Exxon Valdez Oil Spill
Restoration Project Annual Report

Effects of Oiled Incubation Substrate on Straying and Survival of Wild Pink Salmon

Restoration Projects 95076 and 95191B
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Study History: This project effort is the first year of a multi-year program based at the National Marine Fisheries Service research facility at Little Port Walter (LPW) on Baranof Island in Southeast Alaska. Field activities will continue through FY 96, FY 97, and into FY 98. The project will be closed out with a Final Report Prepared in FY 98. In addition, this report contains results obtained in FY 95 for Trustee Restoration Project number 95191B, a project that is now a component of Restoration Study 96076.

Abstract: This project examines the effects of oil exposure during embryonic development on the straying, survival to spawning, and gamete viability of pink salmon (*Oncorhynchus gorbuscha)*. The objectives for the straying component are to conduct a related series of controlled experiments on straying of pink salmon to determine the role of oil and other factors (stock, transplant, and tagging) on straying; and to use the results to interpret the high straying rates observed for wild populations of pink salmon in Prince William Sound (PWS) after the *Exxon Valdez* oil spill. In FY95, the objectives of the project were to (1) set up the incubation and oil exposure array, and expose pink salmon embryos from the 1995-brood to oiled gravel; and (2) test fry capture and adult sampling and enumeration techniques. Treatment levels of oil were based on the results of Restoration Project 191B; relatively low dosages were used to ensure high survival to fry emergence. Small but significant reductions in survival of pink salmon embryos were detected, however, even at nominal dosages as low as 0.4 g oil per kg of gravel. Fry capture and adult sampling and enumeration techniques were successfully tested. Based on the return and recovery rate in streams in the Little Port Walter vicinity of pink salmon of fish tagged for Restoration Project 95076, a model was constructed to examine the ability of the experimental design to detect differences in straying rates among treatments. Results from Restoration Project 191 B demonstrate a long-term effect of oil on growth, and suggest that incubating in oiled gravel reduces marine survival and reproductive ability.

Key Words: *Exxon Valdez*, pink salmon, *Oncorhynchus gorbuscha*, straying, homing, survival, genetic damage, reproduction, crude oil.

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Executive Summary

This project examines the effects of oil exposure during embryonic development on the straying, survival to spawning, and gamete viability of pink salmon *(Oncorhynchus gorbuscha)*. The objectives for the straying component are to conduct a related series of controlled experiments on straying of pink salmon to determine the role of oil and other factors (stock, transplant, and tagging) on straying; and to use the results to interpret the high straying rates observed for wild populations of pink salmon in Prince William Sound (PWS) after the *Exxon Valdez* oil spill.

Project 076 is a multi-year program based at the National Marine Fisheries Service research facility at Little Port Walter (LPW) on Baranof Island in Southeast Alaska. This location was chosen to examine the response of pink salmon straying to oil exposure at a geographic locale remote from PWS, away from the confounding effect of prior oil exposure. The project was initiated in 1995 with the collection and spawning of pink salmon, and the placement of the fertilized eggs at LPW into incubators simulating oiled and non-oiled intertidal habitat in PWS after the oil spill. In 1996, about 460,000 pink salmon fry from wild and experimental treatment groups will be marked with coded-wire tags or fin-clips. Fry from the oil-exposed and control groups will be tagged to identify treatments when they emigrate from the incubators, and emigrating wild fry from two streams will also be captured and tagged. Returning adults will be examined for marks in 1997 in natal streams, other streams within 40 km of the natal streams, and an adjacent fishery. Recoveries of tagged adults will determine if oil exposure increases straying and decreases survival to spawning. Escapement and sampling rates in natal and non-natal streams will be estimated so that actual straying rates within the sampling region can be estimated, and the effects of oil, stock, transplant, and tagging on straying rate can be evaluated. Adults from the oil-exposure experiments that return to the release site will be identified to treatment and then spawned. The fertilized eggs will be incubated in a clean environment to determine if oil exposure has decreased the gamete viability of the exposed fish.

In FY95, the objectives of Restoration Project 076 were to:
(1) Set up incubation and oil exposure array for 1995 brood pink salmon.
(2) Spawn pink salmon and expose fertilized eggs to oiled gravel.
(3) Assess 1995 brood survival of exposed and control groups eggs to the eyed stage.
(4) Test techniques for capturing wild pink salmon fry during their emigration to salt water.
(5) Test carcass marking method for estimating spawning escapements of pink salmon.
(6) Estimate localized straying rates of returning tagged pink salmon from Project 95161B.

Gametes were successfully collected from Lovers Cove Creek pink salmon. Treatment levels of oil were selected based on the results of Restoration Project 191B; relatively low dosages were used to ensure high survival to fry emergence. Small but significant reductions in survival of pink salmon embryos to the eyed stage of development were dettected even at nominal dosages

Fall of 1995, approximately 345 mature fish bearing coded-wire tags returned to the hatchery at Little Port Walter. These fish were recovered at a weir, measured and spawned. Their offspring are being incubated in clean water and will be coded-wire tagged and released when they emerge in April 1996.

In FY 95, the objectives for Restoration Project 191 B were to:
(1) Recover all 1993 brood pink salmon that had been coded-wire tagged and released.
(2) Determine if fish exposed to different doses had different sizes at maturity.
(3) Examine the marine survival for each of the tag groups.
(4) Evaluate the gamete viability of fish exposed to different doses of oil during incubation.

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Introduction

This project examines the effects of oil exposure during embryonic development on the straying, survival to spawning, and gamete viability of pink salmon *(Oncorhynchus gorbuscha)*. The objectives for the straying component are to conduct a related series of controlled experiments on straying of pink salmon to determine the role of oil and other factors (stock, transplant, and tagging) on straying; and to use the results to interpret the high straying rates observed for wild populations of pink salmon in Prince William Sound (PWS) after the *Exxon Valdez* oil spill.

Pink salmon were injured at several life-history stages during and shortly after the oil spill. Evidence of long-term damage from the toxic exposures of 1989 continues to build (Bue et al. 1996; Heintz et al. 1996b), and a thorough evaluation of the toxic contribution to pink salmon recovery problems became even more important when there was no explanation for the crash in pink salmon and herring in 1993. Straying was a major concern during the spill; the Trustees supported a multi-million dollar effort to assess straying, and substantial straying of wild and hatchery stocks was observed (Sharp et al. 1995). Unfortunately, the interpretation of that study is severely limited for several reasons. Consequently, the amount of straying caused by oil is not known, natural straying rates are not known, and straying information cannot be used to adjust restoration or management strategies.

This project is a multi-year program based at the National Marine Fisheries Service research facility at Little Port Walter (LPW) on Baranof Island in Southeast Alaska. This location was chosen to examine the response of pink salmon straying to oil exposure at a geographic locale remote from PWS, away from the confounding effect of prior oil exposure. For an extensive justification and overall project design, see the Detailed Project Descriptions for Restoration Study 96076 (Wertheimer et al. 1995). The project was initiated in 1995 with testing of capture techniques for wild pink salmon fry, collection and spawning of adult pink salmon, and placement of the fertilized eggs at LPW into incubators simulating oiled and non-oiled intertidal habitat which occurred in PWS after the oil spill.

Objectives for 1995

The primary objectives of Restoration Study 076 are to conduct a related series of controlled experiments on straying of pink salmon to determine the role of oil exposure of pink salmon embryos on their subsequent straying as adults; determine the role of other factors on straying so that the measurements of straying in PWS after the spill can be interpreted; and evaluate the significance of straying on management and restoration strategies in PWS. The study will also examine the effect of oil exposure during egg and alevin development on subsequent marine survival and gamete viability of pink salmon.

welled through a column of gravel, simulating the incubating environment preferred by pink salmon The incubators were constructed of 70-cm-long sections of 20-cm-diameter polyvinyl chloride (PVC) pipe that were placed on end and glued to a 20 cm-diameter PVC pipe coupling which was sealed with a PVC plate glued to the bottom. Water enters through a 1.9-cm-diameter hole drilled and tapped on the side of the coupling pipe immediately above the bottom plate. Flow to each incubator was regulated with a valve. An aluminum plate was fixed at the end of the PVC pipe, inside and against the center lip of the coupling, providing a false bottom that suspended the gravel in the incubator 10 cm above the bottom PVC plate. The aluminum plate was perforated with 1.2-mm-diameter holes to prevent water from channeling through the substrate and to prevent larvae from escaping. Water exited the incubators through a 1.9-cm-diameter hole drilled and tapped into the side of the incubator, 12.5 cm from the top. Incubators were filled with 28.7 kg of gravel (maximum diameter 5.0 cm). Before treatment with oil or loading into incubators, all gravel was rinsed to remove fine sediments. The gravel was placed in the inucbaters to within 12 cm of the outlet. A second perforated aluminum plate was placed on top of the gravel and the rest of the gravel added on top of the plate. The purpose of this plate was to keep eggs in the upper gravel level so they could be enumerated for determining survival to the eyed stage.

The water supply to the incubators alternates between fresh and estuarine water to simulate an intertidal incubating environment. Incubators receive fresh water from a nearby stream (Sashin Creek) for 8 h followed by estuarine water (maximum salinity = 25‰) estuary for 4 h. All water is filtered to remove macroscopic debris. The water first enters a 1800-L head tank so that the salinity of water supplied to the incubators gradually changes over a 20-min transition period when the supply switches between freshwater and estuarine water. Temperature is monitored every 6 h with a recording thermograph. Estuarine water temperatures has ranged from 3.6 to 11.9 °C, and freshwater temperature has ranged from 0.2 to 12.9 °C. Water flow through each incubator was established before seeding the incubators with eggs, and flow was monitored every other day to ensure a rate of 425 mL/min before eyeing and 460 mL/min thereafter. Dissolved oxygen concentrations in incubator effluent are monitored weekly. Dissolved oxygen is maintained above 7 mg/l at prescribed flows.

Oiling of Gravel

Crude oil produced from the Prudhoe Bay oil field in 1992 was artificially aged ("weathered") and then applied to gravel to be used in the incubators. Oil was weathered by stirring the crude oil overnight at about 70 °C, which resulted in evaporative losses of about 20% of the initial oil weight. These evaporative losses simulate the initial evaporative alterations of crude oil spilled at sea. The weathered oil was applied to the gravel at 2 loading levels (hereafter denoted as doses) by spraying a weighed amount of oil onto 44-kg aliquots of gravel tumbling in a small concrete mixer. Two doses were prepared; control gravel was processed the same way as oiled gravel except that no oil was applied. To preclude contamination of lower dose gravels by oil from higher doses, oil was applied in order of ascending dose. The spraying time was at least 90

and counting. An automatic egg-picker was used to remove and count dead or unfertilized eggs. An electronic egg counter was used to count live eggs. Counts were verified by occasional hand counts. Live eggs were returned to their respective incubators after removing the upper perforated plate. The gravel that had been removed from each incubator was subsequently replaced in the same incubators.

The proportion of eggs surviving to eyeing was calculated for each incubator by dividing the live count by the total count of eggs. To determine if oil affected the survival of pink salmon embryos to the eyed stage, the proportion surviving was statistically tested with a one way analysis of variance (ANOVA) with overall alpha = 0.05. Survival was the dependent variable and dose was the independent variable with three levels: control, low oil, and high oil. The assumptions of homogeneity of variance and normality were tested for the raw data, arcsin-transformed data, inverse arcsin-transformed data, and arcsin square root-transformed data and were best met when the survival data were transformed with the arcsin transformation (Underwood 1981). The differences in survival between each treatment mean (high oil and low oil) and the control mean were further analyzed with Dunnett's Method of pairwise comparison with the overall family error rate of alpha = 0.05 and each individual error rate of alpha = 0.0263.

Hydrocarbon Sampling

Gravel. Composite samples of control and oiled gravels were collected for hydrocarbon analysis during each of 4 sampling periods. Samples were collected from each dose just before addition of the fertilized eggs, after the embryos had visible eyes, at hatching, and at emergence. At each sampling, triplicate samples for each dose were taken. A sample consisted of about 5 gravel particles from each incubator within a dose, which were mixed together in a 500-mL jar fitted with a PFTE-lined lid and were stored at -20 °C until hydrocarbon analysis.

Water. Composite incubator-effluent samples were collected in triplicate during each of the four sampling periods for hydrocarbon analysis. At each sampling, equal aliquots of effluent water from each incubator within a dose (total volume 3.8 L) were combined with predeuterated hydrocarbon surrogate standards dissolved in 1.00 mL acetone and extracted twice with successive 100 mL aliquots of dichloromethane in a 4 L glass jar fitted with a PFTE-lined lid. The dichloromethane extracts were combined and stored at -20 °C for hydrocarbon analysis.

Tissues. Composite samples of fish exposed to control and oiled gravels were collected for hydrocarbon analysis at the eyed stage and at emergence. Approximately 100 eggs or fry were sampled per dose at each of these stages and were stored in a 125-mL jar fitted with a PFTE-lined lid at -20 °C until hydrocarbon analysis.

Initially, the mark-recapture technique was to be tested on both Sashin and Lovers Cove Creeks. Because the weir operations at Sashin Creek provided an independent count of the number of fish escaping to the watershed, estimating the escapement in the system using carcass mark-recapture offered an opportunity to both test and calibrate the technique. However, the record pink salmon return to Sashin Creek of over 117,000 fish overwhelmed our capability to count and tag carcasses, and thus the estimation effort focused on Lovers Cove Creek.

On each survey at Lovers Cove Creek, intact carcasses were tagged with a colored, plastic cinch strap. A different length/color combination was used to distinguish each sampling period. At each sampling period, counts were made of all intact untagged carcasses and of each tagged carcass by length/color group. If a tagged carcass had deteriorated so that the head and pectoral girdle were separated from the body, the tag was retrieved but not counted as a carcass recovery. Initially, tags were labeled with individual numbers so each carcass could be indentified, but this proved too time consuming to accomplish a survey within a 1-2 day period.

Methods for Restoration Study 191B

Overview

Pink salmon embryos were incubated in gravel contaminated with one of four different amounts of oil (doses) beginning in 1993 (Heintz et al. 1995). The doses ranged from no oil (control gravel) to 281 µg oil/kg gravel, and the maximum concentration of total polynuclear aromatic hydrocarbons (TPAH) experience by any group was approximately equal to the State of Alaska water quality standard for TPAH. Embryos incubated in the maximum dose had reduced survival to emergence. Emergent fry were ponded into saltwater netpens prior to tagging. Fish were tagged in order from lowest to highest dose, and the sequence was repeated four times so that each dose was represented by 4 tag codes.

Pink salmon exposed to oil during incubation and returing to the hatchery were recovered at a weir located on Sashin Creek, and held in netpens until they matured. The netpens were inventoried 4 times to examine the maturity of the fish, and on each occassion all the mature fish were removed and spawned the following day. Prior to spawning, each fish was measured for length and weight and the tag recovered. The tags were decoded and gametes refrigerated prior to fertilization, and the fertilizations followed the procedures outlined below.

Analysis of size and marine survival

The size and marine survival of fish from the different exposure groups were analyzed by analysis of variance. Size at maturity and growth for each sex was analyzed by a one-way analysis of variance with dose as a fixed factor. Growth rate, expressed as the percent gain in wet body weight per day, was calculated by taking the difference between the natural logs of initial and final weights, dividing by the number of days that elapsed between tagging and the

effect measured variation among crosses made within a dose, and the group effect measured variation among crosses made on different days. This provided a level of control for the pooled group experiment by illustrating how survival varied among groups of individuals. Thus, any interaction between dose and spawning date detected in the pooled group experiment could be explained by evaluating the variation among groups of crosses. In addition, differences in the errors associated with average survival within a dose may reflect variation in the amount of damage caused by incubating in oiled gravel.

The production lots were designed to provide pools of fish with similar exposure histories that could be used for coded-wire tagging. These lots were created after eggs had been removed for the first two experiments and all available eggs were used. Lots were created using the same procedure for developing pools in the pooled groups experiment, but females contributed disproportionate numbers of eggs to the lots, and lots were not replicated on any day. Lots were created only on the second and third spawning dates and the highest dose was represented on only the second spawning date (Table 1). Survival to eyeing was calculated for each of the lots, and 95% confidence intervals were calculated wherever possible.

Results for Study 076

Hydrocarbon Sampling

Incubation gravel, outflow water, and pink salmon tissue were sampled for hydrocarbon analyses when the embryoes reached the eyed, hatching, and emergent fry stages of development (Table 1). Gravel and water were also sampled just prior to seeding the incubators with fertilized eggs, and gravel was sampled immediately after oiling. Samples have been submitted for analysis at the Auke Bay Laboratory; results are expected by the end of FY-96.

Spawning and survival to eyed-egg stage

A total of 561 adult pink salmon were killed for gamete recovery at Lovers Cove Creek. Eggs were taken from 350 of 354 females killed; four of the females were green and were not used. Sperm was taken from 203 of 207 males killed; four of the males were spawned out and were not used.

The eggs were mixed, divided into aliquots, fertilized, and re-mixed and water-hardened at LPW prior to seeding in the incubator array. Average weight of a water-hardened egg was 0.199 g. Each incubator was seeded with 950-1050 g of water-hardened eggs, or approximately 4800-5300 eggs per incubator. By random chance, the mean number of eggs per incubator was lowest in the control incubators (Table 2); the control density was significantly ($P < 0.05$) lower than the high dose, but was not significantly ($P > 0.10$) different from the low dose.

Mean survival of fertilized pink salmon eggs to the eyed stage was 82% for the control group and

Unfortunately, the tags were not removed from recovered carcasses as should be done for the Jolly-Seber estimator if invidual tag codings cannot be used to account for repeat captures. To calculate the Jolly-Seber estimates, we had to make assumptions about the rate of repeat recoveries of tags so that those tags could be removed from the estimation algorithm. In general, tag recoveries rates were assumed to be high because of the relatively shallow, braided stream system and the high visibility of the tags. We had one tag group to which we could definitively assign a 4% rate of non-detection, which indicates a 96% detection rate. We then calculated escapement estimates for 100%, 96%, and 90% detection rates.

The three modified Jolly-Seber estimates for the 100%, 96%, and 90% detection rates were 31,940; 32,484; and 32,466, respectively. Thus the rate of detection of tags had little effect on the estimate. The Peterson estimate gave a similar result of 31,864, with a SD of 9,106. Variances have not yet been calculated for the modified Jolly-Seber estimates; these will require a bootstrap approach (Sykes and Botsford 1985).

The number of carcasses counted was thus was 58-59% of the estimated escapement. The proportion of the escapement sampled diminished somewhat over time (Figure 4), probably due to higher stream flows in October than in September.

Straying of 1993 Brood Adults

A total of 347 pink salmon with coded-wire tags were recovered in the LPW vicinity in 1995 (Table 4). Of these, 339 were recovered from fish returning to the Sashin Creek weir, and 8 were recovered as strays to either Borodino Creek (6) or Lovers Cove Creek (2). To estimate the total number of strays spawning in Borodino and Lovers Cove Creeks, the observed recoveries were expanded by the proportion of the escapement (58%) estimated to have been surveyed for tags in Lovers Cove. The same expansion rate was used for Borodino Creek because survey efforts for presence of tags was similar in both systems, although carcasses were tagged and the escapement was estimated only in Lovers Cove Creek. An estimated total of 10 and 3 strays spawned in Borodino and Lovers Cove Creeks, respectively. This represents 2.9% and 0.9% of the total tagged fish returning to LPW and Big Port Walter that strayed.

The frequency of tagged fish in the escapement was similar at Borodino and Sashin Creeks, but was significantly ($P < 0.001$) lower at Lovers Cove Creek (Table 4). No tagged pink salmon were recovered in Parry Creek.

Results for Study 191B

Analysis of size and marine survival

Male pink salmon that returned to the weir with coded-wire tags demonstrated a significant

Discussion

The results from 95191B demonstrate a long-term effect of oil on growth and suggest further effects on marine survival and reproductive ability. Identification of these effects is remarkable given the small number of fish exposed to the highest dose and recovered (30 males and 16 females). Study 076 recreates the high dose exposure system and will provided for significantly greater power to resolve effects, conservative estimates suggest potential recoveries of 200 fish exposed to the highest dose (Wertheimer et al 1995). With this greater number of fish, the interaction between spawning date and dose on offspring survival can be properly analyzed and individual variability can be assessed through more powerful experiments. Finally, the tagging protocol used in Study 076 will eliminate biases in estimates for marine survival.

Survival of treatment groups in the gravel incubators through the eyed-stage was adequate to provide the number of fry needed for tagging in the spring, 1996, assuming normal survival rates from eyeing to emergence. Survival rates for the control groups were higher than those observed in previous exposure trials. These survivals are less than the 90%+ survival rates usually achieved in hatchery operations. We attribute this to the extensive prefertilization handling of the eggs necessary to mix the eggs to ensure a random gamete source for the treatment groups.

The low and high exposure levels were chosen to be at or below the threshold levels identified by Heintz et al. (1996a) as causing significant reductions in embryo survival. The high dose in this experiment caused a small (2%) but significant reduction in embryo survival. Heintz et al. et al. (1996a) found that the similar nominal dose had 8% lower average survival than did the controls. Surprisingly, our low dose group also showed a slight but significant reduction in embryo survival. Heintz et al. (1996a) reported maximum PAH concentrations associated with the lowest nominal dosing level to be below State of Alaska water quality standards. They also showed that the pink salmon embryos were picking up PAH contamination from the water, and not from direct contact with contaminated gravel. We need the results from the water chemistry samples to determine if actual water exposures from the nominal low dose were again at or below the state standards. If so, these results imply that the state standards do not provide adequate protection for incubating salmon embryos.

Peak emigration timing of pink salmon fry was later at Sashin than at Lovers Cove Creek. The peak migration period at Lovers Cove Creek (May 4 - May 10) was about one week earlier than at Sashin Creek (May 9 - May 16). Over four times more fry were estimated to have been caught at Sashin than at Lovers Cove Creek indicating a larger escapement of adults to Sashin Creek in 1994 or higher egg-to-fry survival at Sashin Creek. The east channel usually has the highest escapement and the highest water quality Lovers Cove Creek; the middle and west branches typically dewater periodically. Although only one of the three channels of Lovers Cove Creek was trapped for fry, the east channel has a continual flow of ground water and hence should have the highest survival among the channels and cause earlier fry emergence than at Sashin Creek.

Most of the pink salmon tagged and released at LPW in 1993 that returned to Little Port Walter or Big Port Walter in 1995 were recovered at Sashin Creek. Adjusting for sampling effort, 3.7% of the tagged pink salmon strayed from Sashin Creek to either Borodino or Lover's Cove creeks, even though the parents of these fish were from Lovers Cove Creek. The natal watershed, therefore, was a much stronger attractor for the fish than was their genetic origin.

The number and frequency of tagged strays was much higher in Borodino Creek than in Lovers Cove Creek. Both Sashin and Borodino watersheds have relatively large lakes in them, whereas Lovers Cove Creek does not. The similarity of the Borodino watershed to the natal watershed may have been a factor in attracting fish that returned to Big Port Walter to Borodino Creek rather than to their parents' home stream. The frequency of tags per spawner was almost identical for Sashin Creek and Borodino Creek. One possible explanation for this is that there was little natural production from Borodino Creek, and the pink salmon spawning there are almost entirely strays from Sashin Creek. This assumes straying rate of the wild Sashin Creek pink salmon and the tagged pink salmon were the same. A second explanation is that the tagged fish, due to treatment, transplant, culture, or tagging, strayed at a higher rate than wild Sashin Creek pink salmon, and were differentially attracted to Borodino Creek in comparison to Lovers Cove Creek. Restoration Project 076 will provide insight into the factors causing such differential straying rates.

We used the straying rates of tagged fish returning to LPW in 1995 to refine the empirical model used by Wertheimer et al. (1995) to assess the power to detect differences in straying between oil-exposure treatment groups at the release group sizes and sampling regimes proposed. Straying within a 30-km radius of LPW was estimated using three different assumptions about the straying rates observed and the estimated escapements within the 30-km radius (Table 5). Assumption 1 was that the frequency of strays per spawner observed for Borodino and Lovers Cove was representative of the rate in pink salmon escapements within approximately 30 km of Sashin Creek (excluding Sashin Creek). In that case, the 30-km straying rate was estimated at 15%. Assumption 2 was that the frequency of strays per spawner for Lovers Cove Creek was representative of the rate in pink salmon escapements within approximately 30-km of Sashin Creek, and that Borodino had an anomolously high rate of stray occurrence. In that case, the 30 km straying rate was estimated at 9.2%. Assumption 3 was that the frequency of strays per spawner observed for Parry Creek (0%) was representative of the rate in pink salmon escapements within approximately 30-km of Sashin Creek other than Lovers Cove and Borodino Creeks. In that case, the 30-km straying rate is equal to the 3.7% rate observed for these two watersheds.

The ability to detect a difference in straying due to the oil exposure increases with return rate and actual straying rate (Figure 6). At the lowest straying assumptions (3.7%), oil exposure must increase straying by 50-100% at return rates of 2%-0.5%, respectively, to be significant at $P = 0.05$. At the highest straying rate assumption (15%), oil exposure must increase straying by 25-55% at return rates of 2%-0.5%, respectively, to be significant at $P = 0.05$. Although the straying assumptions are slightly more conservative than those used by Wertheimer et al. (1995), the

Underwood, A. J. 1981. Techniques of analysis of variance in experimental marine biology and ecology. Pages 513-605 *In* M. Barnes (Ed.). Oceanogr. Mar. Biol. Ann. Rev., 19, Aberdeen University Press.

Wertheimer, A. C., S. D. Rice, A. G. Celewycz, J. F. Thedinga, and R. A.Heintz. 1995. Effects of Oiled Incubation Substrate on Straying and Survival of Wild Pink Salmon. Restoration Project 96076 Detailed Project Description. *Exxon Valdez* Trustee Council, Anchorage, AK.

Table 2. Number of incubators (N), mean survival of eggs to eyed stage (SE of mean in parantheses), and mean number of live eggs, dead eggs, and total eggs per incubator, listed by oil dose.

Dose	Mean survival (SE)	Mean live eggs/incubator	Mean dead eggs/incubator	Mean total eggs/incubator
Control	0.816 (0.0021)	4090	924	5014
Low	0.800 (0.0037)	4095	1018	5113
High	0.799 (0.0028)	4154	1040	5194

Table 4. Number of fish checked for coded-wire tags and observed number and frequency of coded-wire tagged pink salmon for four stream systems in the vicinity of Little Port Walter in 1995. Expanded numbers of tags recovered in Lovers Cove and Borodino Creeks are the observed numbers of tags adjusted for the proportion of the escapement (0.58) estimated as sampled in Lovers Cove Creek. Dashes indicate an expanded number of tags could not be estimated.

Stream	Number Checked for Tags	Number Tags Observed	Frequency of Tags (%)	Expanded Number Tags
Sashin Creek	117,295	339	2.89	--
Lovers Cove Creek	18,945	2	0.11	3
Borodino Creek	2,258	6	2.66	10
Parry Creek	2,113	0	0.00	--

109-63-007	Malmesbury N Arm E	No	603	NA
109-63-009	Malmesbury N Arm S	No	17	0
109-63-012	Malmesbury Lake Creek	No	1,689	200
109-63-015	Malmesbury S Arm S	No	638	1,300
109-63-017	Malmesbury S Arm S	No	629	NA
109-63-020	Tavin Creek	No	417	NA
	Total for Area[3]		180,524	267,081
	Total, Surveyed Streams[3]		163,311	259,106
	% Total Surveyed 1997[3]		90.5%	97.0%

[1] AKI = Armstrong Keta Incorporated. Numbers are weir counts of fish entering hatchery adult capture and holding traps.

[2] Numbers are from aerial survey counts. Weir count at Sashin Creek in 1995 was 117,000.

[3] Excludes Sashin Creek

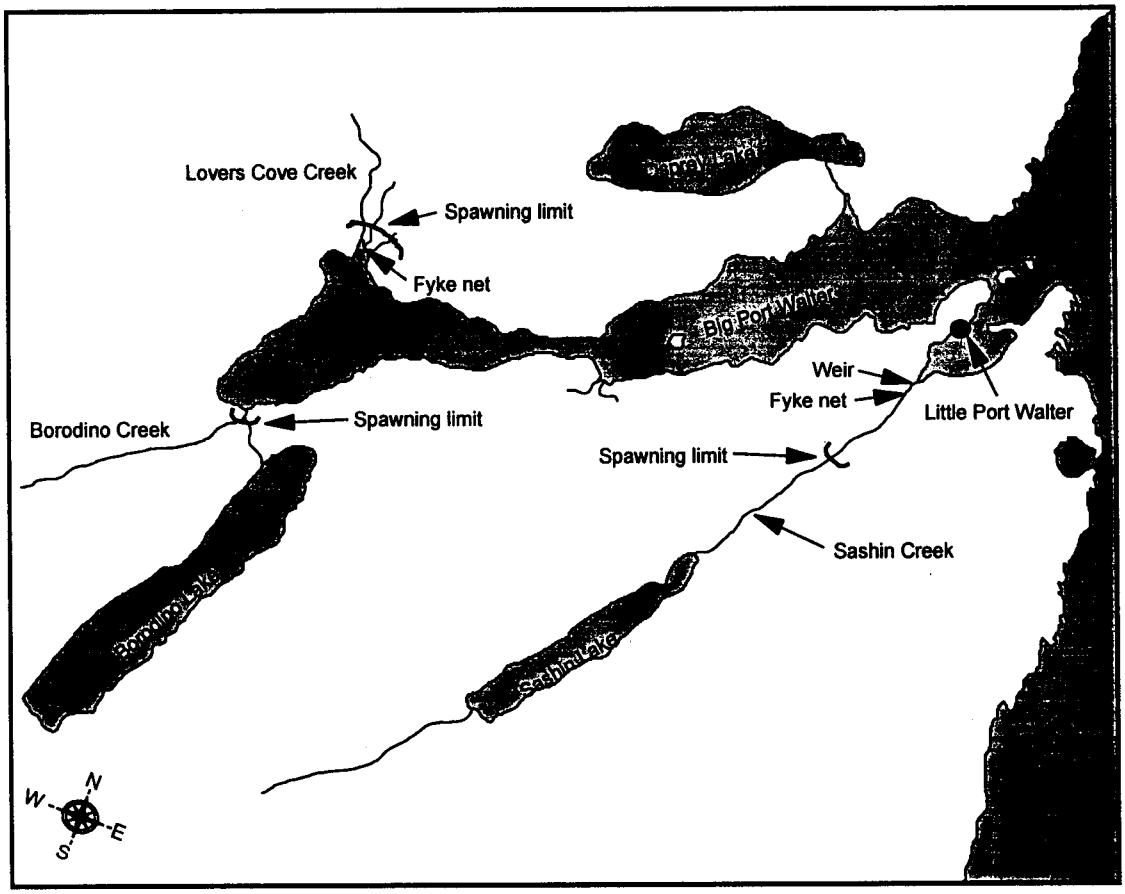

Figure 2. Map of Little Port Walter showing locations of fyke nets on Sashin and Lovers Cove Creeks, the weir on Sashin Creek and the limit of pink salmon spawning on Sashin, Lovers Cove, and Borodino Creeks.

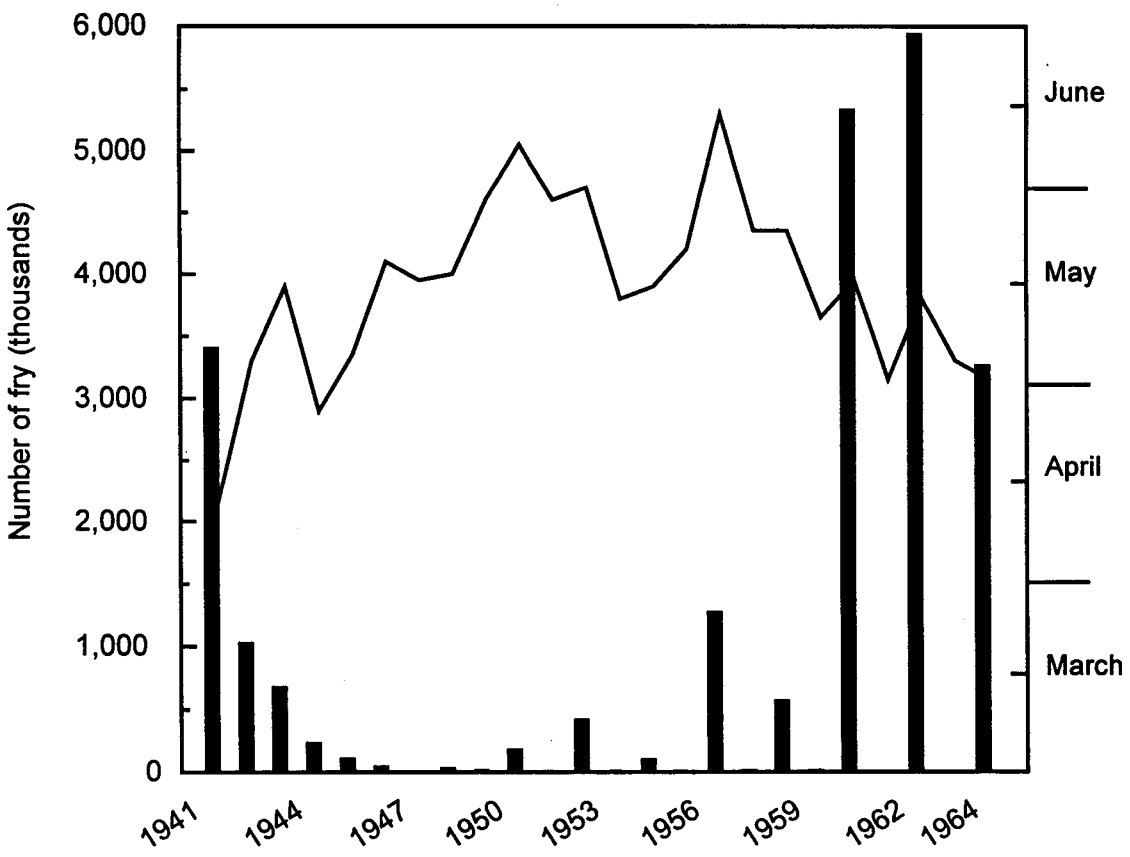

Figure 4. Total number of wild pink salmon fry captured at Sashin Creek weir (bars) and day of peak fry emigration (line).

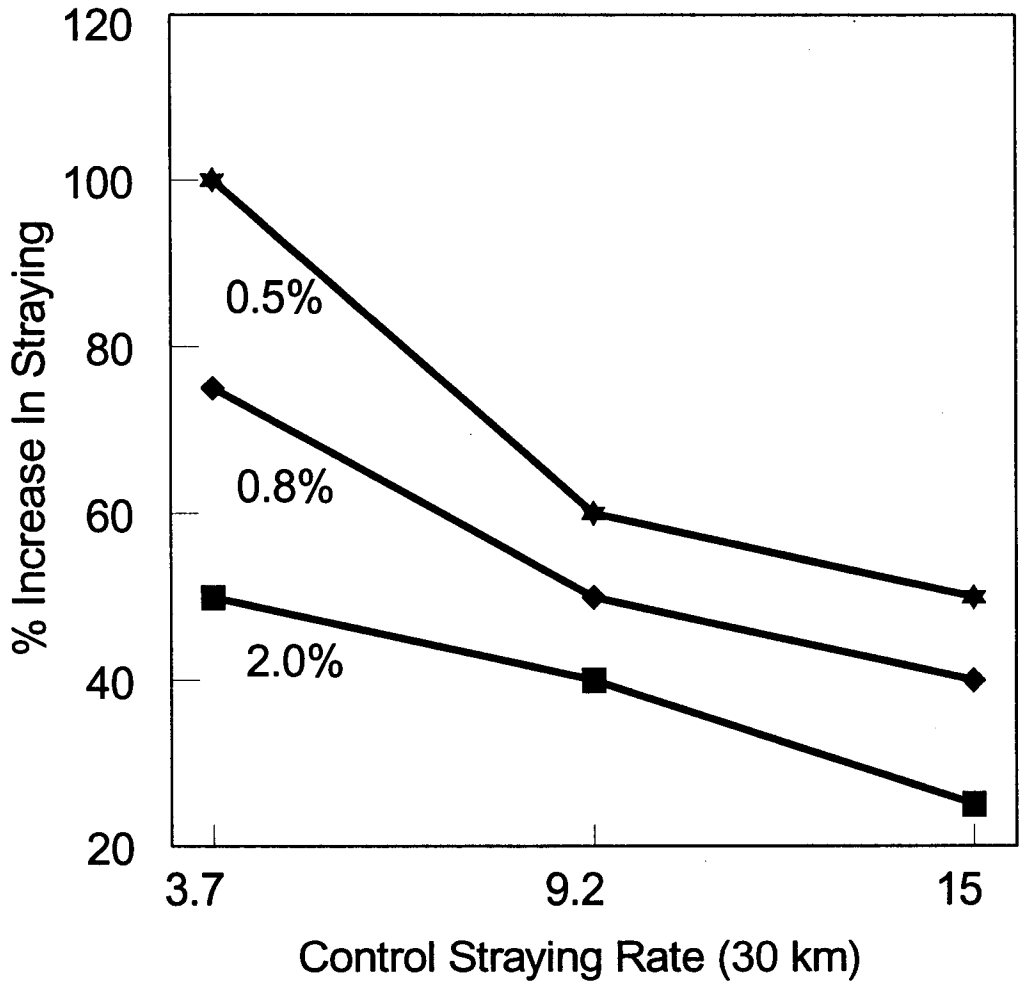

Figure 6. Differences in straying rate detectable at $P < 0.005$ for three different straying and return rate assumptions.