveries in various western Alaska salmon fisheries and estimates of reported fractions.

	Sockeye Salmon			Chum Salmon		
Fishery	Estimated	Actual Reported	Reported Fraction (%)	Estimated	Actual Reported	Reported Fraction (%)
Kuskokwim				260	139	53
Bristol Bay	2,083	1,140	55	381	325	85
North Peninsula	102	125	100	64	57	89
South Peninsula June	281	313	100	77	77	100
South Peninsula July	28	93	100	107	87	81
Average Weighted by Reported Recoveries			69			69

with independent estimates from voluntary recoveries to estimate reported fractions (Table 1).

The estimated reported fraction for Bristol Bay sockeye salmon was 55%. The reported fraction for Alaska Peninsula sockeye was taken to be 100%. The average reported fraction for sockeye salmon across fisheries, weighted by the number of reported recoveries was 69%. There were significant differences ($P < 0.01$) in the reported fraction for sockeye salmon among fisheries, based on a Chi-square test comparing observed recoveries in fishery sampling program to that expected in the fishery sampling program expected, assuming the average reported fraction of 69%, (Table 2).

For chum salmon the reported fraction for Kuskokwim was 53%, Bristol Bay 85%, North Peninsula 89%, South Peninsula June 100%, and South Peninsula July was 81%. The average reported fraction for chum salmon across fisheries weighted by the number of reported recoveries was 69%; this figure was the same as that observed for sockeye recoveries. There were no significant statistical differences ($P = 0.22$) in the reported fraction for chum salmon among fisheries (Table 3).

TABLE 2.—Differences between the observed number of sockeye salmon recoveries in the fishery sampling program and that expected assuming an average reported fraction of 0.69.

Fishery	Sampling Fraction (%)	Reported Recoveries	(1) Observed Recoveries Fishery Sampling Program	(2) Expected Recoveries Using Average Reported Fraction	Contribution to Chi-square[a]
Kuskokwim	8.5	0	0	0	0.00
Bristol Bay					
Togiak	14.7	16	9	3	9.17
Nushagak	6.1	256	23	23	0.01
Naknek Kvichak	2.6	426	25	16	4.99
Egegik	3.3	326	17	16	0.13
Ugashik	5.8	116	10	10	0.01
North Peninsula					
Northern	10.7	103	11	16	1.55
Northwestern	5.4	22	0	2	1.72
South Peninsula June	7.3	313	23	33	3.09
South Peninsula July					
Southwestern	4.1	47	0	3	2.79
Southcentral	12.2	28	0	5	4.95
Shumagin	5.1	16	1	1	0.03
Southeast Mainland	13.3	2	1	0	0.98
		Chi-Square Statistic ($P = 0.01$)			29.4

[a] $(\text{Column \#1 - Column \#2})^2$ / Column #2

The subsistence catches for Yukon summer chum salmon could not be sampled, and only three tags were recovered late in the season in the lower river commercial fishery sampling program. The accuracy of estimates of number of tags in the summer chum return was poor due to the small number of recoveries. Likewise, only one tag was found in the Yukon fall chum recovery program, minimizing the accuracy of the number of tagged fish estimated. Because we could not estimate accurately the number of recoveries from commercial and subsistence harvests in the fishery sampling program, estimates of the reported fraction for the Yukon chum salmon fisheries was instead based on the reported fraction estimated for the Kuskokwim River. This was facilitated by similarities between the fisheries in the Yukon and Kuskokwim Rivers. Twenty-seven Yukon chum salmon tags were recovered in the voluntary program.

Chum Salmon Stock Composition in the South Peninsula June Fishery

Reported Recoveries in Western and Central Alaska Chum Salmon Runs

The reported recoveries from catches in western and central Alaska chum salmon fisheries obtained through the voluntary program were expanded to account for tagged fish in the escapement. This was necessary because the escapement, in general, was not examined for tagged fish, and the few recoveries that were returned from escapement were not considered as part of the reported recoveries. The reported recoveries for each fishery was expanded to the entire run by dividing by the respective rate of exploitation. For example, six tags were reported in the voluntary program for Yukon fall chum salmon. The commercial and subsistence harvests of fall chum salmon in the entire Yukon River drainage was 290 thousand fish, and the total estimated run was 745 thousand fish. Because this harvest represented 38.9% of the total return, we estimated 6 / 0.389 or 15 tagged fish in the

TABLE 3.—Differences between the observed number of chum salmon recoveries in the fishery sampling program and that expected assuming an average reported fraction of 0.69.

Fishery	Sampling Fraction (%)	Reported Recoveries	(1) Observed Recoveries Fishery Sampling Program	(2) Expected Recoveries Using Average Reported Fraction	Contribution to Chi-square[a]
Kuskokwim	8.9	139	23	18	1.43
Bristol Bay					
Togiak	11.9	89	20	15	1.41
Nushagak	8.6	171	10	21	6.01
Naknek Kvichak	0.2	38	0	0	0.11
Egegik	1.4	16	1	0	1.40
Ugashik	4.2	11	1	1	0.16
North Peninsula					
Northern	6.3	37	2	3	0.56
Northwestern	9.3	20	3	3	0.03
South Peninsula June	6.2	77	9	7	0.63
South Peninsula July					
Southwestern	2.8	17	0	1	0.69
Southcentral	0.4	30	0	0	0.17
Shumagin	9.9	20	2	3	0.26
Southeast Mainland	2.3	20	2	1	2.67
		Chi-Square Statistic (P = 0.22)			15.5

[a] (Column n #1 - Column #2)^2 / Column #2

total Yukon fall chum return that would have been reported if the entire run were harvested.

This procedure was repeated for the Shumagin, Unimak, and combined releases in each fishery in western and central Alaska (Table 4). The total number of tagged chum salmon reported to occur in the western and central Alaska return was 1,316. This figure included 77 reported recoveries intercepted in the South Peninsula June fisheries.

Expansions For Under-reporting and Mortality

The estimated reported recoveries in the return were expanded for under-reporting and mortality for

TABLE 4.—Expansion of reported recoveries in the catch to total run for various western and central Alaska chum salmon fisheries.

	Return (thousands)					Recoveries With No Adjustment for Underreporting					
						Unimak Releases		Shumagin Releases		Comb. Releases	
Fishery unit/stock	Catch	Escapement	Total	Rate of Exploit. (%)	Percent of Combined[a] Run	Catch	Return	Catch	Return	Catch	Return
Kotzebue	159	41	200	79.5	0.3	2	3	1	1	3	4
Norton Sound	118	60	178	66.3	0.2	6	9	4	6	10	15
Yukon											
Summer Run	827	499	1,326	62.4	1.7	16	26	5	8	21	34
Fall Run	290	455	745	38.9	0.9	2	5	4	10	6	15
Total Yukon	1,170	954	2,071	53.9	2.6	18	31	9	18	27	49
Kuskokwim											
Kuskokwim Bay	30	54	84	35.7	0.1	6	17	2	6	8	22
Kuskokwim R.	640	527	1,167	54.8	1.5	94	171	45	82	139	253
Total Kuskokwim	670	581	1,251	53.6	1.6	100	188	47	88	147	276
Bristol Bay											
Togiak	422	392	814	51.8	1.0	69	133	20	39	89	172
Nushagak	403	233	636	63.4	0.8	132	208	39	62	171	270
Naknek/Kvichak	441	639	1,080	40.8	1.4	23	56	15	37	38	93
Egegik	148	36	184	80.4	0.2	12	15	4	5	16	20
Ugashik	96	31	127	75.6	0.2	8	11	3	4	11	15
Total Bristol Bay	1,510	1,331	2,841	53.2	3.6	244	423	81	146	325	569
Aleutian Islands	0	1	1	0.0	0.0	0	0	0	0	0	0
North Peninsula											
Northern District	155	165	320	48.4	0.4	25	52	12	25	37	76
N.W. District	176	367	543	32.4	0.7	18	56	2	6	20	62
Total N. Pen.	331	532	863	38.4	1.1	43	107	14	31	57	138
South Peninsula June											
Unimak (S.W.)	406	0	406	100.0	0.5	37	37	38	38	75	75
Shumagin	37	0	37	100.0	0.0	0	0	2	2	2	2
S.E. Mainland	3	0	3	100.0	0.0	0	0	0	0	0	0
Total S. Pen. June	446	0	446	100.0	0.6	37	37	40	40	77	77
South Peninsula July											
Southwestern	216	392	608	35.5	0.8	6	17	11	31	17	48
Southcentral	198	138	336	58.9	0.4	10	17	20	34	30	51
Shumagin	311	16	327	95.1	0.4	6	6	14	15	20	21
S.E. Mainland	241	150	391	61.6	0.5	13	21	7	11	20	32
Total S. Pen. July	966	696	1,662	58.1	2.1	35	61	52	91	87	152
Chignik	127	81	208	61.1	0.3	1	2	9	15	10	16
Kodiak	682	798	1,480	46.1	1.9	0	0	4	9	4	9
Cook Inlet	506	715	1,221	41.4	1.5	1	2	3	7	4	10
Prince Wllm Sound	1,920	319	2,239	85.8	2.8	1	1	0	0	1	1
Coastal USSR	6,613	6,613	13,226	50.0	16.7	7	14	6	12	13	26
Coastal Japan			48,624	100.0	61.3	7	7	30	30	37	37
Japanese High Seas			2,758		3.5	0	0	0	0	0	0
All Areas Combined			79,269			502	885	300	494	802	1,379

[a]Combined chum salmon run for the western and central Alaska stocks.

the Shumagin and Unimak releases. Reported fractions estimated in the fishery sampling program (Table 1) were used to expand the reported recoveries in the respective fishery unit return to account for tags that were not reported to ADF&G. Two cases were examined. In the first case, referred to henceforth as the *observed* case, the reported recoveries in each fishery unit were expanded by the observed reported fraction (Table 5). Note that in the observed case the average reported fraction was assumed for fisheries in which a fishery sampling program was not conducted. In the second case, referred to henceforth as the *average* case, the reported fraction averaged across fishery units was used to expand the reported recoveries for all fishery units (Table 6).

The travel times (Tables 5 and 6) used to compute the delayed mortality rate were based on the difference between the date of release and date of recovery averaged over all recoveries for the respective fishery unit (Eggers et al. 1989). For the observed case reported

TABLE 5.—Estimates of stock composition of chum salmon for Unimak releases, assuming reported fraction is that observed in individual fishery sampling programs.

Parameter	
Reported Fractions	Observed in fishery
Immediate Mortality	45%
Delayed Mortality rate (per/day)	0.01613

Fishery	Reported Tagged Fish In: Catch	Return	Tags Expanded for Underreporting	Travel Time (d)	Tags Expanded for Mortality	Proportion (%) of Released Population
Unimak Releases						
Kotzebue	2	3	5	28.0	14	0.4
Norton Sound	6	9	17	23.8	45	1.3
Yukon Summer	16	26	42	20.4	105	3.1
Yukon Fall	2	5	10	30.0	29	0.9
Kuskokwim	100	188	352	21.7	900	26.3
Bristol Bay	244	423	498	18.0	1200	35.0
North Peninsula	43	107	120	19.6	297	8.7
South Peninsula	37	37	37	2.5	69	
South Peninsula	35	61	78	33.8	242	7.1
Central Alaska	3	5	9	33.8	28	0.8
Coastal U.S.S.R.	7	14	20	134.5	320	9.3
Coastal Japan	7	7	10	161.1	246	7.2
Total Unimak	502	885	1,198		3,495	100
Shumagin Releases						
Kotzebue	1	1	2	38.0	7	0.2
Norton Sound	4	6	11	28.9	32	1.1
Yukon Summer	5	8	15	76.5	93	3.4
Yukon Fall	4	10	19	63.0	95	3.4
Kuskokwim	47	88	164	24.9	442	16.1
Bristol Bay	81	146	170	21.1	430	15.7
North Peninsula	14	31	35	18.6	85	3.1
South Peninsula	40	40	40	4.5	77	
South Peninsula	52	91	115	19.2	283	10.3
Central Alaska	16	31	56	26.9	156	5.7
Coastal U.S.S.R.	6	12	17	119.8	216	7.9
Coastal Japan	30	30	43	152.2	912	33.2
Total Shumagin	196	330	456		2,827	100

	Unimak Return	Unimak Mortality	Unimak Total	Shumagin Return	Shumagin Mortality	Shumagin Total
Total Alaskan Stocks	1,131	1,729	2,860	355	1,266	1,621
South Peninsula June Fishery	37	32	69	40	37	77
Asian Stocks	30	535	566	61	1,068	1,129
Total Releases	1198	2,297	3,495	456	2,371	2,827
Tagging Mortality Rate		65.7%			83.9%	

fractions, the immediate tagging mortality fraction (*K*) was 48%, and delayed mortality rate (*J*), for which the expanded reported recoveries were equal to the actual recoveries, was 0.0161 (Table 5). For the average reported fractions, the immediate tagging mortality fraction (K) was 39% and the delayed mortality rate (*J*) was 0.0174 (Table 6). A unique solution occurred for mortality parameter values in both the observed case and average case reported fractions (i.e., actual and expanded releases were equal for the Unimak and Shumagin releases).

The overall tagging mortality rate was very similar for both cases. The overall tagging mortality rate for the average case was 63.3% for the Unimak and 83.1% for the Shumagin chum salmon releases (Table 6).

Estimates of Stock Composition for the Chum Salmon Releases

Because a unique solution occurred for mortality parameter values in both the observed and average case reported fractions, there was no goodness-of-fit

TABLE 6.—Estimates of stock composition of chum releases assuming reported fraction is the average of 0.69 for all fisheries.

Parameters	
Reported Fraction	69%
Immediate Mortality	38%
Delayed Mortality rate (per/day)	0.0174

Fishery	Reported Tagged Fish In: Catch	Return	Tags Expanded for Underreporting	Travel Time (d)	Tags Expanded for Mortality	Proportion (%) of Released Population
Unimak Releases						
Kotzebue	2	3	4	28.0	11	0.3
Norton Sound	6	9	13	23.8	32	0.9
Yukon Summer	16	26	38	20.4	87	2.6
Yukon Fall	2	5	7	30.0	20	0.6
Kuskokwim	100	188	272	21.7	645	18.9
Bristol Bay	244	423	613	18.0	1,361	40.0
N. Peninsula	43	107	155	19.6	354	10.4
S. Peninsula June	37	37	54	2.5	91	
S. Peninsula July	35	61	88	33.8	258	7.6
Central Alaska	3	5	7	33.8	21	0.6
Coastal U.S.S.R.	7	14	20	134.5	342	10.1
Coastal Japan	7	7	10	161.1	272	8.0
Total Unimak	502	885	1,283		3,495	100
Shumagin Releases						
Kotzebue	1	1	1	38.0	5	0.2
Norton Sound	4	6	9	28.9	23	0.9
Yukon Summer	5	8	12	76.5	71	2.6
Yukon Fall	4	10	14	63.0	70	2.6
Kuskokwim	47	88	128	24.9	319	11.7
Bristol Bay	81	146	212	21.1	496	18.2
N. Peninsula	14	31	45	18.6	101	3.7
S. Peninsula June	40	40	58	4.5	102	
S. Peninsula July	52	91	132	19.2	299	11.0
Central Alaska	16	31	45	26.9	117	4.3
Coastal U.S.S.R.	6	12	17	119.8	227	8.3
Coastal Japan	30	30	43	152.2	998	36.6
Total Shumagin	196	330	478		2,828	100

	Unimak Return	Mortality	Total	**Shumagin** Return	Mortality	Total
Total Alaskan Stocks	1,199	1,591	2,790	359	1,141	1,501
S. Peninsula June Fishery	54	37	91	58	44	102
Asian Stocks	30	584	614	61	1165	1226
Total Releases	1,283	2,212	3,495	478	2,350	2,828
Tagging Mortality Rate		63.3%			83.1%	

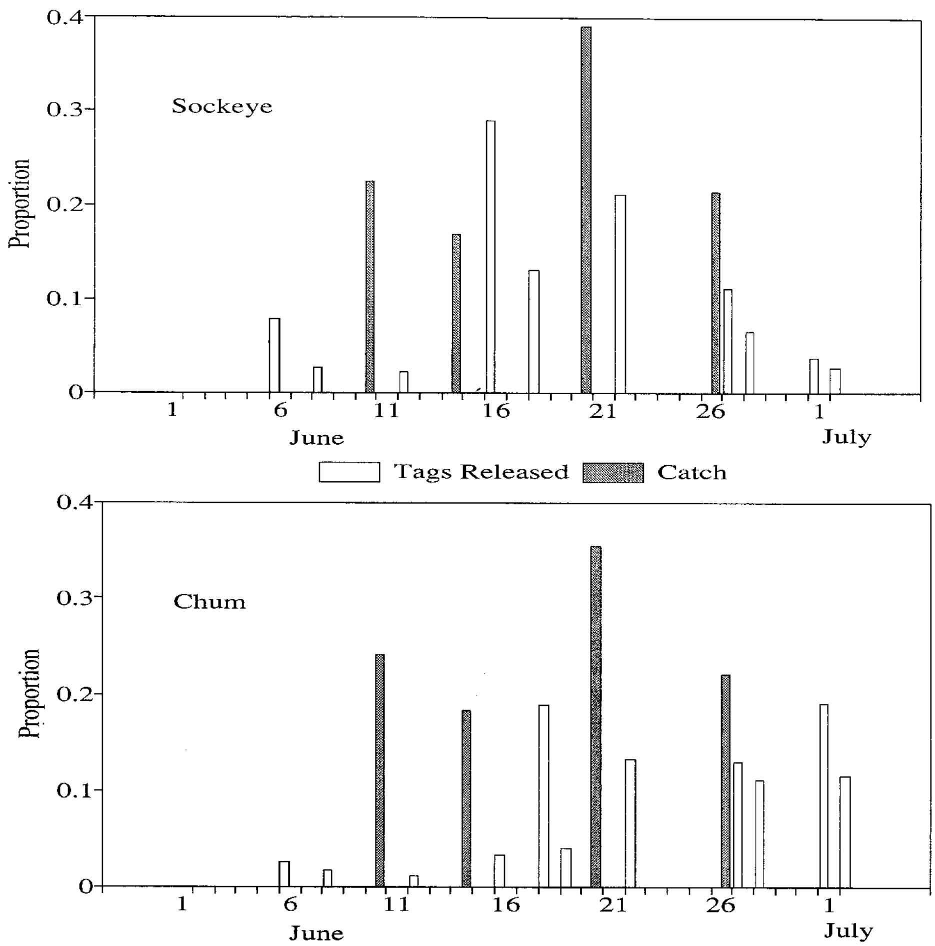

FIGURE 6.—Timing of 1987 tag releases and catches of sockeye and chum salmon in the Shumagin district.

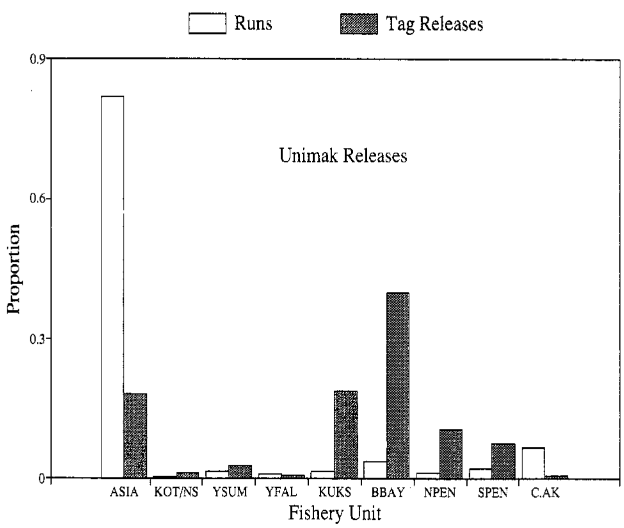

FIGURE 7.—Stock composition (% of total run) of collective Asian and western and central Alaska runs versus stock composition (% of release) of Unimak releases of shum salmon, for various fishery units.

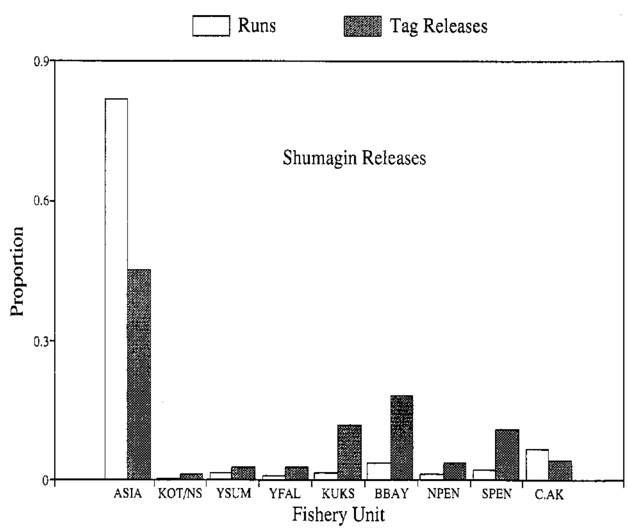

FIGURE 8.—Stock composition (% of total run) of collective Asian and western and central Alaska runs versus stock composition (% of release) of Shumagin releases of shum salmon, for various fishery units.

basis to select a preferred case. The average case was used to calculate stock composition (Table 7) based on the finding of no significant differences in the reported fractions among fisheries (Table 3). However, the finding of no significant differences in the reported fractions among fisheries may have been due to low sampling fractions and the concomitant low statistical power of the test rather than actual similarities in reported fractions among fisheries. The selection of the average case also simplified the analysis of data and avoided subjective assumptions relative to reported fractions in fisheries for which sampling programs were not conducted.

The stock composition for a given fishery unit was the expanded number of recoveries divided by the total expanded recoveries less the estimated recaptures in the South Peninsula June fishery.

The chum salmon releases were a diverse mixture of stocks, and no particular stock dominated the releases (Table 6). Tagged fish of Asian origin were significant and constituted 18% of the Unimak and 44.9% of the Shumagin releases. Tagged fish of Bristol Bay origin were the most abundant stock in the in the Unimak releases, accounting for 40.0%. Tagged fish of Japanese origin were the most abundant stock in the Shumagin releases, accounting for 36.6%. Of the Alaskan stocks, Bristol Bay and Kuskokwim stocks were most abundant in the releases accounting for 59% of the Unimak and 29.9% of the Shumagin releases. The stock composition of the chum salmon releases was also compared to relative abundance as indexed by the respective fishery unit run as a proportion of the collective Asian, western Alaska, and central Alaska runs.

These comparisons were made for Asian (Japan and U.S.S.R.), Kotzebue/Norton Sound, Kuskokwim, Bristol Bay, North Peninsula, South Peninsula July, and central Alaska (Chignik, Kodiak, Cook Inlet, and Prince William Sound) stocks of sockeye (Figures 7, 8).

For the both the Unimak and Shumagin releases, the stock compositions of the western and central Alaska stocks, except for the Kotzebue/Norton Sound and central Alaska stocks were higher than the respective relative abundances. For both releases the contribution of the Asian stocks was lower than the relative abundance. Asian chum salmon abundance was much larger than that of western and central Alaska, constituting 80.9% of the estimated 1987 return to the region (Table 4). It is not surprising that the Asian contribution to the releases was significant, in view of the high Asian chum salmon abundance relative to that of western and central Alaska.

We found significant differences in the stock composition of the Unimak and Shumagin chum salmon releases. Chum salmon of Alaskan origin were more prevalent in the Unimak releases and less prevalent in the Shumagin releases. Correspondingly, the Asian chums were less prevalent in the Unimak releases and more prevalent in the Shumagin releases. Alaskan stocks that spawned closer to the release area tended to be more numerous in the releases. South Peninsula and central Alaska stocks, for example, were more

ABLE 7.—Values of parameters in the Monte Carlo simulation model of chum salmon stock composition estimates. The λ_i's are the mean of the Poisson probability distribution for reported recoveries by area of release and fishery. The δ_i's are is the probabilities of recovering a tagged fish in the fishery sampling programs.

Fishery/Stock	λ_i for Unimak Releases	λ_i for Shumagin Releases	Rate of Exploitation	Catch (thousands)	Catch Sampled (thousands)	δ_i
Kotzebue	2	1	0.80	159	0	
Norton Sound	5	4	0.66	118	0	
Yukon Summer	16	5	0.62	827	0	
Yukon Fall	2	4	0.39	290	0	
Kuskokwim	100	47	0.54	670	57	0.000319
Bristol Bay	225	78	0.53	1,510	91	0.000290
North Peninsula	41	12	0.38	331	30	0.000232
South Peninsula June	37	40	1.00	446	27	0.000251
South Peninsula July	35	53	0.58	966	36	0.000132
Central Alaska	3	19	0.60	3,235	0	
Coastal USSR	7	6	0.50	6,613	0	

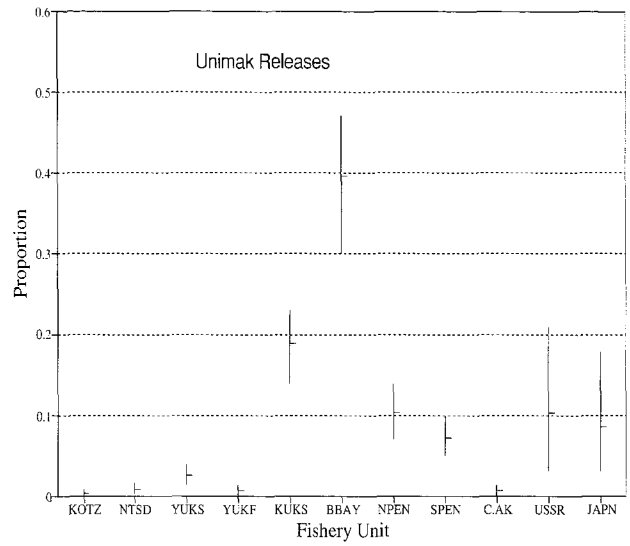

FIGURE 9.—Estimates of stock composition and 95% confidence intervals for the Unimak chum salmon releases.

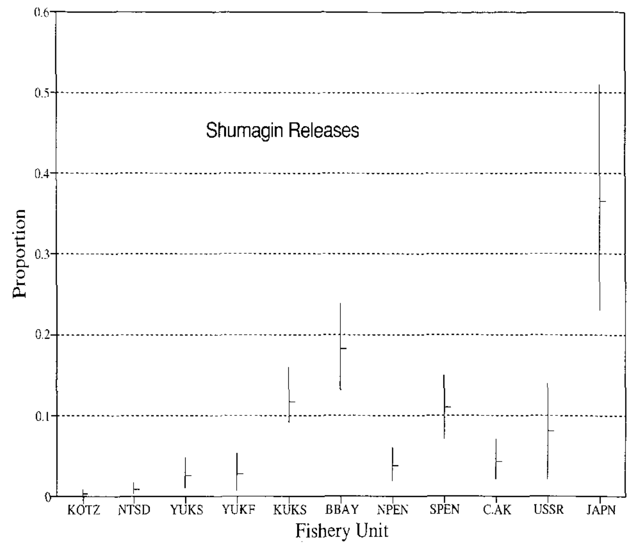

FIGURE 10.—Estimates of stock composition and 95% confidence intervals for the Shumagin chum salmon releases.

abundant in the Shumagin releases (14.3%) than in the Unimak releases (8.2%). Kuskokwim, Bristol Bay, and north Peninsula stocks, however, were more numerous in the Unimak releases (69%) than in the Shumagin releases (33.6%).

This indicated that the stocks closest to the South Peninsula fishery were more vulnerable to the fishery. Asian stocks seem to be more vulnerable to the Shumagin fishery than to the Unimak fishery.

Variance and Confidence Intervals for Stock Composition of Chum Releases

We used a Monte Carlo simulation model to estimate variance and 95% confidence intervals for stock composition of chum salmon releases. Values of parameters used to generate the simulated observations of reported and sampling program recoveries are given in Table 7. For each model run, a random observation of reported recoveries by fishery and area was generated using the Poisson random number generator with the respective parameter (λ_i) in Table 7 implicit. Also random observations for recoveries in the fishery sampling programs were generated using the binomial random number generator with the respective parameters (δ_i), in Table 7 implicit.

The simulation model was coded in FORTRAN and used IMSL subroutines for generating random numbers and solving the 2 × 2 system of nonlinear equations

TABLE 8.—Sampling distributions for chum salmon stock composition estimates of Unimak and Shumagin releases.

	Unimak Releases					Shumagin Releases				
				95 Conf. Limit					95 Conf. Limit	
Fishery/Stock	Mean	S.D	C.V.	Upper	Lower	Mean	S.D.	C.V.	Upper	Lower
Kotzebue	0.3	0.2	68.7	0.0	0.8	0.2	0.2	96.3	0.0	0.8
Norton Sound	0.8	0.4	45.0	0.2	1.6	0.9	0.4	48.8	0.2	1.6
Yukon Summer	2.5	0.7	28.3	1.4	3.8	2.6	1.2	44.7	1.0	4.8
Yukon Fall	0.6	0.4	69.4	0.0	1.4	2.7	1.4	51.4	0.6	5.2
Kuskokwim	18.9	2.6	13.5	14.0	23.0	11.7	2.3	19.5	9.0	16.0
Bristol Bay	39.7	4.8	12.2	30.0	47.0	18.2	3.3	18.0	13.0	24.0
N. Peninsula	10.4	1.9	18.3	7.0	14.0	3.7	1.2	32.9	1.8	6.0
S. Peninsula July	7.3	1.4	18.7	5.0	10.0	11.0	2.1	19.3	7.0	15.0
Central Alaska	0.6	0.4	61.0	0.0	1.4	4.3	1.1	25.9	2.0	7.0
Coastal USSR	10.4	5.4	52.0	3.0	21.0	8.1	3.4	41.5	2.0	14.0
Coastal Japan	8.6	4.8	55.4	3.0	18.0	36.6	8.0	22.0	23.0	51.0

required to estimate K and J. In estimating stock composition from the simulated observations, the average reported fraction was assumed for all fisheries to be the average of the simulated reported fractions for the five fisheries for which sampling programs were conducted (Kuskokwim, Bristol Bay, North Peninsula, South Peninsula June, and South Peninsula July).

The means, standard deviations, coefficients of variation, and 95% confidence intervals for the sampling distributions of the stock composition estimates are given in Table 8. The precision is greatest, as reflected in relatively low coefficients of variation, on stock composition estimates for stocks that had a relatively high expected number of reported recoveries, i.e., the Kuskokwim, Bristol Bay, North Peninsula, and South Peninsula stocks (Table 8). Confidence intervals for the Unimak and Shumagin releases are shown graphically in Figures 9 and 10, respectively. The confidence intervals are relatively wider for the Asian stocks.

Sensitivity of Stock Composition estimates to Assumptions for Asian Stock Expansion

No information was available on the rate of exploitation and reported fractions for the U.S.S.R. and Japanese fisheries. The exploitation rate for Japanese chum salmon, which were entirely hatchery stocks, were therefore taken to be unity. Because assumptions for these quantities were necessary to estimate stock composition of the tag releases and because the assumptions were subjective, the Monte Carlo simulation model was used to examine the sensitivity of stock composition estimates to the assumptions for Asian stock expansion factors.

Three cases were examined: (1) only the Japan expansion factors were in error, (2) only the U.S.S.R. expansion factors were in error, and (3) both the Japan and U.S.S.R. expansion factors were in error and at the same error rates. In addition to the Asian stocks, the stock composition estimates for the two major Alaskan contributors, Bristol Bay and Kuskokwim, were examined.

The results for case (1) are shown in Figure 11 for Unimak and Figure 12 for Shumagin releases. The bias as given by the ratio of the true to estimated stock composition ($P_i^{true}/P_i^{estimated}$) was plotted against the ratio of the true to estimated $U_i \cdot R_i$ (i.e., b_i). When $P_i^{true}/P_i^{estimated}$ was greater than 1, the stock composition was underestimated. If the reported fraction for Japanese coastal fisheries was lower than 0.69 assumed, which was the average observed for western and central Alaska, the estimates of the Japanese, Bristol Bay, and Kuskokwim stock composition were

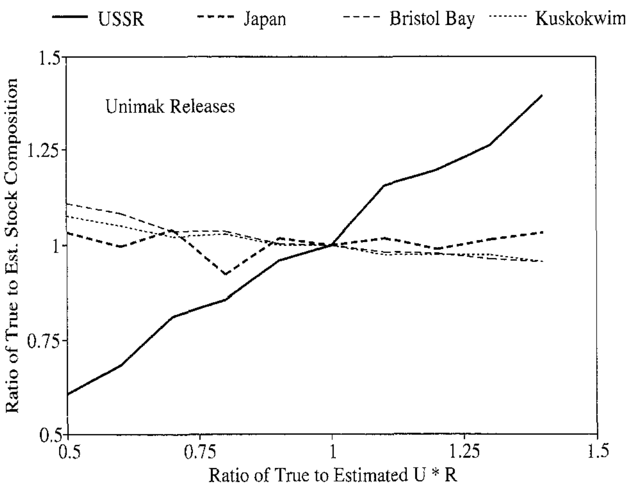

FIGURE 11.—Bias in estimates of stock composition for the Unimak releases (expressed as the ratio of the true to estimated stock composition) as it relates to errors in expansion factor (expressed as the ratio of true to estimated U · R), for the case where only Japanese expansion factors were in error.

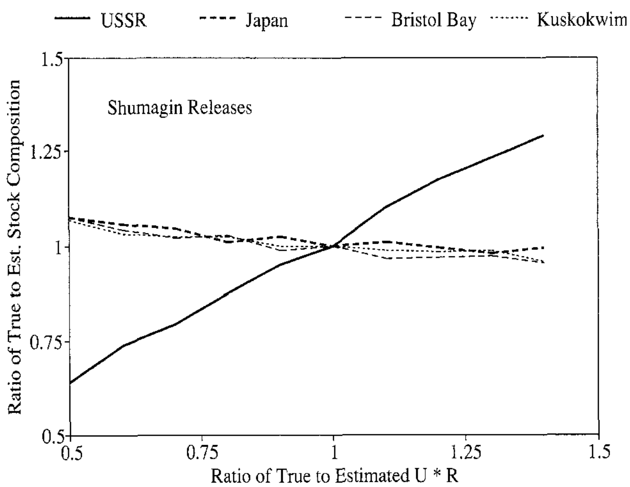

FIGURE 12.—Bias in estimates of stock composition for the Shumagin releases (expressed as the ratio of the true to estimated stock composition) as it relates to errors in expansion factor (expressed as the ratio of true to estimated U · R), for the case where only Japanese expansion factors were in error.

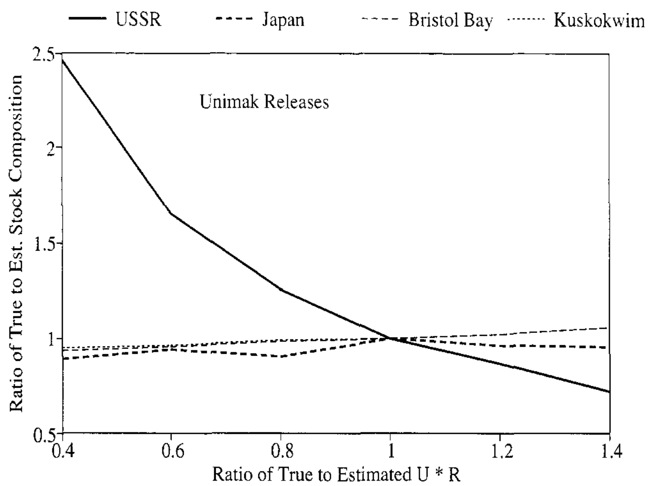

FIGURE 13.—Bias in estimates of stock composition for the Unimak releases (expressed as the ratio of the true to estimated stock composition) as it relates to errors in expansion factor (expressed as the ratio of true to estimated U · R), for the case where only the U.S.S.R. expansion factors were in error.

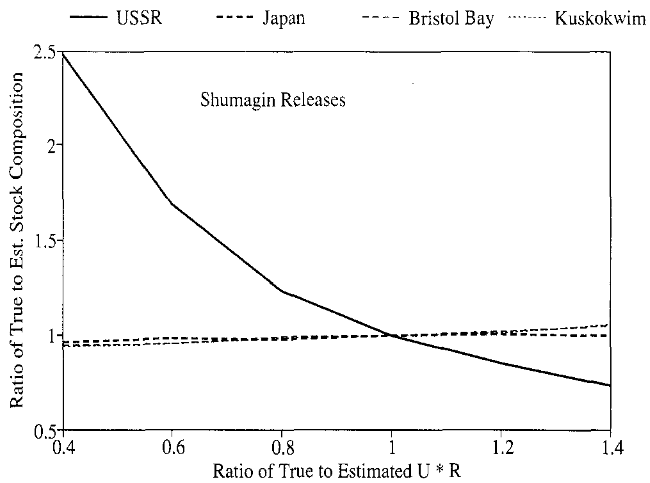

FIGURE 14.—Bias in estimates of stock composition for the Shumagin releases (expressed as the ratio of the true to estimated stock composition) as it relates to errors in expansion factor (expressed as the ratio of true to estimated U · R), for the case where only U.S.S.R. expansion factors were in error.

too low. These low estimates were almost completely compensated for by the high U.S.S.R. estimates. The magnitude of the bias for U.S.S.R. stocks was much larger than the bias for the Japanese, Bristol Bay, and Kuskokwim estimates. The pattern was similar for the Unimak releases (Figure 11) and Shumagin releases (Figure 12). The magnitude of bias was almost negligible for Alaskan stocks for b_i between 0.75 and 1.25.

The results for case (2) releases are shown in Figures 13 for Unimak and Figure 14 for Shumagin. Here, only the U.S.S.R. expansion factors were in error. If the product of reported fraction and rate of exploitation was lower than 0.35 (i.e., 0.69 · 0.5) for the U.S.S.R. coastal fisheries, then the estimates of the U.S.S.R. stock composition of both the Unimak and Shumagin

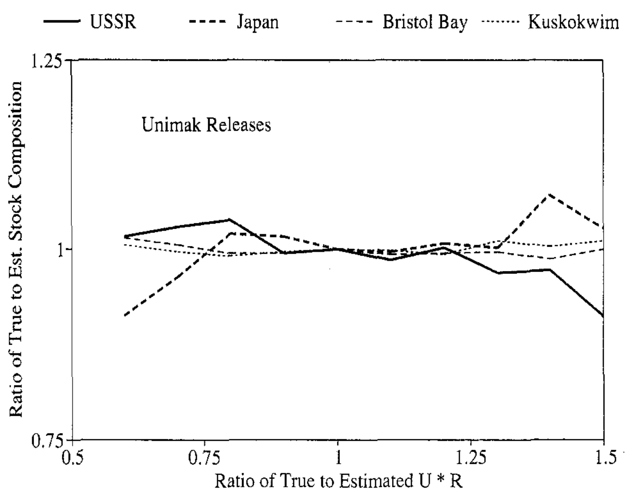

FIGURE 15.—Bias in estimates of stock composition for the Unimak releases (expressed as the ratio of the true to estimated stock composition) as it relates to errors in expansion factor (expressed as the ratio of true to estimated U · R), for the case where both the Japanese and U.S.S.R. expansion factors were in error.

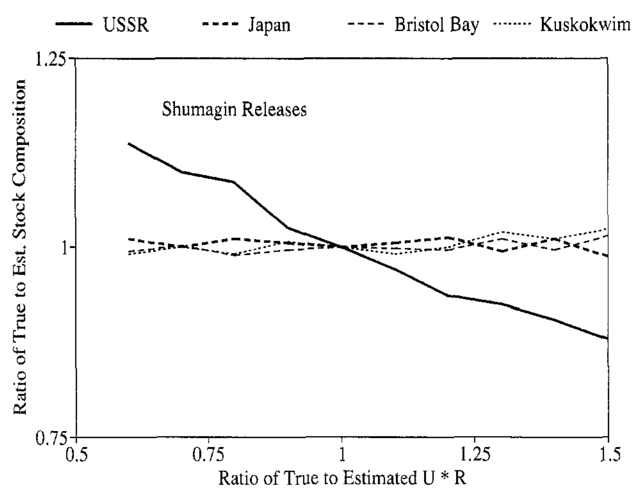

FIGURE 16.—Bias in estimates of stock composition for the Shumagin releases (expressed as the ratio of the true to estimated stock composition) as it relates to errors in expansion factor (expressed as the ratio of true to estimated U · R), for the case where both the Japanese and U.S.S.R. expansion factors were in error.

releases would be too low. This magnitude of this bias for the U.S.S.R. stock composition estimates was potentially large. However, this bias was compensated almost completely by the Japanese estimates being too high. This bias had an almost negligible effect on the estimates for Alaskan stocks (Figures 13 and 14).

The results for case 3, for Unimak and Shumagin releases are shown in Figures 15 and 16, respectively. Here, the expansion factors for both the Japanese and U.S.S.R. stocks were assumed to be in error. If the product of reported fraction and rate of exploitation for the Asian fisheries was lower than assumed, then the estimates for the U.S.S.R. stocks were too low and the estimates for the Japanese stocks too high. Conversely, if the product of reported fraction and rate of exploitation for the Asian fisheries was higher than assumed, then the estimates for the U.S.S.R. stocks were too high and the estimates for the Japanese stocks too low. The magnitude of the bias for the U.S.S.R. and Japanese stocks was similar for the Unimak re-

TABLE 9.—Expansion of reported recoveries in the catch to total run for various western and central Alaska sockeye salmon fisheries.

	Return (thousands)					Recoveries With No Adjustment for Underreporting					
						Unimak Releases		Shumagin Releases		Comb. Releases	
Fishery unit/stock	Catch	Escapement	Total	Rate of Exploit. (%)	Percent of Combined[a] Run	Catch	Return	Catch	Return	Catch	Return
Norton Sound	1	7	7	14.3	0.0	1	7	0	0	1	7
Kuskokwim											
Kuskokwim Bay	35	65	100	35.0	0.2	5	14	0	0	5	14
Kuskokwim R.	163	241	404	40.3	0.8	0	0	0	0	0	0
Total Kuskokwim	198	306	504	39.3	1.0	5	14	0	0	5	14
Bristol Bay											
Togiak	340	316	656	51.8	1.3	13	25	3	6	16	31
Nushagak	3,253	1,894	5,147	63.2	9.9	224	354	32	51	256	405
Naknek/Kvichak	4,949	7,282	12,231	40.5	23.5	376	929	50	124	426	1,053
Egegik	5,387	1,273	6,660	80.9	12.8	292	361	34	42	326	403
Ugashik	2,119	687	2,806	75.5	5.4	103	136	13	17	116	154
Total Bristol Bay	16,048	11,452	27,500	58.4	52.8	1,008	1,806	132	239	1,140	2,045
Aleutian Islands	0	18	18	0.0	0.0	0	0	0	0	0	0
North Peninsula											
Northern District	1,065	576	1,641	64.9	3.1	86	133	17	26	103	159
N.W. District	143	60	203	70.4	0.4	14	20	8	11	22	31
Total N. Pen.	1,208	636	1,844	65.5	3.5	100	152	25	38	125	190
S. Peninsula June											
Unimak (S.W.)	652	0	652		1.3	192	192	100	100	292	292
Shumagin	141	0	141		0.3	1	1	18	18	19	19
S.E. Mainland	56	0	56		0.1	0	0	2	2	2	2
Total S. Pen. June	849	0	849		1.6	193	193	120	120	313	313
S. Peninsula July											
Southwestern	68	51	119	57.1	0.2	37	65	10	18	47	82
Southcentral	39	4	43	90.7	0.1	17	19	11	12	28	31
Shumagin	249	3	252	98.8	0.5	8	8	8	8	16	16
S.E. Mainland	55	23	78	70.5	0.1	1	1	1	1	2	3
Total S. Pen. July	411	81	492	83.5	0.9	63	93	30	39	93	132
Chignik											
Early Run	1,685	610	2,295	73.4	4.4	29	39	42	57	71	97
Late Run	576	193	769	74.9	1.5	3	4	4	5	7	9
S.E. Mainland	170	0	170	100.0	0.3	7	7	13	13	20	20
Total Chignik	2,431	803	3,064	79.3	5.9	39	51	59	76	98	126
Kodiak	1,450	1,709	3,159	45.9	6.1	6	13	17	37	23	50
Cook Inlet	9,750	2,404	12,154	80.2	23.3	2	2	2	2	4	5
Prince Wllm Sound	1,738	789	2,527	68.8	4.8	1	1	0	0	1	1
All Combined	34,084	18,205	52,118	65.4		1,418	2,333	385	551	1,803	2,884

[a]Combined sockeye salmon run for the western and central Alaska stocks.

leases (Figure 15), and for the Shumagin releases the magnitude of the bias was greater for the U.S.S.R. estimates (Figure 16). This bias had almost no effect on the estimates for the Alaskan stocks.

It is clear that the estimates of the Alaskan stock composition were extremely robust with respect to assumptions made regarding reported fraction and rate of exploitation for the Asian stocks. It is likely, because of the poor communication facilities in the Soviet Union and the isolated nature of the U.S.S.R. coastal fisheries, that few of the tags that occurred in the U.S.S.R. catch were actually returned to ADF&G. The assumption of a reported fraction of 0.69 is likely in error and would result in overestimating Japanese contributions and underestimating U.S.S.R. contributions. This error has almost no effect on the estimates of Alaskan stock contributions to the releases.

Sockeye Salmon Stock Composition in the South Peninsula June Fishery

Reported Recoveries in Western and Central Alaska Sockeye Salmon Runs

The recoveries from catches in western and central Alaska sockeye salmon fisheries obtained through the voluntary program were expanded to reflect tags present in the escapement. This expansion was necessary because the escapement, in general, was not examined for presence of tags, and recoveries would not be reported. The few recoveries that were returned from

TABLE 10.—Estimates of stock composition of sockeye releases assuming reported fraction is that observed in individual fishery sampling programs.

Parameters	
Reported Fraction	Observed in fishery
Immediate Tagging Mortality:	
Shumagin	28%
Unimak	45%
Delayed Mortality rate (per day)	0.0161

Fishery	Reported Tagged Fish In: Catch	Return	Tags Expanded for Under-reporting	Travel Time (d)	Tags Expanded for Mortality	Proportion (%) of Released Population
Unimak Releases						
Kuskokwim	5	15	27	22.5	38	0.7
Bristol Bay	1008	1799	3327	16.6	4826	89.4
North Peninsula	100	152	152	17.4	211	4.1
S. Peninsula June	193	193	193	2.9	268	
S. Peninsula July	63	93	93	19.5	129	2.5
Chignik	39	53	90	15.2	125	2.4
Kodiak	6	13	24	22.8	33	0.6
Other Stocks	3	4	8	20	11	0.2
Total Unimak	1417	2322	3914		5441.9	100.0
Shumagin Releases						
Kuskokwim	0	0	0		0	0.0
Bristol Bay	132	237	439	19.2	804	60.6
North Peninsula	25	38	38	26.5	70	5.2
S. Peninsula June	120	120	120	5.2	220	
S. Peninsula July	30	39	39	20.6	71	5.4
Chignik	59	80	134	16.1	245	18.5
Kodiak	17	37	69	19.6	126	9.5
Other Stocks	2	3	5	32.7	9	0.7
Total Shumagin	385	554	844		1545	100.0

	Unimak Return	Unimak Mortality	Unimak Total	Shumagin Return	Shumagin Mortality	Shumagin Total
Total Alaskan Stocks	3721	1453	5174	724	601	1325
S. Peninsula June Fishery	193	75	268	120	100	220
Asian Stocks	0	0	0	0	0	0
Total Releases	3914	1528	5442	844	701	1545
Tagging Mortality Rate		28.1%			45.4%	

escapement were not considered as part of the reported recoveries. The reported recoveries for each fishery was expanded by dividing by the respective rate of exploitation. As an example of this procedure, consider the expansion of the tags from combined Unimak and Shumagin Districts that were reported from Bristol Bay's Nushagak District catches (Table 5). The number of voluntary recoveries reported for Nushagak District totaled 256. Because the catch in the Nushagak District was 3,253/5,147 or 63.3% of the total return, we estimated 256/0.633 or 405 tagged fish in the Nushagak District total run that would have been reported if the entire run was harvested.

This procedure was repeated for the Shumagin, Unimak, and combined releases in each fishery in western and central Alaska (Table 9). The total number of tagged sockeye salmon reported to occur in the western and central Alaska runs was 2,884. This figure included 313 reported recoveries intercepted in the South Peninsula June fisheries.

Expansions For Under-reporting and Mortality

The estimated reported recoveries in the return were expanded for under-reporting and mortality for the Shumagin and Unimak releases. Reported fraction estimated in the fishery sampling program (Table 1) were used to expand the reported recoveries in the respective fishery unit return to account for tags that were reported to ADF&G. Two cases were examined.

TABLE 11.—Estimates of stock composition of sockeye releases assuming the reported fraction is the average of 0.69 for all fisheries.

Parameters	
Reported Fraction	69%
Immediate Tagging Mortality:	
Unimak	38%
Shumagin	48%
Delayed Mortality rate (per day)	0

Fishery	Reported Tagged Fish In: Catch	Reported Tagged Fish In: Return	Tags Expanded for Under-reporting	Travel Time (d)	Tags Expanded for Mortality	Proportion (%) of Relased Population
Unimak Release						
Kuskokwim	5	15	22	22.5	35	0.7
Bristol Bay	1,008	1,799	2,607	16.6	4,216	84.5
North Peninsula	100	152	220	17.4	356	7.1
S. Peninsula June	193	193	280	2.9	452	
S. Peninsula July	63	93	135	19.5	218	4.4
Chignik	39	53	77	15.2	124	2.5
Kodiak	6	13	19	22.8	30	0.6
Other Stocks	3	4	6	20	9	0.2
Total Unimak	1,417	2,322	3,365.22		5,441.8	100.0
Shumagin Release						
Kuskokwim	0	0	0		0	0.0
Bristol Bay	132	237	343	19.2	661	54.6
North Peninsula	25	38	55	26.5	106	8.8
S. Peninsula June	120	120	174	5.2	335	
S. Peninsula July	30	39	57	20.6	109	9.0
Chignik	59	80	116	16.1	223	18.4
Kodiak	17	37	54	19.6	103	8.5
Other Stocks	2	3	4	32.7	8	0.7
Total Shumagin	385	554	803		1,545	100.0

	Unimak Return	Unimak Mortality	Unimak Total	Shumagin Return	Shumagin Mortality	Shumagin Total
Total Alaskan Stocks	3,086	1,904	4,990	683	688	1,371
S. Peninsula June Fishery	280	173	452	120	54	174
Asian Stocks	0	0	0	0	0	0
Total Releases	3,365	2,077	5,442	803	742	1,545
Tagging Mortality Rate		38.2			48.0	

In the first case, referred to henceforth as the *observed* case, the reported recoveries in each fishery unit were expanded by the observed reported fraction (Table 10). Note that in the observed case the average reported fraction was assumed for fisheries for which a fishery sampling program was not conducted. In the second case, referred to henceforth as the *average* case, the reported fraction averaged across fishery units was used to expand the reported recoveries for all fishery units (Table 11).

The travel times (Tables 10, 11) used to compute the delayed mortality rate were based on the difference between the date of release and date of recovery averaged over all recoveries for the respective fishery unit (Eggers et al. 1989). For the sockeye releases, it was not possible to solve equations (8) and (9), i.e., determine a K and a J such that the expanded reported recoveries were equal to the actual releases. This was because the travel times between the Unimak and Shumagin releases were similar, and thus, the delayed mortality did not fully account for the lower recovery rate observed for the Shumagin releases. Because of the similarity in travel times it was not possible to differentiate delayed mortality from immediate mortality. The expansion factor for mortality was reparameterized as follows:

$$E_M^U = \frac{1}{(1 - K^U)} , \qquad (15)$$

and

$$E_M^S = \frac{1}{(1 - K^S)} . \qquad (16)$$

where K^U and K^S were estimated by equating the actual total releases by area to the expanded total reported releases by area and by solving for K^U and K^S.

$$f_1(K^U) = M - [(\sum \hat{M}_i^U) + \hat{M}_{\text{fpf}}^U] = 0 \qquad (17)$$

$$f_2(K^S) = M^S - [(\sum \hat{M}_i^S) + \hat{M}_{\text{fpf}}^S] = 0 \qquad (18)$$

For the case using observed reported fractions, the tagging mortality rate for the Unimak releases (K^U) for which the expanded reported recoveries was equal to the actual releases by area was 0.28; the Shumagin release (K^S) was 0.45 (Table 10). For the case using average reported fractions, K^U was 0.38 and K^S was 0.48 (Table 11). A unique solution occurred for mortality parameter values in both the observed and average reported fraction cases; i.e., actual and expanded releases were equal for the Unimak and Shumagin releases.

The tagging mortality rates estimated for the Unimak and Shumagin releases under both reporting fraction scenarios were consistent with those observed (40–45%) in a tagging program to determine stock interception rates in the Southeast Alaska-British Columbia boundary-area fisheries for pink and sockeye salmon (Pella et al. 1988).

Estimates of Stock Composition for the Sockeye Releases

As with the chum salmon releases, a unique solution for sockeye salmon occurred for mortality parameter values in both the observed and average reported fraction cases, and there was no goodness-of-fit basis to select a preferred case. Although significant differences in reported fractions were found among fisheries (Table 2), the average case was used to calculate stock composition (Table 11). This was to maintain consistency with and rationale for the estimation procedure used for the chum salmon releases. Further, there existed little difference in the estimates of stock composition under the observed and average reported fraction cases (Tables 10, 11).

The stock composition for a given fishery unit was the expanded number of recoveries divided by the total expanded recoveries, less the estimated recaptures in the South Peninsula June fishery. Tagged fish of Bristol Bay origin were dominant in the releases, accounting for 84.5% of the Unimak and 54.6% of the Shumagin releases.

The stock composition of the releases was also compared to relative abundance as indexed by the respective fishery unit return as a proportion of the total western and central Alaska return of sockeye salmon. These comparisons were made for Kuskokwim, Bristol Bay, North Peninsula, South Peninsula July, Chignik and central Alaska (i.e., Kodiak, Cook Inlet, and Prince William Sound) stocks of sockeye (Figures 17, 18). For the Unimak releases, the stock composition of the releases was higher than the respective relative abundance for Bristol Bay, North Peninsula, and South Peninsula July (Figure 17). The composition of Chignik and central Alaska stocks in

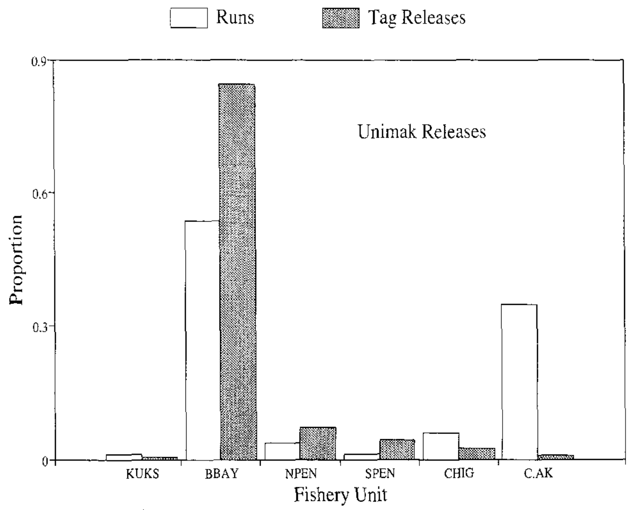

Figure 17.—Stock composition (% of total run) of western and central Alaska sockeye runs versus stock composition (% of releases) of Unimak releases of sockeye salmon, for various fishery units.

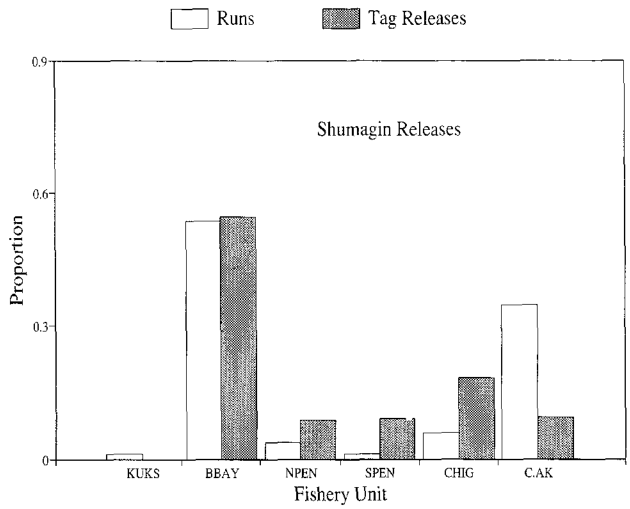

Figure 18.—Stock composition (% of total run) of western and central Alaska sockeye runs versus stock composition (% of releases) of Shumagin releases of sockeye salmon, for various fishery units.

the Unimak releases was lower than respective relative abundance (Figure 17). For the Shumagin releases, the stock composition of the releases was similar to relative abundance for Bristol Bay, higher than relative abundance for North Peninsula, South Peninsula, and Chignik, and lower than relative abundance for central Alaska.

The stock composition of the Unimak releases (Figure 17) was different from the stock composition of the Shumagin releases (Figure 18). Bristol Bay constituted the vast majority (almost 84.5%) of the Unimak releases but was a smaller component (54.6%) of the Shumagin releases. The North Peninsula, South Peninsula, Chignik, and central Alaska stocks were collectively more important in the Shumagin releases, contributing 45.4% of the Shumagin releases compared to 14.8% of the Unimak releases. This indicated that the sockeye stocks closest to the South Peninsula June fishery were more vulnerable to the fishery. This pattern was also found in the chum salmon releases.

Variance and Confidence Intervals for Stock Composition of Sockeye Releases

A Monte Carlo simulation model was used to estimate variance and 95% confidence intervals for stock composition of chum salmon releases. Values of parameters used to generate the simulated observations of reported recoveries and recoveries in the fishery sampling programs are given in Table 12. For each run

TABLE 12.—Values of parameters in the Monte Carlo simulation model of sockeye salmon stock composition estimates. The λ_i's are the mean of the Poisson probability distribution for reported recoveries by area of release and fishery. The δ_i's are the probabilities of recovering a tagged fish in the fishery sampling programs.

Fishery/Stock	λ_i for Unimak Releases	λ_i for Shumagin Releases	Rate of Exploitation	Catch (thousands)	Catch Sampled (thousands)	δ_i
Kuskokwim	5	0	0.3571	198	14	0.000023
Bristol Bay	1,004	132	0.5581	16,048	668	0.000095
N. Peninsula	100	25	0.6579	1208	122	0.000166
S. Peninsula June	193	120	1.000	849	57	0.000928
S. Peninsula July	63	26	0.6774	411	34	0.000365
Chignik	40	61	0.7647	2,431	0	
Kodiak	6	17	0.459	1,450	0	
Other Stocks	3	2	0.785	11,488	0	

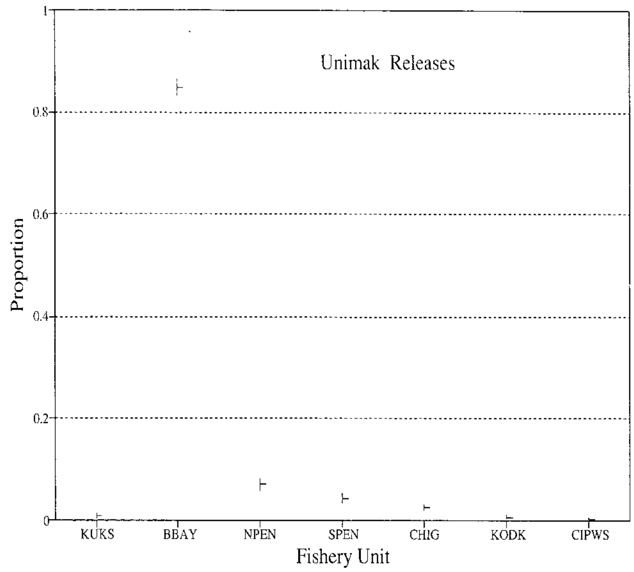

FIGURE 19.—Estimates of stock composition and 95% confidence intervals for the Unimak chum salmon releases.

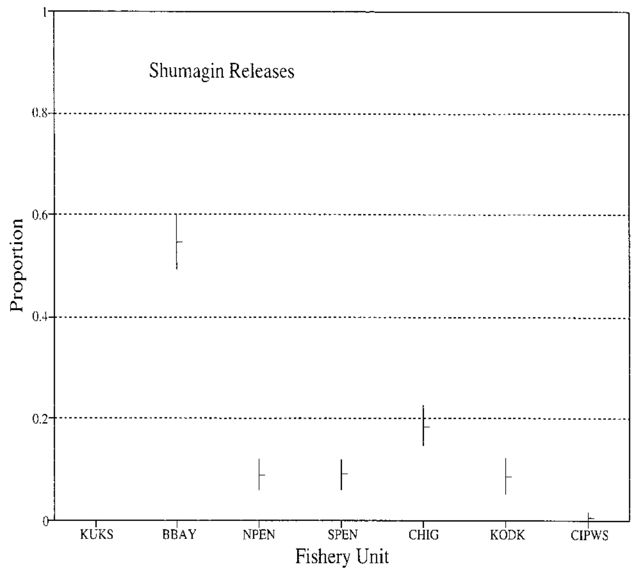

FIGURE 20.—Estimates of stock composition and 95% confidence intervals for the Shumagin chum salmon releases.

of the model, a random observation of reported recoveries by fishery and area was generated using the Poisson random number generator with the respective parameter (λ_i) in Table 12 implicit. Also random observations for recoveries in the fishery sampling programs were generated using the binomial random number generator with the respective parameters (δ_i), in Table 12 implicit.

The simulation model was coded in FORTRAN and used IMSL subroutines for random number generation. In estimating stock composition from the simulated observations, the average reported fraction was assumed for all fisheries and taken to be the average of the simulated reported fractions for the five fisheries (Kuskokwim, Bristol Bay, North Peninsula, South Peninsula June, and South Peninsula July) for which sampling programs were conducted.

The means, standard deviations, coefficients of variation, and 95% confidence intervals for the sampling distributions of the stock composition estimates are given in Table 13. The precision is greatest, as reflected in relatively low coefficients of variation, on stock composition estimates for stocks that had a relative high expected number of reported recoveries for the Bristol Bay stock (Table 13). Confidence intervals for the Unimak releases are shown graphically in Figure 19 and for the Shumagin releases in Figure 20. The confidence intervals were much narrower for the sockeye salmon stock composition estimates than for the chum salmon estimates.

TABLE 13.—Sampling distributions for sockey salmon stock composition estimates of Unimak and Shumagin releases.

	Unimak Releases					Shumagin Releases				
				95% Conf. Limit					95% Conf. Limit	
Fishery/Stock	Mean	S.D.	C.V.	Lower	Upper	Mean	S.D.	C.V.	Lower	Upper
Kuskokwim	0.7	0.3	45.8	0.2	1.2	0.0				
Bristol Bay	84.6	1.0	1.2	82.8	86.4	54.7	3.2	5.8	49.0	60.0
N. Peninsula	7.2	0.7	9.6	5.8	8.4	8.8	1.8	19.8	6.0	12.0
S. Peninsula July	4.3	0.5	12.0	3.4	5.4	8.9	1.7	19.2	6.0	12.0
Chignik	2.5	0.4	16.3	1.8	3.2	18.4	2.3	12.6	14.5	22.5
Kodiak	0.6	0.3	42.6	0.2	1.1	8.6	2.0	23.3	5.0	12.5
Other Stocks	0.2	0.1	59.0	0.0	0.4	0.6	0.4	72.4	0.0	1.5

TABLE 14.—Timing statistics for 1987 tag releases of chum salmon in the area of the South Peninsula June fishery. Also shown are *t*-test statistical significance for simple comparison of mean date of release for recoveries in respective fishery units with (1) the mean date of release for all Unimak and Shumagin releases combined and (2) the midpoint of the combined Unimak and Shumagin District catches.

				Significance Testing	
Fishery Unit of Recovery	Mean Date of Release for Recoveries	Std. Dev. (d)	Number of Recoveries	Mean Date of Release for All Releases	With Midpoint of Catches
Kotzebue	July 1.5	0.71	2	NS	*
Norton Sound	June 21.1	4.8	10	NS	NS
Yukon Summer	June 17.6	5.5	19	NS	NS
Yukon Fall	June 22.8	5.8	6	NS	NS
Kuskokwim River	June 21.2	4.9	139	*	*
Kuskokwim Bay	June 21.7	5	7	NS	NS
Bristol Bay	June 23.9	4.3	316	NS	*
North Penisula	June 23.6	5.7	57	NS	*
Japan	June 22.8	6.9	32	NS	*
Combined District Releases	June 23.5				
Combined District Catches	June 19.0				
Unimak Releases	June 22.8				
Unimak Catches	June 19.1				
Shumagin Releases	June 24.4				
Shumagin Catches	June 17.8				

* Significant at $\alpha \leq 0.05$

Run Timing

Detailed timing statistics by species, fishery unit, and district within fishery unit for both Shumagin and Unimak releases are presented in Eggers et al. 1989. Included are mean and range for date of release, mean and range for date of recovery, mean and range for travel times (days) from the release to recovery for both sockeye and chum salmon recoveries. Recoveries for which the exact date and location of recovery could not be verified were excluded unless otherwise noted.

TABLE 15. —Timing statistics for 1987 tag releases of sockeye salmon in the area of the South Peninsula June fishery. Also shown are *t*-test results for statistical significance in comparison of mean date of release for recoveries in respective fishery units with (1) the mean date of release for all Unimak and Shumagin releases combined and (2) the midpoint of the combined Unimak and Shumagin District catches.

				Significance Testing	
Fishery Unit	Mean Date of Release for Recoveries	Std. Dev. (d)	Number of Recoveries	Mean Date of Release for Allf Releases	With Midpoint of Catches
Kuskokwim River	June 15.5	5	4	NS	NS
Bristol Bay	June 24.4	4.65	1,078	*	*
North Penisula	June 21.0	5.7	120	*	*
Chignik	June 19.0	5.9	73	*	NS
Kodiak	June 16.3	7.49	21	*	NS
Cook Inlet	June 22.25	4.65	4	NS	NS
Combined District Releases	June 22.6				
Combined District Catches	June 19.5				
Unimak Releases	June 23.5				
Unimak Catches	June 19.8				
Shumagin Releases	June 19.4				
Shumagin Catches	June 18.0				

* Significant at $\alpha \leq 0.05$

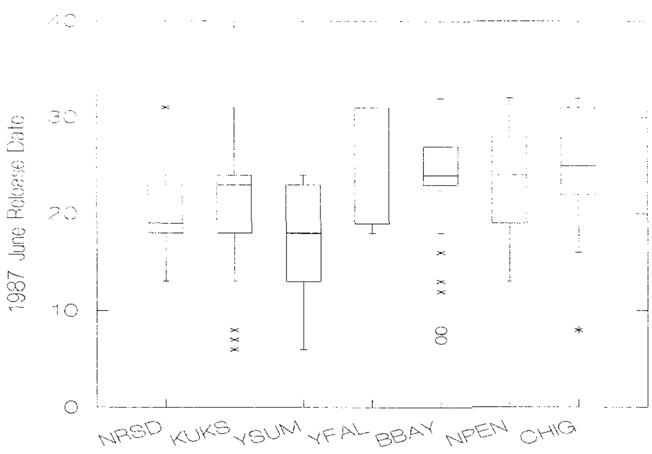

FIGURE 21.—Release date, central 50% of distribution (H), median, values outside 1.5 H (asterisk) and values outside 3 H (open circles), for chum salmon recoveries of Norton Sound, Yukon fall, Yukon summer, Kuskokwim, North Peninsula and Chignik stocks.

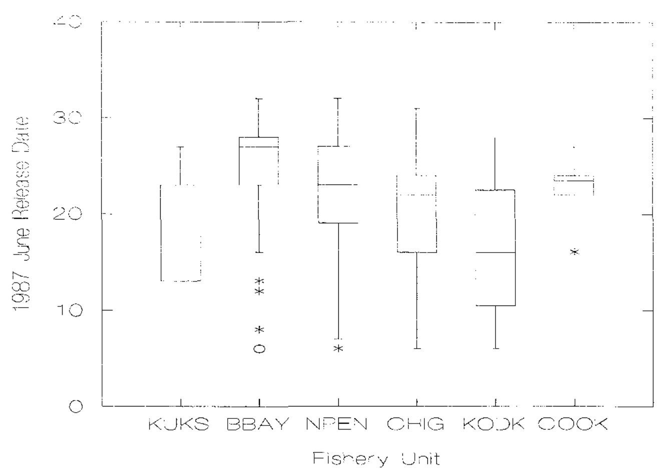

FIGURE 22.—Release date, central 50% of distribution (H), median, values outside 1.5 H (asterisk) and values outside 3 H (open circles), for sockeye salmon recoveries of Kuskokwim, Bristol Bay, North Peninsula, Chignik, Kodiak, and Cook Inlet stocks.

The timing statistics for the combined area releases were summarized by fishery unit for chum salmon (Table 14) and for sockeye salmon (Table 15). The mean date of release for the combined area recoveries was compared (*t*-test) to mean date of release of the combined Unimak and Shumagin releases. Except for the Kuskokwim River, no differences in the timing in the South Peninsula area were found among chum salmon stocks (Table 14). The mean date of release for Kuskokwim River recoveries was 2.3 d earlier, and this difference was statistically significant because of the large number of recoveries. However, the magnitude (2.3 d) of the difference is small compared to the 25-d breadth of the tag releases. The Kotzebue chum stock, with a mean 9 d later than combined area releases, and Yukon summer chum stock, with a mean 5.9 days earlier, exhibited the greatest absolute difference in timing in the South Peninsula area. However, these were not statistically significant because of the low number of recoveries in the terminal areas. It is clear that almost no differences in the time of occurrence in the area of the South Peninsula June fishery occurred for western and central Alaska chum salmon stocks. The overlap in timing is very apparent in box and whisker plots of the distribution of release dates for recoveries in various chum salmon stocks (Figure 21). Box and whisker plots show the range, the median, and middle 50%—that between the lower and upper quartiles—of the data.

The mean date of release for the combined area chum salmon recoveries were compared (*t*-test) to the midpoint of the combined Unimak and Shumagin chum salmon catches for each fishery unit (Table 14). Statistical differences occurred whenever more than 30 tags were recovered. These differences occurred because the mean date of release for combined area releases was 4.5 d greater than the midpoint of the combined Unimak and Shumagin catches. Therefore, the releases were not entirely representative of the South Peninsula June fishery catches. The effect of the late date of tag release on estimates of stock composition was small in view of the small or nonexistant difference in timing among stocks that had large numbers of recoveries in terminal areas.

In contrast to chum salmon, significant differences in the timing in the South Peninsula area were found among sockeye salmon stocks (Table 15). The Bristol Bay stocks were 1.8 d later than the combined area releases. North Peninsula, Chignik, and Kodiak sockeye stocks were 1.6, 3.6, and 6.3 d earlier than the combined area releases. There was substantial separation in the central 50% of the distribution of release date for Bristol Bay, North Peninsula, Chignik, and Kodiak recoveries (Figure 22).

The mean date of release for combined area sockeye releases was 3.1 d later than the midpoint of the combined Unimak and Shumagin catches. Therefore, the releases were not entirely representative of the

South Peninsula June fishery catches of sockeye. Because of these differences, the estimates of stock composition for the fishery catches, based on the stock composition of the releases, was biased in favor of the stocks with later timing in the South Peninsula area. Thus, the estimates of the proportion of Bristol Bay stocks was likely to be higher than the true proportions, and the estimates of proportions of North Peninsula, Chignik, and Kodiak stocks was likely to be lower than the true proportions. However, in view of the breadth of releases and dominance of the Bristol Bay recoveries, this bias was not significant.

DISCUSSION

For chum salmon releases the estimates of stock composition assumed that tagging mortality occurred in two stages: immediate and delayed. The model parameters were the same for the two release areas. For sockeye salmon there were little differences in travel times, based on the data from the tag recoveries. Therefore, no delayed mortality effect for sockeye salmon could be estimated from the study. Mortality was assumed to be immediate, and the tagging mortality was assumed to vary between release areas.

A comparison of the various tagging mortality components by species and release areas is provided in Table 16. Higher estimated mortality rates reflected lower expanded tag recovery rates for the respective release population. The chum salmon releases had a much higher estimated total tagging mortality rates than the sockeye releases. Because the immediate tagging mortality rate for chum salmon was comparable to the total tagging mortality rates for sockeye salmon, the greater total mortality for chum salmon can be attributed to the greater travel times observed for the chum releases. This is consistent with the greater distance averaged over all stocks, to the chum salmon terminal harvest areas. The chum salmon Shumagin releases had a much higher delayed estimated mortality (44.1%) than the Unimak releases (24.3%), probably due to the delayed mortality experienced by the relatively high Asian component of the releases.

In experiments where captured and tagged fish have been held, mortality was immediate and delayed mortality was negligible (Wertheimer 1988; Wertheimer et al. 1989). Unfortunately, in their experiments fish could not be held for extended periods because of confounding effects of disease and other holding problems. Studies where mature sockeye were tagged with disk tags in terminal fishing areas and later recovered at weirs up to 200 miles upstream from their release area, have demonstrated up to 80% combined tag loss during the upstream spawning migration (Pella, J., National Marine Fisheries Service, Juneau, personal communication). However, these high estimates of mortality were believed due to high loss of the disk tags. Therefore, we believe the delayed mortality hypothesis been not been rigorously tested.

TABLE 16.—Tagging mortality rates for the Unimak and Shumagin chum and sockeye salmon releases.

	Mortality (%)		
Population	Total	Immediate	Delayed
Sockeye Salmon:			
Unimak Releases	38.2		
Shumagin Releases	48.1		
Chum Salmon:			
Unimak Re leases	63.3	39.0	24.3
Shumagin Releases	83.1	39.0	44.1

The estimates of stock composition for Yukon fall chum salmon was 0.6% of the Unimak releases and 2.6% of the Shumagin releases (Table 7). These estimates reflect an expansion of six voluntary recoveries from Yukon fisheries to a total of 21 tags estimated to have occurred in the entire Yukon fall chum run. However, based on the collective sampling of 16% of Yukon fall chum return for tag recoveries, a total of 6 tags was estimated to have occurred in the entire Yukon fall chum run (Appendix F.). The Yukon fall chum voluntary recoveries were used because this method was used for other fishery units and reflected a desire to provide an upper bound on the magnitude of the Yukon fall chum interceptions in the South Peninsula June fishery.

The estimate of Yukon fall chum stock composition of South Peninsula June fishery based on the 1987 tagging study was significantly lower than previous estimates. The previous estimate of 10% was the average Yukon fall chum harvest as a percentage of the total western Alaska chum harvest from 1977 to 1985, which included both commercial and subsistence catches. The western Alaska harvest included combined AYK commercial and subsistence catches and commercial catches for Bristol Bay, North Peninsula, and South Peninsula.

The earlier estimates of Yukon fall chum stock composition assumed that relative abundance reflected stock composition of the South Peninsula June fishery catches. Estimates based on relative return magnitude rather than relative catch were believed to be a better approximation of relative abundance, if stocks were harvested at different rates. Relative catches were used because estimates of total return for western and central Alaska chum salmon returns were not available from 1977 through 1985. The Yukon fall chum salmon runs were probably harvested at a much greater rate than other western and central Alaska chum salmon stocks because of the numerous fisheries they enter and their greater economic value. If this is true, then relative catch would overestimate the relative abundance for heavily exploited stocks and would explain the inconsistency of the tagging estimate of fall chum abundance with the earlier estimate.

The estimate of 1987 Yukon fall chum stock composition, based on the Yukon fall chum return as a fraction of the western and central Alaska chum salmon catches, was 5.1%. This was higher than the estimates of stock composition based on the expanded Yukon fall chum recoveries as a percentage of the total expanded recoveries to western and central Alaska chum salmon terminal harvest areas (0.7% and 4.6% for Unimak and Shumagin releases, respectively). The corresponding estimates of Kuskokwim and Bristol Bay stock composition was 27.9% based on returns; based on tagging it was 71.9% of the Unimak and 54.3% of the Shumagin releases. This indicates that the Yukon fall chum stocks are less vulnerable to the South Peninsula fishery than other western Alaska chum stocks.

Recently, Rogers (1987) analyzed the historical releases of maturing chum salmon in the North Pacific Ocean and Bering Sea. He compared the geographic area of releases for tagged fish recovered in various western fisheries with the geographic area of release for tag recoveries in the South Peninsula June fishery. Rogers (1987) found that the area of release for chum salmon recovered in Bristol Bay and Kuskokwim River terminal areas coincided with the release area for chum salmon caught in the South Peninsula June fishery more than did releases of chum salmon bound for other western Alaska terminal harvest areas. The release area for Yukon Fall chum salmon tended to be further to the south and west than did the release area of chums caught in the South Peninsula June fishery. These results were consistent with the Kuskokwim and Yukon chum stocks being dominant and the Yukon fall chum being underrepresented in the 1987 South Peninsula tag releases.

CONCLUSIONS AND RECOMMENDATIONS

The consistency of the stock composition estimates from this study and Rogers more qualitative analysis of the INPFC tagging data suggests that the oceanic feeding areas used by chum salmon may be stock specific and subject to little interannual variation. If this assumption is correct, then stocks contributing to the South Peninsula June fishery may have unique and relatively consistent patterns of vulnerability to fishing efforts in that fishery. This differential vulnerability can be quantified. First, define the following:

V_i^U = vulnerability coefficient for the *i*th chum salmon stock to the Unimak fishery, and

V_i^S = vulnerability coefficient for the *i*th chum salmon stock to the Shumagin fishery.

It is well known that considerable interannual variability in run strength occurs among chum salmon. Intra-annual run strength, however, may not be highly correlated among chum stocks, particularly where there is great geographic diversity between stocks such as those occurring in the South Peninsula June fishery. The stock composition of the South Peninsula June fishery depends on the relative abundance of the various stocks and their relative vulnerability to this fishery.

A model can be developed to estimate stock composition of the South Peninsula June fishery catches in other years based on vulnerability coefficients estimated from the tagging study and stock specific abundance (run size of N_i) of chum salmon for the respective year. Define the following:

q^U = rate of exploitation in the Unimak fishery expressed as a percentage of the total North Pacific (Asia to Central Alaska) chum salmon run;

q^S = rate of exploitation in the Shumagin fishery expressed as a percentage of the total North Pacific (Asia to Central Alaska) chum salmon abundance run;

C_i^U = catch of the *i*th chum salmon stock in the Unimak fishery;

C_i^S = catch of the *i*th chum salmon stock in the Shumagin fishery.

For the Unimak fishery the rate of exploitation is

$$q^U = \frac{\sum C_i^U}{\sum N_i}, \tag{19}$$

and for the Shumagin fishery it is

$$q^S = \frac{\sum C_i^S}{\sum N_i}. \tag{20}$$

If the North Pacific chum salmon stocks were equally vulnerable to the South Peninsula fisheries, then

$$C_i^U = q^U N_i , \tag{21}$$

$$C_i^S = q^S N_i . \tag{22}$$

However, based on the tagging study there is a wide difference in the stock composition estimates and the relative abundance of chum salmon (Figures 7, 8). To account for this difference, define the index of vulnerability (V_i^U and V_i^S) to be a scaler quantity, such that the following equations hold:

$$C_i^U = V_i^U \cdot q^U \cdot N_i , \tag{23}$$

$$C_i^S = V_i^S \cdot q^S \cdot N_i . \tag{24}$$

By substituting equations (19) and (20) into equations (23) and (24), respectively, and by solving for V_i^S and V_i^S, an expression for the vulnerability coefficient is derived based on the stock composition of the 1987 South Peninsula chum salmon catches and the stock specific abundance.

$$V_i^U = \frac{\dfrac{C_i^U}{\sum C_i^U}}{\dfrac{N_i}{\sum N_i}} \tag{25}$$

$$V_i^S = \frac{\dfrac{C_i^S}{\sum C_i^S}}{\dfrac{N_i}{\sum N_i}} \tag{26}$$

Equations (25) and (26) can be used to estimate the vulnerability coefficients based on the stock composi-

TABLE 17.—Relative vulnerability indices for various North Pacific chum salmon stocks.[a]

			Unimak			Shumagin		
	Run (1000s)		Catch (1000s)		Relative Vulnerability	Catch (1000s)		Relative Vulnerability
Fishery/Stock	Number	Percent	Number	Percent	Index	Number	Percent	Index
Kotzebue	200	0.3	1	0.3	0.11	0	0.2	0.09
Norton Sound	178	0.2	4	0.9	0.35	0	0.9	0.51
Yukon Summer	1,326	1.7	10	2.6	0.13	1	2.6	0.21
Yukon Fall	745	1.0	2	0.6	0.05	1	2.6	0.37
Kuskokwim	1,251	1.6	77	18.9	1.00	4	11.7	1.00
Bristol Bay	2,841	3.7	162	40.0	0.93	7	18.2	0.68
N. Peninsula	863	1.1	42	10.4	0.80	1	3.7	0.46
S. Peninsula	1,662	2.2	31	7.6	0.30	4	11.0	0.71
Central Alaska	5,148	6.8	3	0.6	0.01	2	4.3	0.09
Asian	61,850	81.3	73	18.0	0.02	17	44.9	0.08
Total	76,064	100.0	406	100.0		37	100.0	

[a]The relative vulnerability index is the vulnerability index scaled to the stock with the highest vulnerability (i.e., divided by the vulerability index for the Kuskokwim).

tion estimates from the tagging study (P_i^U and P_i^S) and the 1987 stock abundances (N_i) of chum salmon (Table 17). If the stock-specific abundances of chum salmon are known for the respective year, these estimated vulnerability coefficients can be used to estimate the stock composition of the chum salmon catches in the South Peninsula June fisheries in other years as follows:

$$P_i^U = \frac{C_i^U}{\sum C_i^U} = \frac{V_i^U \times N_i}{\sum V_i^U \times N_i} \qquad (27)$$

$$P_i^S = \frac{C_i^S}{\sum C_i^S} = \frac{V_i^S \times N_i}{\sum V_i^S \times N_i} \qquad (28)$$

The stocks closest to the South Peninsula June fishery (i.e., Kuskokwim, Bristol Bay, North and South Peninsula) have the highest relative vulnerability index (Table 17). The Asian stocks which are the most distant from the fishery have the lowest vulnerability index. Because of this consistency, it is recommended that the model be used to estimate the stock composition of the South Peninsula June fishery for years where the relative abundance of chum salmon in terminal areas is known.

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APPENDIX

Appendix A.—Description of methods used to estimate the 1987 sockeye and chum salmon catch and escapement by fishery unit.

Fishery Unit/Stock	Component	Methods
Kotzebue	Catch	Combined area commercial and estimated subsistence harvest data.
	Escapement	Escapement estimated from catches based on a 73% rate of exploitation.
Norton Sound	Catch	Combined area commercial and subsistence harvests data. Documented subsistence harvest is expanded two fold to account for the undocumented subsistence harvest throughout the management area.
	Escapement	Sum of peak aerial survey counts for all systems and tower counts (Kwiniuk and North Rivers). Sum of peak aerial survey counts for the Sinuk (Nome Subdistrict) and Pilgrim River (Port Clarence section) systems.
Yukon Summer Chum	Catch	Combined commercial and subsistence harvest for the entire drainage and subsistence catches for Hooper and Scammon Bay.
	Escapement	Tower and aerial survey counts for Andreafsky River, sonar counts from the Main River site at Pilot Station expanded to account for a 20% under-count, less upriver commercial and subsistence harvests.
Yukon Fall Chum	Catch	Commercial and subsistence harvests for the entire drainage (US & Canada) .
	Escapement	Expanded aerial survey indices of four index tributaries (2X expansion).
Kuskokwim Bay	Catch	Combined commercial and subsistence harvest for Districts W-4 and W-5 (Quinhagak and Goodnews Bay).
	Escapement	Goodnews River tower count and peak escapement counts expanded by tower count/peak escapement ratio. Kanektok River sockeye and chum escapement estimated from Goodnews Bay catches based on a 35% exploitation rate.
Kuskokwim River	Catch	Combined commercial and subsistence harvest for Districts W-1 and W-2 in the Kuskokwim River.
	Escapement	Estimated from gillnet test fishery less upriver commercial subsistence catches.
Bristol Bay	Catch	Commercial harvest by fishing district and species.
Togiak District	Escapement	Chum escapements extimated from catches based on the rate of exploitation observed for sockeye in the Naknek/Kvichak District. Combined tower counts and aerial survey estimates for sockeye salmon.
Nushagak District	Escapement	Nushagak River sonar counts, tower counts at Wood and Igushik Rivers for sockeye. Chum escapements extimated from catches based on the rate of exploitation observed for sockeye in the Naknek/Kvichak District.
Naknek/Kvichak Dist.	Escapement	Sockeye escapements from Tower counts (Naknek & Kvichak Rivers) and expanded aerial survey counts (Branch River). Chum escapements extimated from catches based on the rate of exploitation observed for sockeye in the Naknek/Kvichak District.
Egegik District	Escapement	Sockeye escapement from Tower counts (Egegik River). Chum escapements estimated from catches based on the rate of exploitation observed for sockeye in the Egegik District.
Ugashik District	Escapement	Sockeye escapement from Tower counts (Ugashik River). Chum escapements estimated from catches based on the rate of exploitation observed for sockeye in the Ugashik District.
Aleutian Islands	Catch	Commercial harvest data.
	Escapement	Expanded aerial survey counts based on area under the curve the curve (AUTC) with 15 day stream life.

– Continued –

Appendix A. (page 2 of 2).

Fishery Unit/Stock	Component	Methods
North Peninsula	Catch	Commercial harvest data.
Northern District	Escapement	Chum salmon escapements based on expanded aerial survey counts based on area under the curve (AUTC) with 15 day stream life. Sockeye escapement based on Nelson R. tower, Bear R. weir, and expanded aerial survey counts (AUTC, 15 day stream life).
Northwestern District	Escapement	Expanded aerial survey counts based on area under the curve the curve (AUTC) with 15 day stream life.
South Peninsula - June	Catch	Commercial harvest data for Unimak District and Shumagin Islands, including commercial harvest for the Southeast Mainland section less 80% of the East Stepovak, West Stepovak, Balboa Bay, and Beaver Bay sections which are assigned to the Chignik commercial harvest.
	Escapement	None
South Peninsula - July	Catch	Commercial harvest data from Southwestern, Southcentral, Shumagin, and Southeast Mainland Districts, except that 80% of the sockeye catchtaken in East Stepovak, West Stepovak, Beaver Bay sections through 7/25 which are assigned to the Chignik commercial harvest.
	Escapement	Sockeye escapements based on 1.25 - 2 fold expansion of peak aerial survey counts. Chum salmon escapements based on expanded aerial survey counts based on area under the curve (AUTC) with 15 day stream life.
Chignik	Catch	Commercial harvest by early and late run in the Chignik Management Area in addition to 80% of the sockeye slmon catch from the Southease Mainland Balboa Bay, Beaver Bay, East Stepovak and West Stepovak sections through 7/25 and 80% of the sockeye salmon caught in the Cape Igvak section of the Kodiak Management area through 7/25.
	Escapement	Chum salmon escapements based on expanded aerial survey counts based on area under the curve (AUTC) with 15 day stream life. Sockeye escapements based Chignik weir counts and late run estimates based on a 1.25 - 2 fold expansion of peak aerial survey counts.
Kodiak	Catch	Commercial harvest data less 80% sockeye salmon catch from Cape Igvak section throuth 7/25 which is assigned to the Chignik commercial harvest.
	Escapement	Chum salmon escapements based on expanded aerial survey counts based on area under the curve (AUTC) with 15 day stream life. Sockeye escapements based on weir counts on 10 systems and minor system escapements based on a 2 fold expansion of peak aerial survey counts.
Cook Inlet	Catch	Combined commercial harvest data for Upper and Lower Cook Inlet.
	Escapement	Chum salmon escapement in Upper Cook Inlet based 60 % rate of exploitation. Chum salmon escapements in Lower Cook Inlet based on expanded aerial survey counts based on area under the curve (AUTC) with 17.5 day stream life. Sockeye escapements in Upper Cook inlet based on sonar estimates for Kenai, Kasilof, Yentna, and Crescent Rivers, weir counts for Packers Creek and Fish Creek plus 10% (+) correction applied to account for unmonitored sockeye salmon producing systems.
Prince William Sound	Catch	Commercial harvest data, includes Copper/Bering Rivers.
	Escapement	Combined sonar counts (Miles Lake, includes subsistence harvest), Coghill weir counts, expanded aerial survey counts for Eshamy Lake and Copper River Delta.

Appendix B.1.—Comparison of catches and tag releases by species for Unimak and Shumagin Districts combined.

	Sockeye Salmon				Chum Salmon			
	Catch		Tags Released		Catch		Tags Released	
Date	No. Fish	Prop. (%)	No. Fish	Prop.(%)	No. Fish	Prop. (%)	No. Fish	Prop. (%)
June 1								
2								
3								
4								
5								
6			123	1.8			73	1.2
7			4	0.1			27	0.4
8	4,497	0.6	41	0.6	4,893	1.1	49	0.8
9								
10	41,637	5.3			19,818	4.5		
11	17,786	2.2			22,480	5.1		
12			35	0.5			31	0.5
13			486	7.0			367	5.8
14	67,752	8.5			30,898	7.0		
15	47,812	6.0			30,213	6.8		
16	612	8.8					186	2.9
17	85,411	10.8			63,805	14.4		
18	66,708	8.4	376	5.4	54,898	12.4	602	9.5
19	513	7.3					456	7.2
20	111,563	14.1			36,264	8.2		
21	97,780	12.3			48,047	10.8		
22	76,509	9.6	326	4.7	42,731	9.6	378	6.0
23			659	9.4			750	11.9
24			1,238	17.7			840	13.3
25	45,022	5.7			24,173	5.5		
26	130,487	16.5			64,799	14.6		
27			1,170	16.7			905	14.3
28			1,161	16.6			688	10.9
29								
30								
July 1			201	2.9			595	9.4
2			42	0.6			376	5.9
Totals	792,964		6,987		443,019		6,323	
Mean Date: month		6		6		6		6
day		19.49		22.59		18.98		23.49

Appendix B.2.—Comparison of catches and tag releases by species for Unimak District.

	Sockeye Salmon				Chum Salmon			
	Catch		Tags Released		Catch		Tags Released	
Date	No. Fish	Prop. (%)	No. Fish	Prop.(%)	No. Fish	Prop. (%)	No. Fish	Prop. (%)
June 1								
2								
3								
4								
5								
6								
7			4	0.1			27	0.8
8	4,383	0.7			4,889	1.2		
9								
10	10,017	1.5			10,880	2.7		
11	17,786	2.7			22,480	5.5		
12								
13			486	8.9			367	10.5
14	44,185	6.8			24,095	5.9		
15	47,812	7.3			30,213	7.4		
16			165	3.0				
17	85,411	13.1			63,805	15.7		
18	66,708	10.2	173	3.2	54,898	13.5	68	1.9
19			513	9.4			342	9.8
20	56,463	8.7			23,116	5.7		
21	97,780	15.0			48,047	11.8		
22	76,509	11.7			42,731	10.5		
23			659	12.1			750	21.5
24			1,238	22.7			840	24.0
25	45,022	6.9			24,173	6.0		
26	100,321	15.4			56,628	13.9		
27			998	18.3			538	15.4
28			1,061	19.5			373	10.7
29								
30								
July 1			145	2.7			53	1.5
2							47	1.3
Total s	652,397		5,442		405,955		3,495	
Mean Date: month		6		6		6		6
day		19.80		23.5		19.08		22.79

Appendix B.3.—Comparison of catches and tag releases by species for Shumagin District.

	Sockeye Salmon				Chum Salmon			
	Catch		Tags Released		Catch		Tags Released	
Date	No. Fish	Prop. (%)	No. Fish	Prop.(%)	No. Fish	Prop. (%)	No. Fish	Prop. (%)
June 1								
2								
3								
4								
5								
6			123	8.0			73	2.6
7								
8	114	0.1	41	2.7	4	0.0	49	1.7
9								
10	31,620	22.5			8,938	24.1		
11								
12			35	2.3			31	1.1
13								
14	23,567	16.8			6,803	18.4		
15								
16			447	28.9			96	3.4
17								
18			203	13.1			534	18.9
19							114	4.0%
20	55,100	39.2			13,148	35.5		
21								
22			326	21.1			378	13.4
23								
24								
25								
26	30,166	21.5			8,171	22.0		
27			172	11.1			367	13.0
28			100	6.5			315	11.1
29								
30								
July 1			56	3.6			542	19.2
2			42	2.7			329	11.6
Total s	140,567		1,545		37,064		2,828	
Mean Date: month		6		6		6		6
day		18.02		19.40		17.81		24.36

Appendix C.1—Summary of unadjusted chum salmon recoveries from voluntary program, South Peninsula tagging study.

Fishery Unit or Stock	Recoveries in Fisheries: Unimak Releases No. Fish	Unimak Releases Percent	Shumagin Releases No. Fish	Shumagin Releases Percent	Combined Area Releases	Non-Fishery Recoveries: Unimak Releases	Non-Fishery Recoveries: Shumagin Releases
Kotzebue	2	66.7	1	33.3	3		
Norton Sound	6	60.0	4	40.0	10	3	
Yukon							
Summer Run	16	76.2	5	23.8	21	1	
Fall Run	2	33.3	4	66.7	6		
Total Yukon	18	66.7	9	33.3	27	1	
Kuskokwim							
Kuskokwim Bay	6	75.0	2	25.0	8	5	1
Kuskokwim River	94	67.6	45	32.4	139	1	1
Total Kuskokwim	100	68.0	47	32.0	147	6	2
Bristol Bay							
Togiak	69	77.5	20	22.5	89	1	3
Nushagak	132	77.2	39	22.8	171		
Naknek/Kvichak	23	60.5	15	39.5	38	1	
Egegik	12	75.0	4	25.0	16		
Ugashik	8	72.7	3	27.3	11		
Total Bristol Bay	244	75.1	81	24.9	325	2	3
North Peninsula							
Northern District	25	67.6	12	32.4	37		
Northwestern District	18	90.0	2	10.0	20		
Total N. Peninsula	43	75.4	14	24.6	57		
South Peninsula June							
Unimak (Southwestern)	37	49.3	38	50.7	75		
Shumagin		0.0	2	100.0	2		
S.E. Mainland		0.0		0.0	0		
Total S. Peninsula June	37	48.1	40	51.9	77		
South Peninsula July							
Southwestern	6	35.3	11	64.7	17	1	
Southcentral	10	33.3	20	66.7	30		
Shumagin	6	30.0	14	70.0	20		
S.E. Mainland	13	65.0	7	35.0	20		
Total S. Peninsula July	35	40.2	52	59.8	87	1	
Chignik	1	10.0	9	90.0	10		
Kodiak		0.0	4	100.0	4		
Cook Inlet	1	25.0	3	75.0	4	2	
Prince William Sound	1	100.0		0.0	1	2	
Southeast						1	
Coastal British Columbia	0	0.0	1	100.0	1		
Coastal Japan	7	18.9	30	81.1	37		
Coastal U.S.S.R.	7	53.8	6	46.2	13		
Unknown Area	14	82.4	3	17.6	17		
All Areas Combined	516	304	820[a]	12	11		

[a]A total of 843 tags were recovered and 820 were assigned to a fishery unit.

Appendix C.2.—Summary of unadjusted sockeye salmon recoveries from voluntary program, South Peninsula tagging study.

Fishery Unit or Stock	Recoveries in Fisheries: Unimak Releases No. Fish	Recoveries in Fisheries: Unimak Releases Percent	Recoveries in Fisheries: Shumagin Releases No. Fish	Recoveries in Fisheries: Shumagin Releases Percent	Combined Area Releases	Non-Fishery Recoveries: Unimak Releases	Non-Fishery Recoveries: Shumagin Releases
Norton Sound	1	100.0		0.0	1		
Kuskokwim							
Kuskokwim Bay	5	100.0		0.0	5		
Kuskokwim River		0.0		0.0	0		
Total Kuskokwim	5	100.0		0.0	5		
Bristol Bay							
Togiak	13	81.3	3	18.8	16		
Nushagak	224	87.5	32	12.5	256		
Naknek/Kvichak	376	88.3	50	11.7	426	8	1
Egegik	292	89.6	34	10.4	326		
Ugashik	103	88.8	13	11.2	116		
Total Bristol Bay	1,008	88.4	132	11.6	1140	8	1
North Peninsula							
Northern District	86	83.5	17	16.5	103	17	1
Northwestern District	14	63.6	8	36.4	22		
Total N. Peninsula	100	80.0	25	20.0	125	17	1
South Peninsula June							
Unimak(Southwestern)	192	65.8	100	34.2	292	1	
Shumagin	1	5.3	18	94.7	19		
S.E. Mainland		0.0	2	0.0	2		
Total S. Peninsula June	193	61.7	120	38.3	313	1	
South Peninsula July							
Southwestern	37	78.7	10	21.3	47		
Southcentral	17	60.7	11	39.3	28		
Shumagin	8	50.0	8	50.0	16		
S.E. Mainland	1	50.0	1	50.0	2		
Total S. Peninsula July	63	67.7	30	32.3	93		
Chignik							
Early Run	29	40.8	42	59.2	71		
Late Run	3	42.9	4	57.1	7		
S.E. Mainland	7	35.0	13	65.0	20		
Total Chignik	39	39.8	59	60.2	98		
Kodiak	6	26.1	17	73.9	23		1
Cook Inlet	2	50.0	2	50.0	4	2	
Prince William Sound	1	100.0		0.0	1		
Unknown Area	75	86.2	12	13.8	87		
All Areas Combined	1,493		397		1,890	28	3

Appendix D.—Date and location of tag release, date and fishing district of recovery, and fall or summer run designation for tagged chum salmon returning to the Yukon River.

Tag Number[a]	Release Area	Release Date	Fishing District of Recovery	Statistical Area of Recovery	Recovery Date	Run Designation[b]
15600	Shumagins	6/08/87	Hooper Bay	337-00	6/24/87	Summer
16007	Unimak	6/13/87	Hooper Bay	337-00	6/27/87	Summer
16654	Unimak	6/23/87	Y-1	334-10	7/10/87	Summer
24749	Shumagins	6/18/87	Y-1	334-10	7/07/87	Summer
26229	Shumagins	7/01/87	Y-1	334-10	6/23/88	
22082	Unimak	6/24/87	Y-1	334-11	7/10/87	Summer
15501	Shumagins	6/06/87	Y-1	334-12	6/29/87	Summer
16260	Unimak	6/16/87	Y-1	334-13	7/02/87	Summer
16689	Unimak	6/23/87	Y-1	334-13	7/13/87	Summer
24654	Shumagins	6/18/87	Y-1	334-13	7/10/87	Summer
16591	Unimak	6/19/87	Y-1	334-13	7/10/87	Summer
17157	Unimak	6/24/87	Y-1	334-14	7/10/87	Summer
24905	Shumagins	6/19/87	Y-1	334-15	7/10/87	Summer
17115	Unimak	6/24/87	Y-1	334-17	7/10/87	Summer
15371	Unimak	6/19/87	Y-2	334-20	7/19/87	Fall
16164	Unimak	6/13/87	Y-2	334-20	7/02/87	Summer
16319	Unimak	6/18/87	Y-2	334-20	7/09/87	Summer
16384	Unimak	6/19/87	Y-2	334-20	7/19/87	Fall
16033	Unimak	6/13/87	Y-2	334-21	7/01/87	Summer
24818	Shumagins	6/19/87	Y-2	334-22	7/19/87	Fall
16401	Unimak	6/19/87	Y-2	334-23	7/12/87	Summer
24522	Shumagins	6/18/87	Y-4	334-40	8/19/87	Fall
16182	Unimak	6/13/87	Y-4	334-41	7/14/87	Summer
17130	Unimak	6/24/87	Y-4	334-42	7/31/87	Summer
26038	Shumagins	7/01/87	Y-6	334-62	9/27/87	Fall
26052	Shumagins	7/01/87	Y-6	334-62	9/11/87	Fall

[a]Includes only tag recoveries for which the date and location of recovery are known.

[b]Date and location serve as criteria for classification of each recovery to the summer or fall run of chum salmon. In accordance with management strategy and implementation of guideline harvest levels, all chum salmon through District Y-1 prior to 7/16 are classified as summer chum salmon. Fish passing through District Y-1 on 7/16 and after are fall chum salmon. Estimated travel time between Districts Y-1 and Y-2 is three days. Chum salmon passing through District Y-2 prior to 7/19 are summer chum salmon. Fish passing through District Y-2 on 7/19 and after are considered fall run chum salmon. District Y-4a is closed by regulation 8/1 to conserve fall chum salmon returns.

Appendix E.—Estimated number of tagged summer run chum salmon in the Y1 and Y2 commercial catch, by fishing period, based on the fishery sampling program.

Date	District	Commercial Catch[a]	Interviewed Catch	Percent Sampled	Recovered Tags	Expanded Recoveries
6/15	Y1	10951	60	0.5	0	0
6/17-6/18	Y1	10323	0	0.0	0	0
6/18-6/19	Y1	19817	1059	5.3	0	0
6/21-6/22	Y2	12415	0	0.0	0	0
6/22-6/23	Y1	13586	1811	13.3	0	0
6/24-6/25	Y2	17911	2219	12.4	0	0
6/25-6/26	Y1	23488	1608	6.8	0	0
6/29-6/30	Y2	4337	408	9.4	0	0
6/29-6/30	Y1	67330	2742	4.1	0	0
7/01-7/02	Y2	39737	2177	5.5	0	0
7/02-7/03	Y1	50698	1624	3.2	0	0
7/06	Y2	15666	768	4.9	0	0
7/09	Y2	21961	3269	14.9	0	0
7/10	Y2	37028	4479	12.1	3	25
Total		345248	22224	6.4	3	25
Total Expanded Commercial Catch Recoveries			25			

[a]Preliminary harvest data. Includes commercial harvest data for District Y-1 and the statistical areas for District Y-2 down river and within the vicinity of the Main River sonar site at Pilot Station.

Appendix F.—Estimated number of Yukon River fall chum in the 1987 run based on the sampling program for Yukon River fall chum salmon tag recoveries. Shown are the description of project, agency conducting the project, location of project, number of fish examined for tags, and number of tags reported.

Project	Location	Number of Fish	Tags Reported
ADF&G Test Fisheries	District Y-1	4,343[a]	0
	District Y-2	1,065[b]	0
	District Y-4	4,500[c]	0
Subtotal		9,908	0
Biological Sampling[d] (ADF&G)	Delta River	450	0
	Bluff Cabin Slough	150	0
	Toklat River	450	0
	Sheenjek River	909[e]	0
Subtotal		1,959	0
Biological Sampling[d] (US Fish and Wildlife Service)[c,e]			
	Nulato River	260	0
	Gisasa River	190	0
	Koyukuk River drainage	154	0
Subtotal		604	0
Subsistence Harvest	District Y-1	1,357	0
Surveys	District Y-5	5,606	
Subtotal		6,963	0
Escapement Studies			
Spawning Ground Surveys	Delta River	20,014	0
(ADF&G)[f]	Bluff Cabin Slough	9,245	0
	Toklat River	17,400	0
	Sheenjek River	2,125	0
Subtotal		48,784	0
Escapement Enumeration	Fishing Branch River Weir	48,956	1[h]
Tagging Project[g] (Department of Fisheries and Oceans)		3,022	0
Total number of fish examined and tags reported:		120,196	1
Percent of fall chum salmon run handled or observed[h] by agency personnel:		16.1[i]	
Expanded number of tagged fall run chum salmon relative to the total estimated run size and number of fish examined by agency personnel:		6	
Percent of the fall chum salmon run examined, including fish caught during commercial and subsistence fishery openings:		55.1[j]	

[a]Combined test fish catches by gill net at Big Eddy and Middle Mouth.

[b]Test gill net catches at the Main River Sonar site, Pilot Station.

[c]Test fishwheel catches at Ruby.

[d]Fish sampled for length, scales and tissue for electrophoresis analysis.

[e]Number of fish handled. Fish actually sampled for biological data totaled 450 chum salmon.

[f]Foot surveys. Numbers do not include fish sampled for biological data.

[g]Fish wheels operated above the US/Canada border to attain data for population estimates.

[h]Tag sighted 9/15/87, not recovered; visibility moderate to good.

[i]Based on total run estimate for fall run chum salmon of 745,000 fish derived from escapement surveys, and available subsistence and commercial harvest figures for the US and Canada.

Appendix G.—Estimated number of tagged Kuskokwim River chum salmon in the W1 commercial catch, by fishing period, based on the fishery sampling program.

Date	Commercial Catch[a]	Interviewed Catch	Fraction Sampled (%)	Recovered Tags
6/18	14,137	523	3.7	0
6/24	54,454	6,057	11.1	0
6/30	112,963	7,921	7.0	1
7/03	66,783	6,838	10.2	1
7/07	103,059	11,074	10.7	4
7/11	72,118	7,919	11.0	6
7/15	71,923	9,000	12.5	8
7/20	55,135	7,371	13.4	3
7/21-9/07	5,927	0	0	0
Totals	640,436[b]	56,703	8.9	23
Total Expanded Commercial Catch Recoveries			0	260

[a]Final harvest data representing commercial catches in District W-1.

[b]Includes 76,100 subsistence caught chum salmon from the Kuskokwim River drainage and 7,837 commercially caught chum salmon from District W-2.