Exxon Valdez Oil Spill
Restoration Project Final Report

Injury to Pink Salmon Embryos in Prince William Sound - Field Monitoring

Restoration Project 98191A-1
Final Report

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June 2002

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Study History: This study originated in March of 1989 and continued through February of 1991 as Natural Resource Damage Assessment Fish/Shellfish Study 2. The project consisted of embryo sampling in the fall and pre-emergent fry sampling in the spring at oil-contaminated and reference streams to determine if embryo mortalities in pink salmon were correlated with the presence of oil from the *Exxon Valdez* oil spill. The work continued in 1992 as Restoration Project R60C. From 1993 through 1998, the work was continued as Restoration Projects 93003, 94191, 95191, 96191, 97191, and this project, 98191. Final reports have been written for Fish/Shellfish Study 2 and Restoration Projects R60C and 93003. Annual reports have been written for 94191, 95191, 96191, and 97191. This document constitutes the final report for the project.

Abstract: We examined pink salmon embryo mortality in oil-contaminated and reference streams in Prince William Sound. Pink salmon embryo mortalities were significantly greater in oiled than in reference streams during 1989-1993 ($P<0.020$). Results from controlled incubation studies conducted in 1993 and 1994 were consistent with results obtained from field sampling indicating that natural environmental differences between oiled and reference streams did not cause differences in embryo mortality. From 1994 through 1996, embryo mortalities were not significantly different ($P>0.400$) between oiled and reference streams. In 1997, embryo mortalities were again significantly greater ($P=0.017$) in oiled than in reference streams possibly due to a minor shift in the location of stream deltas or sampling-induced mechanical shock. We conducted several statistical analyses of our embryo mortality data to evaluate whether sampling-induced mechanical shock affected our results. Our analysis using sampling date as a covariate indicated no significant effect of sampling-induced mechanical shock on our results. However, analyses using a measure of the difference between spawn timing and sampling date (*Day75*) as a covariate indicated that sampling-induced mechanical shock may have affected our results. But, questions regarding the usefulness of *Day75* as a measure of embryo sensitivity to mechanical shock in specific years and lack of sufficient run timing data in most years leaves us unable to conclusively determine the magnitude of the effect.

Key Words: Alevins, crude oil, embryos, *Exxon Valdez* oil spill, hydrocarbons, mortality, *Oncorhynchus gorbuscha,* pink salmon, Prince William Sound.

Project Data: *Description of data* – Counts of numbers of live and dead salmon embryos and alevins obtained from sampling stream gravels using a hydraulic pump. Counts of numbers of live and dead salmon embryos and alevins obtained from a controlled incubation study. *Format* – Excel spreadsheets. *Custodian* – The data resides on the local area network in the Cordova ADF&G office. *Availability* – Data can be provided on a case-by-case basis upon request.

<u>Citation</u>:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

This study was designed to monitor pink salmon *Oncorhynchus gorbuscha* populations in Prince William Sound that may have been affected by the *Exxon Valdez* oil spill. Embryo mortality and embryo to pre-emergent fry survival were examined in intertidal and upstream areas of oil-contaminated and unoiled (reference) streams since the spring of 1989.

Embryo mortality was elevated in oil-contaminated streams from 1989 through 1993 ($P<0.020$ for all years). From 1994 through 1996, embryo mortalities were not elevated in oil-contaminated streams ($P>0.400$). In 1997, embryo mortality was again elevated in oil-contaminated streams ($P=0.017$). Embryo mortality was greater in oiled streams in all intertidal areas in 1989 but only in the highest intertidal area in 1990. These results were consistent with observations of intertidal oiling from other studies. Among oiled streams, all intertidal areas were contaminated in 1989, whereas in 1990 visible oil remained only in the upper intertidal zone.

In 1991-1992, embryo mortality was significantly greater in oil-contaminated than in reference streams in both the intertidal and upstream zones. This finding was unexpected, because the presence of observable oil was dramatically reduced in all areas and the upstream zone had not been contaminated with oil. This result led investigators to propose three hypotheses: (1) that oil-induced damage to the 1989 and 1990 broods included deleterious mutations in the germline, (2) that incubating embryos continued to be damaged physiologically by an oiled environment even after observable oil was gone, and (3) that differences in embryo mortality were due to natural environmental factors that differed between oiled and reference streams.

We tested the hypothesis that differences in pink salmon embryo mortality observed in recent years were due to natural environmental conditions between oiled and reference streams. In 1993, gametes were collected from adults in spawning condition as they aggregated on or near the spawning grounds at eight oil-contaminated and eight reference streams. The gametes were flown to the Armin F. Koernig hatchery in southwest Prince William Sound where intra-stream crosses were made. The resulting embryos from each stream were placed in a common incubator. The pink salmon embryos from oil-contaminated streams showed elevated mortalities when compared to the embryos from reference streams ($P<0.010$). This finding clearly indicated that the elevated embryo mortalities observed in the field monitoring portion of the study were not due to systematic differences between the incubating environments of oiled and reference streams. This embryo incubation experiment was repeated in 1994, but no significant difference in embryo mortality between oil-contaminated and reference streams was detected. This result is consistent with results obtained from the field-monitoring portion of the project in 1994. This study was attempted in 1992 and 1995 but was not completed due to lack of spawning salmon in some study streams.

In recent years, other investigators hypothesized that observed differences in embryo mortality between oiled and reference streams were due to sampling-induced mechanical shock to embryos. Pink salmon embryos are sensitive to mechanical shock until completion of epiboly two to three weeks after fertilization depending on developmental rate. If spawn timing were later or sampling times were earlier in oil-contaminated than reference streams, our results could have been biased by sampling-induced mechanical shock to embryos. We conducted several statistical analyses using field data collected since 1989 to evaluate this hypothesis.

Our statistical analyses of embryo mortality data indicated that oiling was associated with elevated mortality although sampling time may have also affected our results. Our analysis using sampling date as a covariate supported the conclusion that sampling-induced mechanical shock to embryos did not substantially affect our results. However, using a measure of the difference between spawn timing and sampling date (*Day75*) as a covariate and pooling data across all years, results were consistent with an effect of sampling-induced mechanical shock suggesting that our tests for oiling effects may have been affected by sampling date. But, questions regarding the usefulness of *Day75* as a measure of embryo sensitivity to mechanical shock in specific years and lack of sufficient run timing data in most years leaves us unable to conclusively determine the magnitude of the effect. Elevated embryo mortalities observed in oil-contaminated streams in 1997 may have resulted from a minor shift in the location of stream deltas or sampling induced mechanical shock.

INTRODUCTION

Wild salmon play a major role in the Prince William Sound (PWS) ecosystem while also contributing to the region's commercial fisheries. Migrating salmon fry are an important food source in the spring for various mammals, birds, and fishes. Marine mammals prey on the ocean life stages of Pacific salmon while terrestrial mammals and birds, such as bears, river otters, eagles, and gulls depend on salmon for a large portion of their summer diet. Salmon also provide a pathway for transferring nutrients from marine ecosystems to nearshore and terrestrial ecosystems. In recent years, commercial catches of wild salmon have ranged from 10 to 15 million pink salmon *Oncorhynchus gorbuscha* in PWS.

Salmon alevins are more sensitive to oil exposure in intertidal environments, where up to 75% of pink salmon in PWS spawn (Helle et al. 1964). Moles et al. (1987) and Rice et al. (1975) measured higher mortalities in pink salmon embryos and reduced growth and survival of alevins exposed to crude oil. The effects were greater for alevins exposed to oil in seawater and in simulated intertidal environments due to the greater solubility of oil in seawater or perhaps physiological changes associated with smoltification (Rice et al. 1975). Intertidal habitats are highly susceptible to contamination from marine oil spills in PWS due in part to the high tidal range.

The March 24, 1989 oil spill from the *T\V Exxon Valdez* contaminated many intertidal spawning areas in central and southwest PWS just prior to the spring emigration of salmon fry into the sound. Embryo mortality was significantly greater ($P=0.005$) in all intertidal areas of oiled streams compared to reference streams in the fall of 1989 (Sharr et al. 1994a, Bue et al. 1996). In 1990, embryo mortality was only elevated in the highest intertidal areas of oiled streams ($P=0.020$, Figure 1). These results were consistent with observations of intertidal oil-contamination (Wolfe et al. 1996). Among oiled streams, oil contamination was observed in all intertidal areas in 1989, whereas in 1990 visible oil remained only in the upper intertidal zone.

Continued high mortality in previously oiled streams after 1990 was unexpected, because visible oil contamination was greatly reduced by that time. In 1991, embryo mortality was significantly greater ($P=0.005$) in oiled than in reference streams and mortality in upstream areas of oil-contaminated streams was also elevated (Figure 1; Sharr et al. 1994a). Elevated mortality in these upstream areas was unexpected, because stream gravels above the intertidal zones were not contaminated. Similar patterns of embryo mortality were observed again in 1992 ($P=0.006$), but the mortality differences were smaller than in 1991 (Figure 1; Sharr et al. 1994b and Sharr et al. 1994c). In 1993, embryo mortality was again elevated in oiled-contaminated streams ($P=0.011$), and estimated contrasts indicated the differences were in the two lower intertidal zones. In 1994 and 1995, embryo mortality was not significantly different ($P>0.400$) between oiled and reference streams suggesting recovery from the effects of oil contamination (Figure 1; Craig et al. 1996).

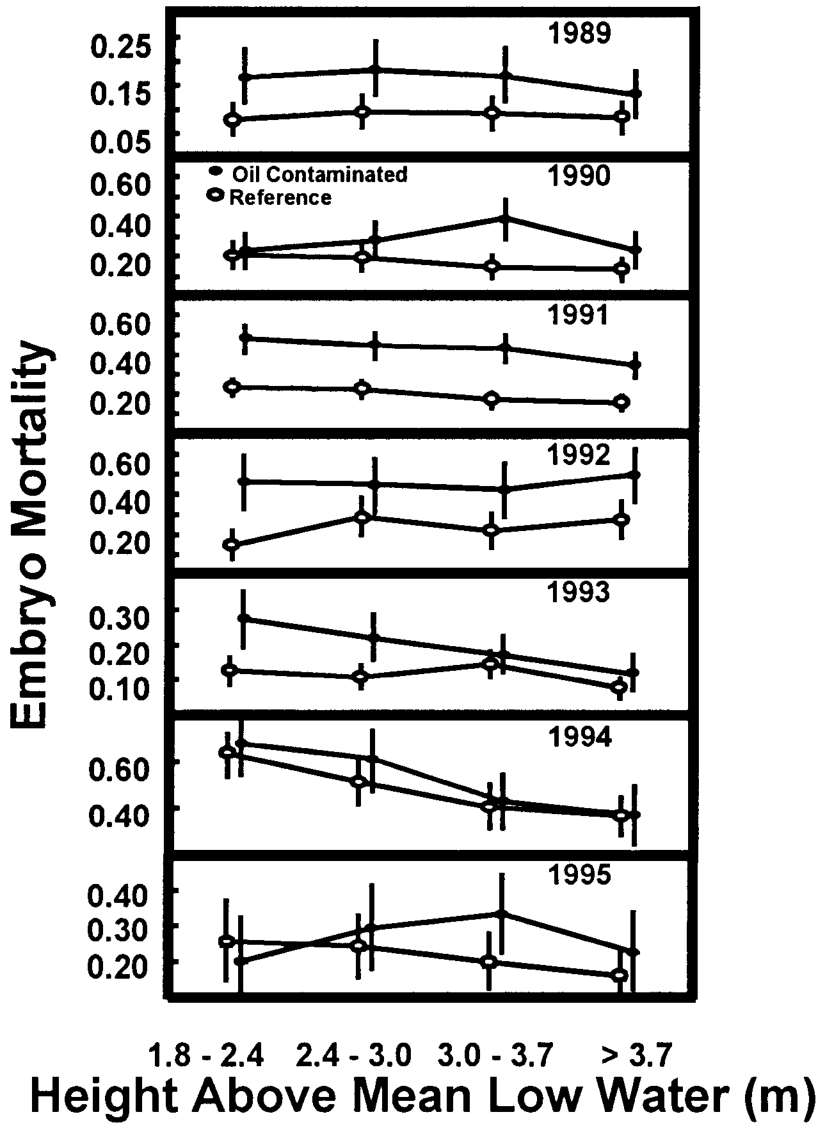


Figure 1. Mean mortality of pink salmon embryos in oil-contaminated (solid circles) and reference streams (open circles) bordering Prince William Sound, 1989-1995.

Elevated mortalities observed in the intertidal zones of oil-contaminated streams in 1989 through 1993 may have been due to direct exposure to oil. Brannon et al. (1995) attempted to measure exposure of pink salmon embryos to hydrocarbons in our oiled and reference streams. During the spawning period in 1989, mean PAH concentrations measured at the surface of the streambed were 116.8 ppb (range 0.8-267.0 ppb) in 6 of our oiled study streams and 10.1 ppb (range 0.2-64.0 ppb) in our reference streams (Brannon et al. 1995). During the spawning period in 1990, mean PAH concentrations declined to 27.7 ppb (range 1.8-108.2) in oiled streams and 1.6 ppb (range 0.7-3.2) in reference streams. During the spawning period in 1991, mean PAH concentrations increased to 93.9 ppb (range 1.1-235.5 ppb) in oiled streams but remained relatively low in reference streams (mean=1.5 ppb, range 0.8-2.4). Although, Brannon et al. (1995) found consistently higher mean PAH concentrations at the surface of stream gravels in our oiled than reference streams, their results probably did not provide a reliable estimate of embryo exposure. Murphy et al. (1999) observed PAH concentrations in stream delta sediments that were about 1-2 orders of magnitude higher than those observed by Brannon et al. (1995) at the surface of the streambed. Murphy et al. (1999) concluded that tidal leaching from residual oil deposits in stream delta sediments intermittently exposed embryos incubating in adjacent stream gravels to low aqueous hydrocarbon concentrations. This mechanism probably exposed embryos and alevins incubating in oil-contaminated intertidal spawning habitats to low hydrocarbon concentrations over a 7-8 month period. Such long-term exposure to low PAH concentrations derived from weathered oil caused embryo mortality in the laboratory (Heintz et al. 1999). Long-term exposure to low aqueous PAH concentrations may cause mortality, because lipid-rich embryos scavenge the more toxic phenanthrenes and chrysenes from the environment until lethal tissue concentrations are achieved (Heintz et al. 1999). Murphy et al. (1999) concluded that PAH concentrations in some PWS streams were above the minimum threshold observed to cause embryo mortality in the laboratory from 1989-1993, consistent with our field observations of embryo mortality.

Elevated embryo mortalities observed in upstream areas of oil-contaminated streams in 1991 and 1992 led to development of three hypotheses: (1) natural environmental differences between oiled and reference streams caused elevated mortality in oiled streams, (2) oil-induced chromosome damage during incubation affecting the germline caused later embryo mortality in oiled streams, and (3) oil-induced physiological damage during incubation later affected reproductive success.

Observed differences in embryo mortality may have been due to systematic differences in environmental conditions between oil-contaminated and reference streams. Our study was based on observational data, so we were unable to randomize stream oiling to account for environmental differences among streams. We attempted to address this concern in our original experimental design by selecting reference streams in close proximity to oil-contaminated streams; however, there was a definite pattern to the oil contamination in southwest PWS. Oil-contaminated streams were often located on points of land facing northeastward, whereas uncontaminated streams often faced west and southwestward.

Genetic or physiological damage resulting from exposure to hydrocarbons during embryonic development may have contributed to elevated embryo mortalities observed in oil-contaminated streams after 1990. Hypotheses regarding possible genetic and physiological damage were developed from knowledge of previous field observations and laboratory experiments on the effects of crude oil during the early life stages of fish. Petrochemicals and the polynuclear aromatic hydrocarbons (PAH) abundant in crude oil and are capable of inducing chromosomal lesions (Longwell 1977; McBee and Bickham 1988; Bickham et al. 1998), so it is possible that oil-induced germline damages affecting later reproduction are transmitted between generations (Malkin 1994). Pink salmon alevins exposed to hydrocarbons in the laboratory exhibited elevated gonadal cell apoptosis (Marty et al. (1997), but exposure to hydrocarbons at these early life stages has not yet been linked to reduced reproductive success. Hydrocarbon contamination can also influence endocrine function (Thomas and Budiantara 1995) and later reproduction (Trustcott et al. 1983).

Genetic or physiological damages affecting pink salmon in one brood year could be expressed in that lineage two or more years later, because this species has an obligate two-year life cycle with genetically isolated lineages reproducing in odd- and even-numbered years. The pink salmon that spawned during the fall of 1991 and 1993 were from the odd broodline that spawned in 1989. Embryos and alevins that incubated in oiled gravel during the winter of 1989-1990 were probably exposed to the highest concentrations of hydrocarbons during incubation (Brannon et al. 1995; Murphy et al. 1999). Similarly, pink salmon that spawned in 1992 were from the even broodline that had probably been exposed to the second highest hydrocarbon concentrations during incubation in the winter of 1990-1991.

This study was initially designed to monitor pink salmon embryo mortality and embryo to pre-emergent fry survival in oil-contaminated streams bordering PWS. However, in 1992, the project was amended to examine whether systematic environmental differences between oil-contaminated and reference streams or genetic damage may have caused observed embryo mortality. Experiments were initiated to: (1) evaluate the environmental-difference hypothesis by incubating embryos from oiled and reference streams in a common environment (Appendix C); (2) use laboratory experiments to further examine how oil contamination may have caused embryo mortality (Heintz et al. 1999); and (3) test for genetic damage using flow cytometry and androgenesis screens (Seeb et al. 1996).

After initiation of these studies, project reviewers suggested that outbreeding depression may have caused differential mortalities observed in the field. This hypothesis was developed from data provided by NRDA Fish/Shellfish Study 1 and Study 3 (F/S 1 and F/S 3) and Restoration project 99188 (Joyce and Evans 1999) which indicated that large numbers of pink salmon were straying into streams in or near our study area. Higher straying rates into oil-contaminated streams may have caused introgression of non-locally adapted genes and elevated embryo mortality. Evaluation of this hypothesis was beyond the scope of our study.

We observed no difference in embryo to pre-emergent fry survival between oil-contaminated and reference streams (Sharr et al. 1994a, 1994b, and 1994c). Lack of a difference in embryo-to-fry survival may have resulted, because (1) oil contamination did not affect survival, (2) compensation masked reduced survival, or (3) our experimental design was inadequate to detect reduced survival. It seems unlikely that embryo-to-fry survival was not affected by oil contamination, because embryo mortality was elevated in oiled streams and alevins were more vulnerable to oil contamination than embryos (Moles et al. 1987). Compensation during intragravel life stages also probably did not affect the number of emerging fry during the years of our study, because embryo and alevin densities were too low (Geiger et al. 1996). Rather, our experimental design was probably inadequate to detect effects of oil contamination on embryo-to-fry survival. Unexpected changes in stream characteristics probably prevented sampling the same areas for embryos in the fall and pre-emergent fry in the spring. Stream channels in PWS are not well defined in intertidal areas, and some intertidal stream segments migrate along the beach when exposed to winter storms. The magnitude of these changes was unexpected when this study was designed. Subsequent power analyses indicated that our experimental design was inadequate to detect a biologically meaningful difference in embryo-to fry survival.

Finally, Brannon and Maki (1996) postulated that differences in embryo mortality between oiled and reference streams reported by Bue et al. (1998b) were due to differences in sampling-induced mechanical shock to embryos. Pink salmon embryos are sensitive to mechanical shock until completion of epiboly two to three weeks after fertilization, depending on water temperature and other factors affecting developmental rate (Jenson and Alderice 1983; Smoker et al. 1998). Brannon and Maki (1996) hypothesized that embryos from oiled streams were sampled at an earlier stage of development, and therefore experienced more mechanical shock than embryos from reference streams. We conducted several analyses using data collected since 1989 to evaluate this hypothesis.

OBJECTIVES

1. Test for a difference in mortality of pink salmon embryos between oiled and reference streams.

2. Test the hypothesis that differences in embryo mortality between oiled and reference streams were due to mechanical shock during sampling.

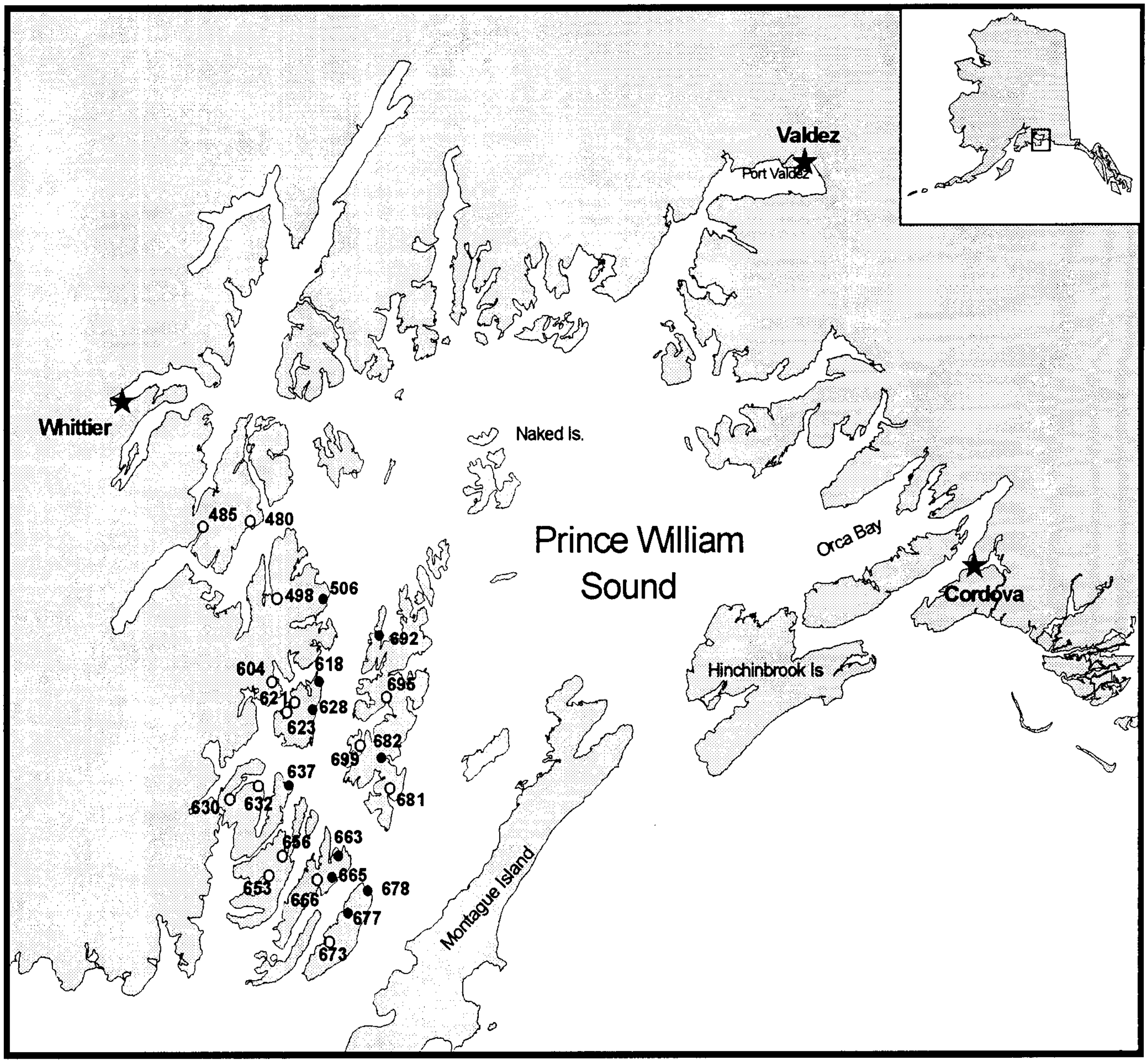


Figure 2. Locations of oil-contaminated (black circles) and reference streams (white circles) sampled in southwestern Prince William Sound (1989-1997).

METHODS

Sampling design

Mortality of pink salmon embryos was examined annually in 10 oil-contaiminated (oiled) and 15 nearby uncontaminated (reference) streams (Figure 2). The following criteria were used to select the streams used in the study:

1. They had significant spawning populations in both odd and even years.
2. They were accessible for sampling in most years.
3. They were representative of oiled and reference streams in the oil-impacted area of PWS.

Stream oiling was assessed through visual observations of the stream and the adjacent area during the spring of 1989. The observations were reviewed and adjusted if necessary according to the results of anadromous stream surveys conducted in southwestern Prince William Sound by the Alaska Department of Fish and Game (ADF&G), Habitat Division (Middleton et al. 1992). The oiling classifications of the streams correlated with the findings of the fall of 1989 shoreline surveys (ADEC-SRS 1989; Neff et al. 1995) and similar pink salmon work by Brannon et al. (1995).

Craig et al. (1995) and Sharr et al. (1994a and 1994b) described the methods used to sample embryos. Sampling was stratified by tide zone to control for possible differences in salinity, temperature, predation, or a combination of these factors. Zone boundaries were established with a surveyor's level and stadia rod and staked prior to sampling. Four zones were sampled in each stream whenever possible: 1.8 - 2.4 m, 2.4 - 3.0 m, 3.0 - 3.7 m above mean low water, and upstream of mean high tide (3.7 m). No sampling was done below the 1.8 - 2.4 m zone, because mortality in this zone was very high (Helle et al. 1964).

During each survey, separate linear transects were established within each tide zone. Although most transects were 30.5 m long, some were shorter due to steep stream gradients. Transects were placed in riffle areas where spawning was observed during escapement surveys conducted for F/S 1. Transects ran diagonally across the river starting downstream against the left bank and moved upstream to the right bank. A map drawn for each stream indicated the tide zones and transect locations in relation to major landmarks. Each embryo transect was photographed and marked with surveyor's flagging to insure that future transects could be located in the same area of the stream.

Fourteen circular samples (0.186 m^2) were systematically collected along each transect. The number of digs was a compromise between reducing variance and the practicality of conducting the study. Fewer digs were completed on narrow stream channels to avoid excessive sampling of the stream. Streams that split into two or more channels within a zone were sampled either by allocating digs among channels based on spawner distribution observed during F/S 1 or, where spawner distribution was unknown, by an equal allocation.

The following data were collected for each tide zone transect during both embryo and fry sampling:

1. Sample date.
2. Sample tide zone.
3. Start and stop time for the tide zone transect.
4. Numbers of live and dead fry and embryos for each species in each dig.

Pink salmon embryos were separated from chum *O. keta* and coho *O. kisutch* salmon embryos by their smaller size. Chum salmon embryos were separated from coho salmon embryos by their greater development and different coloration. An embryo was considered dead if it was opaque or discolored with coagulated lipids. Eggs that were considered unfertilized were counted as dead. Fry were considered dead only if decomposition was evident, because sampling often killed fry. To minimize the effects of sampling induced mechanical shock on our results, we counted live and dead embryos as soon as possible after their removal from stream gravels. During the early years of the study, up to one half hour elapsed between removal of embryo samples from stream gravels and counting of live and dead embryos. This time was reduced to less than 5-10 minutes during the last few years of the study.

Effects of oil contamination on embryo mortality

We summarized the numbers of live and dead embryos and fry by level of hydrocarbon contamination, stream and tidal zone. Densities of live embryos (E_{ij}) per m^2 were estimated using,

$$\hat{E}_{ij} = \frac{\sum_k LE_{ijk}}{0.186 n_{ij}} \quad , \qquad (1)$$

where LE_{ijk} was the number of live embryos found in the k^{th} dig, in stream i, zone j, and n_{ij} was the number of digs. Densities of dead embryos were calculated using the same estimator with appropriate substitutions.

Pink salmon embryo mortality was estimated for each stream and zone using,

$$\hat{M}_{ij} = \frac{\sum_k (DE_{ijk} + DF_{ijk})}{\sum_k (LE_{ijk} + DE_{ijk} + LF_{ijk} + DF_{ijk})} \quad , \qquad (2)$$

where DE_{ijk}, DF_{ijk}, LE_{ijk}, and LF_{ijk} were the number of dead embryos, dead fry, live embryos, and live fry for the k^{th} dig from stream i and zone j, respectively.

The arcsine square root transformation was examined as well as the logit transform of embryo mortality [ln (odds)], i.e.

$$Logit_{ij} = \ln \left[\frac{\sum_k (DE_{ijk} + DF_{ijk})}{\sum_k (LE_{ijk} + LF_{ijk})} \right] \quad . \tag{3}$$

Differences in embryo mortality were examined using a completely randomized experimental design with a split-plot treatment structure (Neter et al. 1990):

$$Y_{ijk} = \mu_{...} + O_i + Z_j + (OZ)_{ij} + S_{k(i)} + \varepsilon_{(ijk)} \quad . \tag{4}$$

The main plot treatment was level of oiling, (O_i, 2 levels; oiled and reference), and the split-plot treatment was height in the intertidal zone (Z_j, 4 levels; 2.1, 2.7, and 3.4 m above mean low water, and upstream), both fixed effects. Stream was included as a random effect nested within level of oiling, ($S_{k(i)}$). The interaction of level of oiling and height in the intertidal zone was also examined. Equality of variances was tested using the F_{max}-test (Sokal and Rohlf, 1969), while normality of error terms was visually assessed using normal quantile-quantile and box plots (Chambers et al. 1983). Arcsine square root, logit, log, and square root transforms were examined if the data indicated non-constant variances or non-normal error terms. Assumptions inherent in the use of the split-plot analysis were tested by examination of the homogeneity of between treatment covariance matrices and the degree of sphericity of the pooled covariance matrix. The procedure PROC MIXED (SAS Institute Inc., 1998) and Akaike's Information Criterion (AIC) were used to assess a variety of covariance structures, other than that of compound symmetry assumed in the split-plot analysis, to describe the within-stream errors. Four contrasts (oil vs. reference for the four stream zones) and corresponding Bonferroni family confidence intervals ($\alpha = 0.10$ overall) were estimated if a significant difference due to oiling was detected. The SAS (SAS Institute Inc. 1998) General Linear Models Procedure was used to analyze the data.

We also conducted a repeated-measures analysis that included all nine years of data collected from the same 25 streams, because this approach provided a more powerful statistical test of the effects of oil contamination on embryo mortality. Year was treated as a repeated measure in time and zone as a repeated measure in space in the analysis (doubly-repeated measures), because neither year nor zone could be randomized. Oiling was treated as a fixed effect in a completely randomized design. The procedure PROC MIXED (SAS Institute Inc. 1998) was used with the *repeated* statement specifying the two repeated measures and the Kronecker product structure designed for multivariate repeated measures (SAS Institute Inc. 1998). The "*Type=*"

specification was determined using AIC. An analysis in which year was treated as a repeated measure was also performed where logit(mortalities) were averaged over zone, such that each stream yielded one logit(mortality) measure. The PROC MIXED procedure, specifying year as the only repeated measure was used for this analysis.

Effects of mechanical shock on embryo mortality

We used covariate analysis to test the hypothesis that differences in embryo mortality between oiled and reference streams were due to sampling-induced mechanical shock to embryos. Two covariates were identified that may correlate with the sensitivity of embryos to mechanical shock: (a) *Sample Date*, defined as the day of the year on which embryo sampling was conducted, and (b) *Day75,* defined as the number of days between *Sample Date* and the date at which 75% of the escapement was estimated to have entered the stream (*E75*):

$$Day75 = Sample\,Date - E75 \quad . \tag{5}$$

E75 was used as a rough measure of the relative timing of the end of the spawning run, because numbers of salmon observed in the streams were generally declining by this time, and few observations were available to document the actual end of the run (zero count). E75 was estimated from periodic counts of live pink salmon obtained from ground surveys conducted by the ADF&G in 1990-1992 (Fried et al. 1998). Periodic counts of live pink salmon obtained from ground surveys conducted by the Exxon Corporation (E. Brannon, pers. comm.) were used for streams and years in which data were not available from ADF&G surveys. If ground surveys were not conducted throughout the entire spawning run to a stream, ADF&G aerial survey data were used to help identify the beginning and/or end of the run. If aerial survey data were not available to document the end of the run, it was estimated by assuming that all fish observed during the last survey died within 7 days (Bue et al. 1998a).

Of the 2 covariates, *Day75* was probably the more robust measure of embryo sensitivity to mechanical shock, because it accounted for relative differences in run timing (*E75*) and time of sampling. But, *Day75* could only be calculated when sufficient run timing data were available to calculate *E75*. *Sample Date* was considered an adequate relative measure of embryo sensitivity when no difference in *E75* between oiled and reference streams could be detected with sufficiently powerful tests.

Tests for differences in *E75* between oiled and reference streams were conducted using PROC MIXED with year as a repeated measure. AIC was used to examine a series of covariance structures that described within stream correlations. The approximate power of tests for differences in *E75* between oiled and reference streams was calculated according to standard procedures (e.g. Snedecor and Cochran, 1989).

The PROC MIXED procedure was used to determine if inclusion of either of the covariates caused previously significant mortality differences between oiled and reference streams within years to become non-significant. The model for an individual year was:

$$Y_{ijk} = \mu + \beta D_{ijk} + O_i + Z_j + OZ_{ij} + S_{k(i)} + \varepsilon_{(ijk)} \quad , \qquad (6)$$

where D_{ijk} was either the *Sample Date* or the value of *Day75* associated with the j[th] zone in the k[th] stream for the i[th] oiling treatment. A more powerful test of the significance of the covariate was also conducted by including the covariate in a single repeated-measures (*i.e.* year) analysis with data from all years pooled. AIC was used to choose the most appropriate covariance structure.

RESULTS

Effects of oil contamination on embryo mortality

Twenty-five streams were sampled between October 3 and October 22, 1996 to estimate embryo mortality. Mean embryo densities during the 1996 egg deposition survey were 984.54 eggs per m^2 in the intertidal zones and 1089.78 eggs per m^2 in the upstream (Appendix A). The 1996 embryo mortality data indicated no significant difference between the oiled and reference streams (P=0.47; Figure 3). No significant stream zone effect (P=0.35) or oil-by-zone interaction was found (P=0.27). The overall mean embryo mortalities for the oiled and reference streams were 0.25 and 0.19 in 1996.

Twenty-five streams were sampled between September 28 and October 21, 1997 to estimate embryo mortality. Mean embryo densities during the 1997 egg deposition survey were 838.39 eggs per m^2 in the intertidal zones and 1368.53 eggs per m^2 in the upstream (Appendix A). A split-plot analysis of the 1997 data revealed a significant difference in embryo mortality between oiled and reference streams (P=0.03). The stream zone (P=0.15) and zone by oiling interaction (P=0.75) terms in the model were not significant. The back-transformed least-squares mean mortalities were 0.42 (oiled) and 0.27 (reference). Mortality differences between oiled and reference streams appeared to be driven by effects at the two intermediate stream-tide zones (Figure 3).

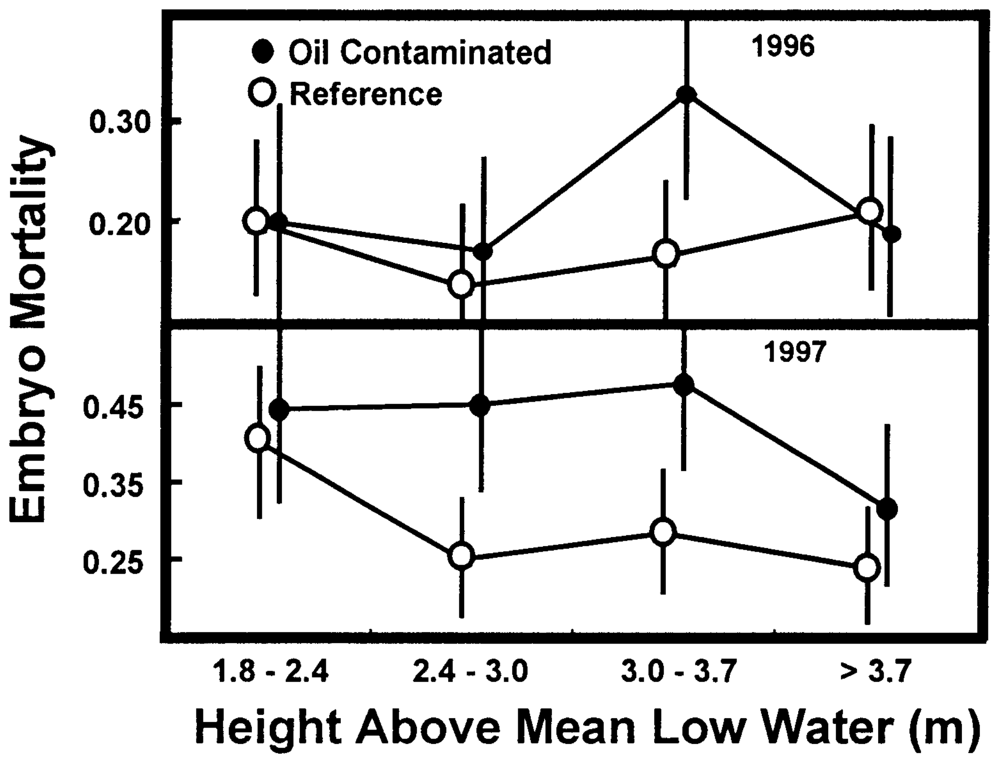


Figure 3. Mean pink salmon embryo mortality and corresponding 90% confidence bounds by tide zone for oil-contaminated and reference streams in Prince William Sound, 1996 and 1997. Solid circles represent data from 10 oil-contaminated streams, and open circles represent data from 15 reference streams.

Using the *repeated* facility in PROC MIXED, it was found that an auto-regressive structure more adequately described the covariance between zones than did the compound symmetry structure assumed in the regular split-plot analysis. Mauchly's criterion test for the sphericity of the covariance matrix supported this conclusion (P=0.03). An additional analysis of the 1997 data was conducted using the auto-regressive covariance structure. The results indicated little change in the P-values (oil: P=0.03, zone: P=0.14, oil by zone: P=0.70). Similar analyses were performed for all previous years, and the results indicated that the compound symmetry assumption inherent in the split-plot analysis was entirely adequate.

An analysis of all 9 years of data was conducted by treating year as a repeated measure in time and zone as a repeated measure in space. While the overall three-factor interaction was not significant (P=0.32), examination of the oiling by zone interactions by year revealed some evidence of a three-factor interaction. Plots of least-square means suggested the interaction was small. Examination of the year by oiling interaction revealed a pattern of statistical significance of oiling effects that was similar to that obtained in the analyses conducted for each year separately. The pattern of statistical significance of oiling effects obtained from the doubly-repeated measures analysis were: 0.01, 0.01, 0.01, 0.01, 0.01, 0.67, 0.33, 0.40, 0.03 for 1989 through 1997, respectively. A simpler analysis was performed in which logit(mortality) was averaged over zone, such that each stream in a given year yielded only one mortality measurement, and year formed the only repeated measure. A compound symmetry structure was found to most appropriately model the covariance among years. The pattern of statistical significance of oiling effects from this analysis was similar to that obtained from the doubly-repeated measures analysis (P=0.02, 0.03, 0.01, 0.01, 0.05, 0.72, 0.42, 0.65, 0.06 for 1989 through 1997, respectively).

Analysis of the influence of physical shock on oiling effects

Sample Date as Covariate

Results of inclusion of Sample Date (Figure 4a) as a covariate for all years are given in Table 1. The analyses indicated a pattern of significant differences in embryo mortality between oiled and reference streams that was very similar to that obtained without the covariate. The *Sample Date* covariate was significant in 1989, 1990, 1991 and 1994, and the sign of the parameter estimate indicated that embryo mortality tended to decrease when sampling was conducted later in the season.

The degree to which Sample Date should be considered a useful relative measure of the extent of physical shock experienced by sampled embryos depends on the extent to which differences in run-timing exist between oiled and reference streams. The combined Exxon Corporation ground survey data and ADF&G aerial survey data used to estimate run timing for some streams are summarized in Appendix B. A plot of estimated mean run timing by oiling and year is provided in Figure 4b. Significant and large differences in mean run timing between oiled and reference streams were found only in 1990 (estimated difference of 14 days; P=0.01) and 1992 (estimated difference of 13 days; P=0.02), although a test using carcass count data for 1992 failed to reveal a difference (P=0.25). For the remaining years, estimated differences in run-timing were much smaller and ranged from two days for 1991 (P=0.37) to four days for 1995 (P=0.07). A test using carcass count data for 1991 also failed to reveal any difference in run timing (P=0.14). No carcass data were available for other years.

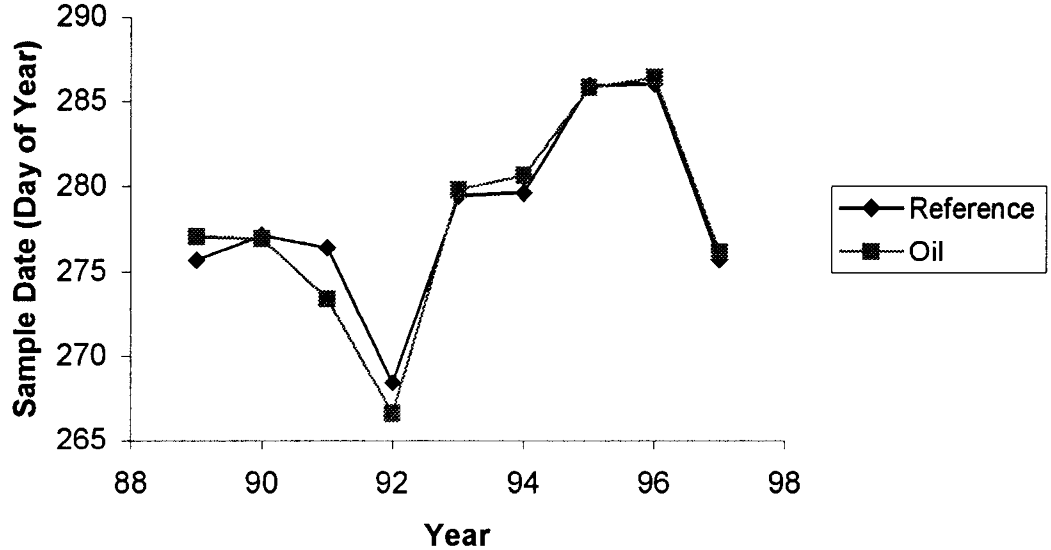
Of the tests where no difference in run-timing was found, the test for 1991 was estimated to be the most powerful, having an 80% probability of detecting a difference of 6 days at α=0.05. Power for the remaining insignificant tests was lower, ranging from 80% power for detecting a difference of 12 days (1989) to 8 days (1994).

Day75 as covariate

For analyses pertaining to the Day75 covariate, only data from those streams for which run-timing estimates were available were used. When the Day75 covariate was excluded from the analysis, no significant differences in embryo mortality between oiled and reference streams were detected at $\alpha=0.05$ for any year (Table 2), although the tests pertaining to 1991 and 1992 were marginally significant ($P=0.06$ and $P=0.07$, respectively). When *Day75* was included in the analysis, it was not significant for any year except 1992, for which the *P*-value for an oiling effect increased from 0.07 to 0.51 with inclusion of *Day75* as the covariate. The parameter estimate for the covariate in 1992 indicated that mortalities tended to decrease as sampling was conducted later in the season relative to run timing. The *P*-value for the oiling effect in 1991 changed from 0.06 to 0.08 after inclusion of the *Day75* covariate.

When the data from all years were pooled in a single repeated-measures (i.e. year) analysis, the *Day75* covariate was significant ($P=0.01$) and the parameter estimate (-0.038) was again negative. A plot of embryo mortality versus *Day75* over all years is given in Figure 5. When tests of the influence of oiling on the *Day75* variable were conducted for each year separately, no significant differences were found (Fig. 6) except in 1992 ($P=0.01$). However, when data from all years were pooled, *Day75* was significantly greater in reference than in oiled streams ($P=0.05$).

(a)



(b)

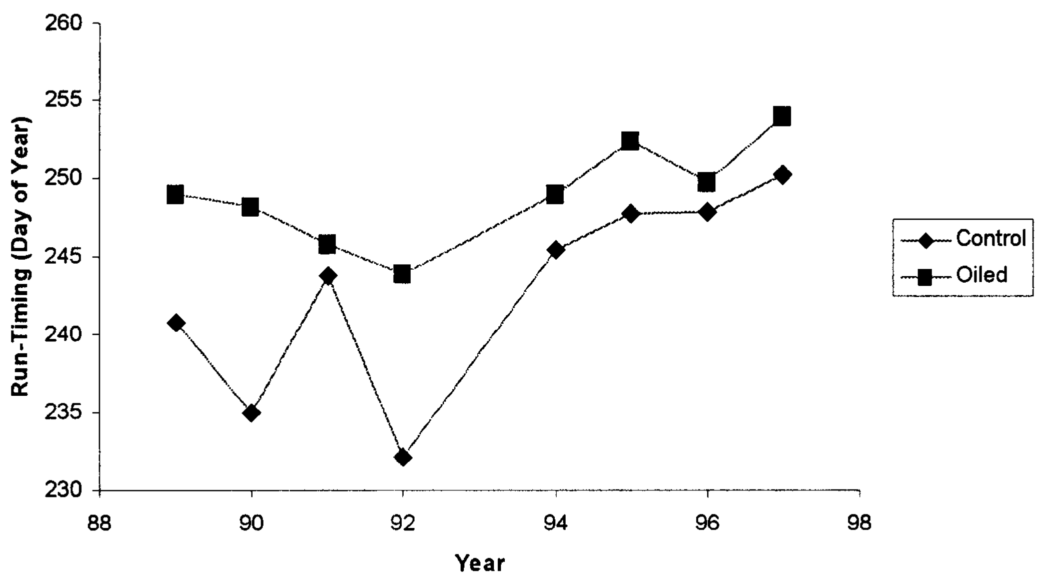


Figure 4. (a) Mean *Sample Date* and (b) run timing (*E75*) for oiled and reference streams by year.

Table 1. Statistical significance (*p*-values) for fixed effects and the *Sample Date* covariate obtained from a split-plot analysis. The dependent variable was logit(embryo mortality).

		Year								
		1989	1990	1991	1992	1993	1994	1995	1996	1997
No Covariate										
	Main-Plot									
	Oil	0.005	0.020	0.005	0.006	0.011	0.440	0.403	0.864	0.017
	Sub-Plot									
	Zone	0.544	0.572	0.021	0.185	0.008	0.005	0.163	0.133	0.232
	Oil*Zone	0.895	0.120	0.723	0.916	0.371	0.449	0.729	0.673	0.471
Linear Covariate										
	Main-Plot									
	Oil	0.003	0.010	0.009	0.018	0.010	0.126	0.414	0.893	0.019
	Sub-Plot									
	Zone	0.582	0.585	0.020	0.186	0.007	0.007	0.159	0.120	0.231
	Oil*Zone	0.913	0.106	0.642	0.916	0.382	0.427	0.744	0.570	0.468
	Covariate	0.094	0.012	0.019	0.460	0.285	0.001	0.794	0.178	0.690
	Est. ofCovariate	-0.043	-0.050	-0.060	-0.064	-0.030	-0.100	-0.014	-0.073	-0.012

Table 2. Statistical significance (*p*-values) for fixed effects and the *Day75* covariate obtained from a split-plot analysis. The dependent variable was logit(embryo mortality).

		Year								
		1989	1990	1991	1992	1993	1994	1995	1996	1997
# Streams	Oiled	3	5	8	10	0	5	3	5	3
	Control	4	5	9	7	0	5	4	5	4
No Covariate										
	Main-Plot									
	Oil	0.689	0.237	0.06	0.067	-	0.795	0.420	0.733	0.683
	Sub-Plot									
	Zone	0.422	0.140	0.02	0.216	-	0.001	0.869	0.024	0.626
	Oil*Zone	0.794	0.594	0.88	0.876	-	0.020	0.426	0.782	0.272
Linear Covariate										
	Main-Plot									
	Oil	0.850	0.482	0.08	0.512	-	0.964	0.640	0.650	0.205
	Sub-Plot									
	Zone	0.403	0.161	0.02	0.220	-	0.001	0.834	0.021	0.643
	Oil*Zone	0.811	0.573	0.91	0.871	-	0.015	0.364	0.764	0.597
	Covariate	0.623	0.479	0.13	0.049	-	0.271	0.304	0.713	0.281
	Est. ofCovariate				-0.051					

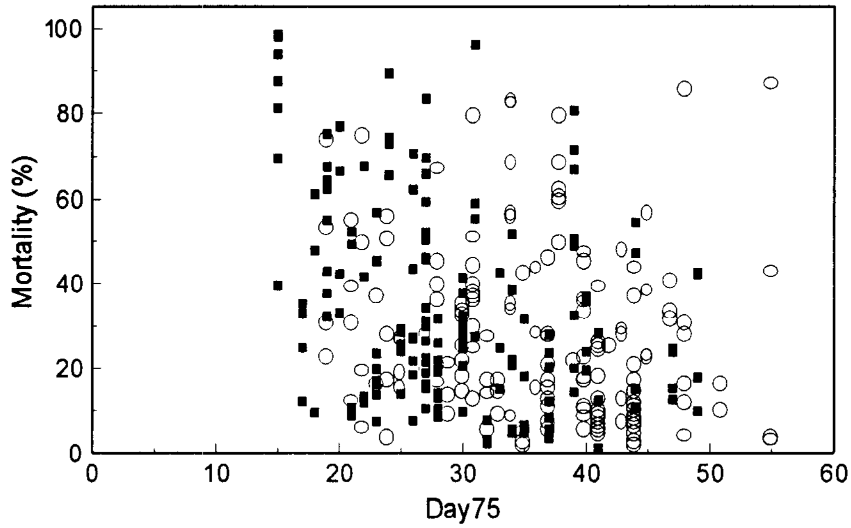


Figure 5. Relationship between embryo mortality and Day75 for oiled (solid squares) and reference streams (open circles).

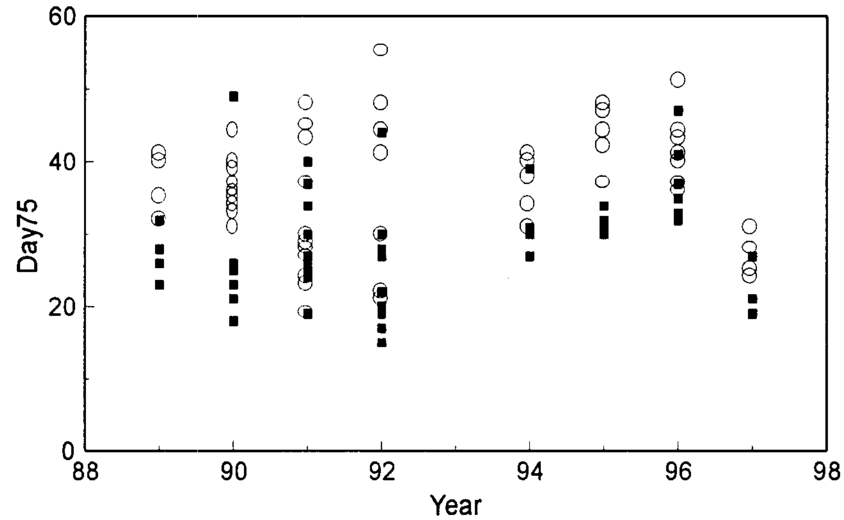


Figure 6. Frequency of occurrence of Day75 for oiled (solid squares) and reference streams (open circles) by year.

DISCUSSION

Pink salmon embryos that incubated in oil-contaminated spawning areas in PWS appear to have been adversely affected by the *Exxon Valdez* oil spill. Our statistical analyses of embryo data indicate that oiling was associated with elevated mortality although sampling time may have also affected our results. Murphy et al. (1999) concluded that PAH concentrations in some PWS streams were above the minimum threshold observed to cause embryo mortality in the laboratory from 1989-1993. Our observations of elevated embryo mortality in oiled-contaminated streams during this same period are consistent with Murphy's et al. (1999) conclusions. The question of concern regarding the effect of sampling time is whether inclusion of the covariates (*Sample Date* or *Day75*) caused significant oiling effects to become non-significant. In the analysis with *Sample Date* as the covariate, significant oiling effects in 1989-1993 and 1997 remained significant with inclusion of the covariate (Table 1). In the analysis with *Day75* as the covariate, the changes in significance of the oiling effect with and without the covariate were largely trivial. However, due to the reduced sample sizes, oiling effects were only marginally significant in 1991 and 1992 when run timing data were available from the greatest number of streams. In 1991, a marginally significant oiling effect remained as such with addition of the *Day75* covariate. However, in 1992 a marginally significant oiling effect became non-significant with inclusion of the covariate (Table 2). This change in significance likely resulted because the covariate and the treatment effect were themselves correlated; i.e. *Day75* was significantly different between oiled and reference streams in 1992. This was not the case in 1991.

However, we question whether the covariate *Day75* provided an adequate measure of embryo sensitivity to mechanical shock. This variable was intended to account for relative differences between spawn timing and time of sampling. Pink salmon embryos are sensitive to mechanical shock until epiboly is reached after about 200-210 deg. days of development (Smirnov 1976; Jensen and Alderdice 1989). At the time we sampled embryos, individuals within the population were at various developmental stages depending on the timing of egg fertilization and various factors affecting developmental rate (Heard 1991). Spawning probably occurred over a period of a month or more in our study streams (Appendix B), so a large range of development stages was present among embryos at the time of sampling. Lacking any data on the distribution of development stages within these populations at the time of sampling, we based our analysis on periodic counts of live salmon to estimate the date at which 75% of the run had entered the stream. But, we recognized that carcass counts were likely a better indicator of spawn timing than live counts, because pink salmon die shortly after spawning. We could not calculate *Day75* using carcass counts, because carcass counts were only available from two years (1991 & 1992). When we tested for differences in run timing between oiled and reference streams using carcass counts there were no differences in both years. But, when run timing was calculated using live counts (*E75*), there was a difference in 1992 but not in 1991. These contradictory results suggest that *E75* may have provided a biased measure of spawn timing in 1992. In 1991, the only other year when sufficient data were available for a more powerful test, embryo mortality was still marginally significantly greater in oiled than in reference streams when *Day75* was included as a covariate (Table 2). The power of our statistical tests using *Day75* was substantially reduced in all other years due to lack of sufficient run timing data for all streams. However, when we pooled the data across all years, the covariate *Day75* was statistically significant, and the parameter estimate indicated that mortality declined as the value of *Day75* increased. This result was consistent with an effect of sampling-induced mechanical shock suggesting that our results may have been affected by sampling date. But, questions regarding the usefulness of *Day75* as a measure of embryo sensitivity to mechanical shock in specific years and lack of sufficient run timing data in most years leaves us unable to conclusively determine the magnitude of the effect.

Elevated embryo mortalities observed in oil-contaminated streams in 1997 may have resulted from a minor shift in the location of stream deltas or sampling induced mechanical shock. Differences in embryo mortality observed in 1997 were largely driven by elevated mortalities in 3 of the most heavily oiled streams included in this study. A minor shift in the location of stream deltas, a common occurrence in PWS, may have brought embryos incubating in these streams within closer proximity to weathered deposits of oil. However, lacking any data on PAH concentrations in embryo tissues or stream sediments, we cannot conclusively determine whether the elevated mortalities observed in these oiled study streams were caused by exposure to hydrocarbons. Embryos may have also been more sensitive to sampling-induced mechanical shock in 1997, because our field sampling was conducted relatively early in the season that year (Fig. 4). But, we do not have sufficient run timing data to determine if this effect can account for the differences in embryo mortality observed between oiled and reference streams in 1997 or any other specific year.

CONCLUSIONS

1. Our statistical analyses of embryo mortality data indicate that oiling was associated with elevated mortality although sampling time may have also affected our results. Our analysis using *Sample Date* as a covariate supported the conclusion that sampling-induced mechanical shock to embryos did not substantially affect our results. However, using *Day75* as a covariate and pooling data across all years, results were consistent with an effect of sampling-induced mechanical shock suggesting that our tests for oiling effects may have been affected by sampling date. But, questions regarding the usefulness of *Day75* as a measure of embryo sensitivity to mechanical shock in specific years and lack of sufficient run timing data in most years leaves us unable to conclusively determine the magnitude of the effect.

2. Pink salmon embryo mortalities were significantly greater in oiled than in reference streams during 1989-1993. Results from controlled incubation studies conducted in 1993 and 1994 were consistent with results obtained from field sampling indicating that natural environmental differences between oiled and reference streams did not cause differences in embryo mortality observed from 1989 through 1993. From 1994 through 1996, embryo mortalities were not significantly different between oiled and reference streams. In 1997,

embryo mortalities were again significantly greater in oiled than in reference streams. Elevated embryo mortalities observed in oil-contaminated streams in 1997 may have resulted from a minor shift in the location of stream deltas or sampling induced mechanical shock.

ACKNOWLEDGMENTS

We would like to thank the staff of the Alaska Department of Fish and Game who endured difficult field conditions to obtain the samples needed for this study. This project would not have been possible without the assistance, and expertise of the captain and crew of the R/V Montague.

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Appendix A. Summary of pink and chum salmon egg dig data from Prince William Sound, 1989-1997.

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
480	Mink Creek	1	27-Sep-89	2.13	20	71	1169	1	0	14
			27-Sep-89	2.74	30	160	1138	0	0	14
			28-Sep-89	3.35	40	98	2597	0	1	14
			28-Sep-89	6.1	60	85	1311	0	2	14
485	W. Finger Creek	1	28-Sep-89	2.13	20	0	0	0	0	14
			28-Sep-89	2.74	30	52	656	0	0	14
			28-Sep-89	3.35	40	13	3026	0	0	14
			28-Sep-89	6.1	60	65	2772	0	5	14
498	McClure Creek	1	29-Sep-89	2.13	20	317	1355	0	1	14
			28-Sep-89	2.74	30	484	3119	0	1	14
			28-Sep-89	3.35	40	843	6625	0	210	14
			28-Sep-89	6.1	60	61	1174	0	0	14
506	Loomis Creek	2	30-Sep-89	2.13	20	1094	2369	0	2	14
			30-Sep-89	2.74	30	2474	2929	0	0	14
			30-Sep-89	3.35	40	1591	7250	0	0	14
			30-Sep-89	6.1	60	360	1688	0	0	7
604	Erb Creek	1	02-Oct-89	2.13	20	57	999	0	18	14
			02-Oct-89	2.74	30	83	1181	0	0	14
			02-Oct-89	3.35	40	842	2407	0	18	14
			02-Oct-89	6.1	60	164	1876	0	95	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
618	Junction Creek	2	02-Oct-89	2.13	20	422	1507	0	0	12
			02-Oct-89	2.74	30	274	1669	0	0	12
			02-Oct-89	3.35	40	305	1266	0	0	12
			30-Sep-89	6.1	60	78	946	0	0	12
621	Totemoff Creek	1	02-Oct-89	2.13	20	126	140	0	2	14
			02-Oct-89	2.74	30	242	2136	0	16	14
			02-Oct-89	3.35	40	828	2732	0	176	14
			02-Oct-89	6.1	60	432	788	0	3	14
623	Brizgaloff Creek	1	03-Oct-89	2.13	20	13	507	0	1	14
			03-Oct-89	2.74	30	47	1960	0	0	14
			03-Oct-89	3.35	40	1083	2760	0	191	14
			03-Oct-89	6.1	60	1567	4335	0	59	14
628	Chenega NE	2	30-Sep-89	2.13	20	468	1898	0	0	14
			30-Sep-89	2.74	30	516	1687	0	1	14
			30-Sep-89	3.35	40	544	2814	0	0	14
			30-Sep-89	6.1	43 and 63	1509	7264	0	50	28
630	Bainbridge Creek	1	03-Oct-89	2.13	20	1	206	0	0	14
			03-Oct-89	2.74	30	180	973	0	1	14
			03-Oct-89	3.35	40	159	3469	0	184	14
			03-Oct-89	6.1	60	725	5215	0	18	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
632	Claw Creek	1	04-Oct-89	2.13	20	10	294	0	0	14
			04-Oct-89	2.74	30 and 33	58	430	0	0	19
			03-Oct-89	3.35	40	146	6993	0	16	14
			03-Oct-89	6.1	60	67	1914	0	0	14
637	Pt. Countess	2	04-Oct-89	2.13	20	1814	1429	0	0	14
			04-Oct-89	2.74	30	170	1828	0	0	14
			04-Oct-89	3.35	41 and 42	762	4542	0	0	14
			04-Oct-89	6.1	61 and 62	457	3491	0	0	14
653	Hogg Creek	1	26-Oct-89	2.13	20	10	1783	0	0	14
			05-Oct-89	2.74	31 and 32	36	1103	0	0	14
			04-Oct-89	3.35	40	20	2153	9	0	14
			04-Oct-89	6.1	60	68	1952	0	4	14
656	Halverson Creek	1	05-Oct-89	2.13	20	75	373	0	0	14
			05-Oct-89	2.74	30	737	1973	0	3	14
			05-Oct-89	3.35	40	600	3731	0	26	14
			05-Oct-89	6.1	60	296	5459	0	180	14
663	Shelter Bay	2	09-Oct-89	2.13	20	19	771	0	0	14
			09-Oct-89	2.74	30 and 33	93	1113	0	0	13
			05-Oct-89	3.35	40	1128	4315	0	0	12
			05-Oct-89	6.1	60	250	2149	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
665	Bjorne Creek	2	10-Oct-89	2.13	20	408	2359	0	0	14
			09-Oct-89	2.74	30	1147	3940	0	0	14
			10-Oct-89	3.35	41 and 42	481	1197	0	0	14
			10-Oct-89	6.1	60	554	4971	0	0	14
666	O'Brien Creek	1	10-Oct-89	2.13	20 and 23	258	1365	0	0	26
			10-Oct-89	2.74	30	175	2655	0	0	14
			11-Oct-89	3.35	40	223	3529	0	1	14
			11-Oct-89	6.1	60 and 63	423	1805	0	0	14
673	Falls Creek	1	10-Oct-89	2.13	21 and 22	56	1144	0	1	22
			10-Oct-89	2.74	30	53	2089	0	31	14
			10-Oct-89	3.35	40	80	1345	0	10	14
			10-Oct-89	6.1	60	29	1757	0	1	14
677	Hayden Creek	2	10-Oct-89	2.13	21 and 22	178	1928	0	1	14
			09-Oct-89	2.74	31 and 32	115	1461	0	7	14
			09-Oct-89	3.35	41 and 42	110	360	0	0	14
			09-Oct-89	6.1	61 and 62	30	161	0	0	14
678	Sleepy Bay	2	09-Oct-89	2.13	20	13	381	0	0	12
			09-Oct-89	2.74	30	111	956	0	0	12
			09-Oct-89	3.35	40	231	1770	0	0	12
			08-Oct-89	6.1	60	316	901	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
681	Hogan Bay	1	11-Oct-89	2.13	20	186	2178	0	0	14
			11-Oct-89	2.74	31 and 32	573	3720	0	0	14
			11-Oct-89	3.35	40	960	8167	0	1	14
			11-Oct-89	6.1	60	93	1290	0	1	14
682	Snug Harbor	2	11-Oct-89	2.13	20	350	1644	0	0	12
			12-Oct-89	2.74	30	1000	2658	0	31	14
			12-Oct-89	3.35	40	477	4582	0	27	14
			12-Oct-89	6.1	60	134	1000	0	8	14
692	Herring Bay	2	29-Sep-89	2.13	20	286	1887	0	0	14
			29-Sep-89	2.74	30	1163	2619	0	0	14
			29-Sep-89	3.35	40	718	5044	0	0	14
			29-Sep-89	6.1	60	301	3841	0	0	14
695	Port Audrey	1	01-Oct-89	2.13	21 and 22	110	2246	0	21	14
			01-Oct-89	2.74	31 and 32	297	2094	0	0	14
			01-Oct-89	3.35	40	1015	3821	0	5	14
			01-Oct-89	6.1	60	94	1669	0	0	14
699	Cathead Bay	1	01-Oct-89	2.13	20	137	814	0	0	14
			01-Oct-89	2.74	30	88	691	2	0	14
			01-Oct-89	3.35	40	118	999	0	0	14
			01-Oct-89	6.1	60	59	737	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
480	Mink Creek	1	25-Sep-90	2.13	20	1441	3886	0	0	14
			25-Sep-90	2.74	30	450	3033	0	18	14
			25-Sep-90	3.35	40	417	1979	0	70	14
			26-Sep-90	6.1	60	350	3595	0	7	14
485	W. Finger Creek	1	26-Sep-90	2.13	20	89	1694	0	0	14
			26-Sep-90	2.74	30	138	3827	0	158	14
			26-Sep-90	3.35	40	302	4131	0	14	14
			26-Sep-90	6.1	60	710	2588	0	16	14
498	McClure Creek	1	25-Sep-90	2.13	20	1769	1937	0	0	14
			25-Sep-90	2.74	30	3396	3460	0	7	14
			25-Sep-90	3.35	40	3480	5665	0	28	14
			25-Sep-90	6.1	60	469	2702	0	0	14
506	Loomis Creek	2	30-Sep-90	2.13	20	1245	3377	0	0	14
			30-Sep-90	2.74	30	4348	2627	0	1	14
			30-Sep-90	3.35	40	3283	1350	0	0	14
			30-Sep-90	6.1	60	1914	2487	0	0	14
604	Erb Creek	1	02-Oct-90	2.13	20 and 23	461	1670	0	9	14
			28-Sep-90	2.74	30	2884	3930	0	1	14
			27-Sep-90	3.35	40	845	1662	0	2	14
			27-Sep-90	6.1	60	119	1302	0	1	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
618	Junction Creek	2	01-Oct-90	2.13	20	267	2268	0	0	12
			28-Sep-90	2.74	30	151	1446	0	0	12
			28-Sep-90	3.35	40	1539	974	0	0	12
			28-Sep-90	6.1	60	452	495	0	0	12
621	Totemoff Creek	1	02-Oct-90	2.13	20	3195	3843	52	16	14
			28-Sep-90	2.74	30	406	2494	0	7	14
			28-Sep-90	3.35	40	595	2673	0	290	14
			28-Sep-90	6.1	60	39	423	1	0	14
623	Brizgaloff Creek	1	02-Oct-90	2.13	20	1855	4747	0	1	14
			27-Sep-90	2.74	30	1749	1694	0	0	14
			27-Sep-90	3.35	40	2585	4331	0	0	14
			02-Oct-90	6.1	60	3301	4220	0	76	14
628	Chenega NE	2	01-Oct-90	2.13	20	169	276	0	0	14
			29-Sep-90	2.74	30	969	5465	0	0	14
			29-Sep-90	3.35	40	1507	2066	0	0	14
			01-Oct-90	6.1	60	989	7325	0	0	14
630	Bainbridge Creek	1	14-Oct-90	2.13	20	164	17	0	0	14
			14-Oct-90	2.74	30	780	3342	13	342	14
			14-Oct-90	3.35	40	622	8727	12	798	14
			14-Oct-90	6.1	60	817	7867	22	571	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
632	Claw Creek	1	14-Oct-90	2.13	20	67	1665	0	261	14
			14-Oct-90	2.74	30	263	4038	0	248	14
			14-Oct-90	3.35	40	260	7164	0	639	14
			14-Oct-90	6.1	60	0	0	0	1	7
637	Pt. Countess	2	03-Oct-90	2.13	20	1793	3324	0	0	14
			03-Oct-90	2.74	30	1400	4349	0	37	14
			03-Oct-90	3.35	41	1777	3321	0	8	14
			03-Oct-90	6.1	61 and 62	619	2800	0	7	14
653	Hogg Creek	1	15-Oct-90	2.13	20	132	2044	0	185	14
			15-Oct-90	2.74	31 and 32	35	847	0	2	14
			15-Oct-90	3.35	40	35	2553	0	299	14
			15-Oct-90	6.1	60	517	1795	0	14	14
656	Halverson Creek	1	15-Oct-90	2.13	20	100	774	0	75	14
			15-Oct-90	2.74	30	223	1473	0	1467	14
			15-Oct-90	3.35	40	590	5282	0	659	14
			15-Oct-90	6.1	60	1282	4639	0	879	14
663	Shelter Bay	2	13-Oct-90	2.13	20	81	1223	0	0	12
			13-Oct-90	2.74	30	291	2287	0	0	12
			13-Oct-90	3.35	40	629	3597	0	0	12
			13-Oct-90	6.1	60	148	1026	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
665	Bjorne Creek	2	04-Oct-90	2.13	20	697	1255	0	0	14
			04-Oct-90	2.74	30	1957	2038	0	0	14
			04-Oct-90	3.35	40	1820	1718	0	16	14
			04-Oct-90	6.1	60	1357	2271	0	0	14
666	O'Brien Creek	1	11-Oct-90	2.13	20	177	1275	0	0	14
			11-Oct-90	2.74	30	88	1239	0	4	14
			11-Oct-90	3.35	40	675	3579	0	118	14
			11-Oct-90	6.1	60	645	1607	0	1	14
673	Falls Creek	1	12-Oct-90	2.13	20	57	1299	0	183	14
			12-Oct-90	2.74	30	204	4995	0	1399	14
			12-Oct-90	3.35	40	98	843	0	85	14
			12-Oct-90	6.1	60	63	489	0	122	14
677	Hayden Creek	2	12-Oct-90	2.13	21 and 22	76	440	0	47	14
			12-Oct-90	2.74	31 and 32	337	3174	0	347	14
			12-Oct-90	3.35	41	293	1049	0	0	7
			12-Oct-90	6.1	61 and 62	461	1450	0	61	14
678	Sleepy Bay	2	03-Oct-90	2.13	20	37	462	0	0	12
			03-Oct-90	2.74	30	117	141	0	0	12
			03-Oct-90	3.35	40	574	433	0	0	12
			03-Oct-90	6.1	60	131	827	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
681	Hogan Bay	1	16-Oct-90	2.13	20	60	201	0	1	14
			13-Oct-90	2.74	30	33	9	0	0	14
			13-Oct-90	3.35	40	207	1303	0	7	14
			13-Oct-90	6.1	60	159	1489	0	10	14
682	Snug Harbor	2	16-Oct-90	2.13	20	1218	1438	0	234	14
			16-Oct-90	2.74	30	2208	2908	0	63	14
			16-Oct-90	3.35	40	1289	5018	0	894	14
			16-Oct-90	6.1	60	616	4667	3	1042	14
692	Herring Bay	2	30-Sep-90	2.13	20	394	954	0	0	14
			30-Sep-90	2.74	30	629	1563	0	1	14
			30-Sep-90	3.35	40	1089	3150	0	0	14
			30-Sep-90	6.1	60	564	1796	0	0	14
695	Port Audrey	1	29-Sep-90	2.13	21 and 22	202	1653	4	30	14
			29-Sep-90	2.74	30	1863	2279	0	6	14
			29-Sep-90	3.35	40	908	1578	0	14	14
			29-Sep-90	6.1	60	490	2434	1	9	14
699	Cathead Bay	1	01-Oct-90	2.13	20	381	3043	0	39	14
			01-Oct-90	2.74	30	153	3160	0	3	14
			01-Oct-90	3.35	40	183	2071	0	0	14
			01-Oct-90	6.1	60	156	2437	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
480	Mink Creek	1	09-Oct-91	2.13	20	46	726	0	0	14
			09-Oct-91	2.74	30	126	1880	0	2	14
			09-Oct-91	3.35	41 and 42	203	1852	3	201	14
			09-Oct-91	6.1	60	60	2291	0	0	14
485	W. Finger Creek	1	08-Oct-91	2.13	20	0	15	0	0	14
			08-Oct-91	2.74	30	172	5346	0	1	14
			08-Oct-91	3.35	40	94	5546	3	10	14
			08-Oct-91	6.1	60	126	3855	0	1	14
498	McClure Creek	1	08-Oct-91	2.13	20	402	1452	0	0	14
			08-Oct-91	2.74	30	813	4375	0	3	14
			08-Oct-91	3.35	40	681	4695	0	193	14
			08-Oct-91	6.1	60	3238	5242	0	1	14
506	Loomis Creek	2	09-Oct-91	2.13	20	520	830	0	0	14
			09-Oct-91	2.74	30	1299	2064	0	0	14
			09-Oct-91	3.35	40	2300	2150	0	0	14
			09-Oct-91	6.1	60	557	1978	0	1	14
604	Erb Creek	1	10-Oct-91	2.13	20	222	3641	0	31	14
			10-Oct-91	2.74	30	1825	6606	0	1	14
			10-Oct-91	3.35	40	167	2633	0	0	14
			10-Oct-91	6.1	60	252	3688	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
618	Junction Creek	2	01-Oct-91	2.13	20	28	9	0	0	12
			01-Oct-91	2.74	30	486	690	0	0	12
			01-Oct-91	3.35	40	822	1855	0	0	12
			01-Oct-91	6.1	60	189	499	0	0	12
621	Totemoff Creek	1	10-Oct-91	2.13	20	3892	4286	0	1	14
			10-Oct-91	2.74	30	885	2166	0	2	14
			10-Oct-91	3.35	40	2065	5026	4	451	14
			10-Oct-91	6.1	60	648	4406	0	154	14
623	Brizgaloff Creek	1	11-Oct-91	2.13	20	797	608	0	0	14
			11-Oct-91	2.74	30	820	2824	0	0	14
			11-Oct-91	3.35	40	1926	3119	0	0	14
			11-Oct-91	6.1	60	2682	9093	0	56	14
628	Chenega NE	2	01-Oct-91	2.13	20	437	1169	0	1	14
			01-Oct-91	2.74	30	907	3979	0	0	14
			01-Oct-91	3.35	40	1087	3910	0	4	14
			30-Sep-91	6.1	60	1059	6564	0	0	14
630	Bainbridge Creek	1	11-Oct-91	2.13	20	773	1010	0	0	14
			11-Oct-91	2.74	30	1632	4896	0	0	14
			11-Oct-91	3.35	40	1440	8924	0	210	14
			11-Oct-91	6.1	60	1931	6384	0	125	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
632	Claw Creek	1	30-Sep-91	2.13	20	301	2600	0	0	14
			30-Sep-91	2.74	30	117	2145	0	0	14
			30-Sep-91	3.35	40	497	6728	0	0	14
			11-Oct-91	6.1	60	17	438	0	0	7
637	Pt. Countess	2	30-Sep-91	2.13	20	975	1143	0	0	14
			30-Sep-91	2.74	30	757	2619	0	0	14
			29-Sep-91	3.35	41 and 42	718	1892	0	0	14
			29-Sep-91	6.1	61 and 62	519	2281	0	0	14
653	Hogg Creek	1	12-Oct-91	2.13	20	702	4657	0	0	14
			28-Sep-91	2.74	31 and 32	128	491	0	0	14
			28-Sep-91	3.35	40	321	4439	0	0	14
			28-Sep-91	6.1	60	546	3876	0	0	14
656	Halverson Creek	1	30-Sep-91	2.13	20	91	2726	0	0	14
			29-Sep-91	2.74	30	518	886	0	0	14
			29-Sep-91	3.35	40	1383	2360	0	0	14
			29-Sep-91	6.1	60	858	4405	0	0	14
663	Shelter Bay	2	27-Sep-91	2.13	20	10	6	0	0	12
			27-Sep-91	2.74	30	474	155	0	0	12
			27-Sep-91	3.35	40	3528	1941	0	0	12
			27-Sep-91	6.1	60	718	957	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
665	Bjorne Creek	2	27-Sep-91	2.13	20	316	116	0	0	14
			27-Sep-91	2.74	30	1610	188	0	0	14
			27-Sep-91	3.35	40	2738	941	0	0	14
			27-Sep-91	6.1	60	3942	2060	0	0	14
666	O'Brien Creek	1	28-Sep-91	2.13	20	145	51	0	0	14
			28-Sep-91	2.74	30	508	451	0	0	14
			28-Sep-91	3.35	40	272	960	0	0	14
			28-Sep-91	6.1	60	1037	2395	0	0	14
673	Falls Creek	1	28-Sep-91	2.13	20	918	3417	0	0	14
			28-Sep-91	2.74	30	1967	4095	0	0	14
			28-Sep-91	3.35	40	1810	6742	0	0	14
			28-Sep-91	6.1	60	1254	5683	0	0	14
677	Hayden Creek	2	12-Oct-91	2.13	21 and 22	468	3365	0	14	14
			12-Oct-91	2.74	31 and 32	722	2842	0	2	14
			12-Oct-91	3.35	41 and 42	906	2927	0	0	14
			12-Oct-91	6.1	61 and 62	952	2438	0	0	14
678	Sleepy Bay	2	25-Sep-91	2.13	20	199	182	0	0	12
			25-Sep-91	2.74	30	1264	1245	0	0	12
			25-Sep-91	3.35	40	1335	688	0	0	12
			25-Sep-91	6.1	60	1510	1027	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
681	Hogan Bay	1	27-Sep-91	2.13	20	925	877	0	0	14
			27-Sep-91	2.74	30	1091	994	0	0	14
			27-Sep-91	3.35	40	3367	4681	0	0	14
			27-Sep-91	6.1	60	1340	1356	0	0	14
682	Snug Harbor	2	26-Sep-91	2.13	20	1957	1073	0	5	14
			26-Sep-91	2.74	30	3663	3049	0	0	14
			26-Sep-91	3.35	40	1677	1357	0	0	14
			26-Sep-91	6.1	60	5256	3624	0	0	14
692	Herring Bay	2	07-Oct-91	2.13	20	1039	1864	0	0	14
			07-Oct-91	2.74	30	2336	3971	0	0	14
			07-Oct-91	3.35	40	1084	3445	0	0	14
			07-Oct-91	6.1	60	748	3081	0	0	14
695	Port Audrey	1	02-Oct-91	2.13	20	286	1866	0	3	14
			02-Oct-91	2.74	31 and 32	419	1579	0	0	14
			02-Oct-91	3.35	40	250	1620	0	7	14
			02-Oct-91	6.1	60	170	1719	0	0	14
699	Cathead Bay	1	02-Oct-91	2.13	20	1781	2750	0	0	14
			02-Oct-91	2.74	30	584	2226	0	0	14
			01-Oct-91	3.35	40	654	1719	0	0	14
			01-Oct-91	6.1	60	679	2744	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
480	Mink Creek	1	22-Sep-92	2.13	20	126	1568	0	0	14
			22-Sep-92	2.74	30	807	3767	0	2	14
			22-Sep-92	3.35	41 and 42	590	2978	0	0	14
			22-Sep-92	6.1	60	146	1242	0	0	14
485	W. Finger Creek	1	22-Sep-92	2.13	20	37	1106	0	0	14
			22-Sep-92	2.74	30	162	1073	0	0	14
			22-Sep-92	3.35	40	707	3447	0	0	14
			22-Sep-92	6.1	60	717	2489	0	0	14
498	McClure Creek	1	22-Sep-92	2.13	20	185	1237	0	0	14
			22-Sep-92	2.74	30	249	1384	0	0	14
			22-Sep-92	3.35	40	1393	4460	0	2	14
			22-Sep-92	6.1	60	263	3500	0	0	14
506	Loomis Creek	2	24-Sep-92	2.13	20	1419	2873	0	0	14
			24-Sep-92	2.74	30	1514	2061	0	0	14
			24-Sep-92	3.35	40	3463	1732	0	0	14
			24-Sep-92	6.1	60	3760	1121	0	0	14
604	Erb Creek	1	27-Sep-92	2.13	20	528	3973	0	0	14
			27-Sep-92	2.74	30	773	4101	0	1	14
			27-Sep-92	3.35	40	832	2195	0	0	14
			27-Sep-92	6.1	60	46	104	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
618	Junction Creek	2	23-Sep-92	2.13	20	1	0	0	0	12
			23-Sep-92	2.74	30	11	13	0	0	12
			23-Sep-92	3.35	40	472	226	0	0	12
			23-Sep-92	6.1	60	70	147	0	0	12
621	Totemoff Creek	1	27-Sep-92	2.13	20	904	2698	0	42	14
			27-Sep-92	2.74	30	70	1686	0	7	14
			27-Sep-92	3.35	40	364	3553	7	408	14
			27-Sep-92	6.1	60	701	1090	0	2	14
623	Brizgaloff Creek	1	27-Sep-92	2.13	20	199	1716	0	0	14
			27-Sep-92	2.74	30	531	1127	0	0	14
			27-Sep-92	3.35	40	78	557	0	0	14
			27-Sep-92	6.1	60	834	3583	0	6	14
628	Chenega NE	2	23-Sep-92	2.13	20	1319	3067	0	2	14
			23-Sep-92	2.74	30	1613	3097	0	0	14
			23-Sep-92	3.35	40	360	1538	0	0	14
			23-Sep-92	6.1	60	343	2931	0	0	14
630	Bainbridge Creek	1	28-Sep-92	2.13	20	156	380	0	1	14
			28-Sep-92	2.74	30	337	2078	0	1	14
			28-Sep-92	3.35	40	491	5073	0	4	14
			28-Sep-92	6.1	60	719	6898	0	11	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
632	Claw Creek	1	28-Sep-92	2.13	20	117	2100	0	1	14
			28-Sep-92	2.74	30	1027	1832	0	0	14
			28-Sep-92	3.35	40	1496	2742	0	0	14
			28-Sep-92	6.1	60	34	197	0	0	7
637	Pt. Countess	2	26-Sep-92	2.13	20	1326	1489	0	0	14
			26-Sep-92	2.74	30	377	3152	0	0	14
			26-Sep-92	3.35	41 and 42	169	944	0	1	14
			26-Sep-92	6.1	61 and 62	124	103	0	0	14
653	Hogg Creek	1	26-Sep-92	2.13	20	82	488	0	0	14
			26-Sep-92	2.74	31 and 32	15	1	0	0	14
			26-Sep-92	3.35	40	309	386	0	0	14
			26-Sep-92	6.1	60	1116	1469	0	0	14
656	Halverson Creek	1	26-Sep-92	2.13	20	91	1500	0	0	14
			26-Sep-92	2.74	30	1202	5088	0	0	14
			26-Sep-92	3.35	40	9299	3145	0	0	14
			26-Sep-92	6.1	60	1087	1126	0	2	14
663	Shelter Bay	2	25-Sep-92	2.13	20	99	737	0	0	12
			25-Sep-92	2.74	30	271	129	0	0	12
			25-Sep-92	3.35	40	187	1217	0	0	12
			25-Sep-92	6.1	60	382	536	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
665	Bjorne Creek	2	21-Sep-92	2.13	20	847	17	0	0	14
			21-Sep-92	2.74	30	3233	456	0	0	14
			21-Sep-92	3.35	40	2375	1035	0	0	14
			21-Sep-92	6.1	60	2223	512	0	0	14
666	O'Brien Creek	1	25-Sep-92	2.13	20	345	286	0	0	14
			25-Sep-92	2.74	30	365	571	0	0	14
			25-Sep-92	3.35	40	134	990	0	0	14
			25-Sep-92	6.1	60	610	1398	0	0	14
673	Falls Creek	1	25-Sep-92	2.13	20	65	1698	0	0	14
			25-Sep-92	2.74	30	155	208	0	0	14
			25-Sep-92	3.35	40	47	1632	0	0	14
			25-Sep-92	6.1	60	1581	240	0	0	14
677	Hayden Creek	2	21-Sep-92	2.13	21 and 22	246	452	0	0	14
			21-Sep-92	2.74	31 and 32	80	579	0	2	14
			21-Sep-92	3.35	41 and 42	422	859	0	0	14
			21-Sep-92	6.1	61 and 62	28	85	0	0	14
678	Sleepy Bay	2	21-Sep-92	2.13	20	449	685	0	0	12
			21-Sep-92	2.74	30	409	27	0	0	12
			21-Sep-92	3.35	40	382	25	0	0	12
			21-Sep-92	6.1	60	215	3	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
681	Hogan Bay	1	28-Sep-92	2.13	20	347	1805	0	0	14
			28-Sep-92	2.74	30	3293	1405	0	0	14
			28-Sep-92	3.35	40	2237	3910	0	0	14
			28-Sep-92	6.1	60	972	1848	0	0	14
682	Snug Harbor	2	29-Sep-92	2.13	20	1240	2991	0	4	14
			29-Sep-92	2.74	30	1349	4114	0	3	14
			29-Sep-92	3.35	40	1718	2840	0	1	14
			29-Sep-92	6.1	60	2138	4482	0	0	14
692	Herring Bay	2	23-Sep-92	2.13	20	33	356	0	0	14
			23-Sep-92	2.74	30	108	307	0	0	14
			23-Sep-92	3.35	40	88	590	0	0	14
			23-Sep-92	6.1	60	146	314	0	0	14
695	Port Audrey	1	24-Sep-92	2.13	20	204	1231	0	0	14
			24-Sep-92	2.74	31 and 32	1181	2226	0	0	14
			24-Sep-92	3.35	40	934	2840	0	7	14
			24-Sep-92	6.1	60	1680	3379	0	0	14
699	Cathead Bay	1	24-Sep-92	2.13	20	1368	2386	0	0	14
			24-Sep-92	2.74	30	101	939	0	0	14
			24-Sep-92	3.35	40	142	1251	0	0	14
			24-Sep-92	6.1	60	277	3811	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
480	Mink Creek	1	02-Oct-93	2.13	20	43	1217	0	1	14
			02-Oct-93	2.74	30	403	3384	0	38	14
			02-Oct-93	3.35	40	594	3177	2	532	14
			02-Oct-93	6.1	60	220	3272	0	128	14
485	W. Finger Creek	1	30-Sep-93	2.13	20	0	3	0	0	14
			01-Oct-93	2.74	30	134	564	0	386	14
			01-Oct-93	3.35	40	64	424	16	394	14
			01-Oct-93	6.1	60	56	2223	0	35	14
498	McClure Creek	1	01-Oct-93	2.13	20	99	2366	0	0	14
			01-Oct-93	2.74	30	1246	3439	0	27	14
			01-Oct-93	3.35	40	1610	7909	6	449	14
			01-Oct-93	6.1	60	440	2239	0	0	14
506	Loomis Creek	2	02-Oct-93	2.13	20	1748	4451	0	0	14
			02-Oct-93	2.74	30	3371	6075	0	4	14
			02-Oct-93	3.35	40	4278	2902	0	0	14
			02-Oct-93	6.1	60	1043	4985	0	0	14
604	Erb Creek	1	04-Oct-93	2.13	20 and 23	300	2748	0	0	14
			04-Oct-93	2.74	30	42	683	0	0	14
			04-Oct-93	3.35	40	547	2747	0	0	14
			04-Oct-93	6.1	60	3	2449	0	47	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
618	Junction Creek	2	03-Oct-93	2.13	20	1	1	0	0	12
			03-Oct-93	2.74	30	59	166	0	0	12
			03-Oct-93	3.35	40	314	2728	0	1	12
			03-Oct-93	6.1	60	34	1004	0	0	12
621	Totemoff Creek	1	04-Oct-93	2.13	20	1570	4888	0	0	14
			04-Oct-93	2.74	30	258	2455	0	0	14
			04-Oct-93	3.35	40	727	4627	0	0	14
			04-Oct-93	6.1	60	606	4309	0	0	14
623	Brizgaloff Creek	1	04-Oct-93	2.13	20	194	960	0	0	14
			04-Oct-93	2.74	30	316	2725	0	0	14
			04-Oct-93	3.35	40	475	621	0	1	14
			04-Oct-93	6.1	60	721	4545	0	17	14
628	Chenega NE	2	03-Oct-93	2.13	20	96	169	0	0	14
			03-Oct-93	2.74	30	426	6277	0	0	14
			03-Oct-93	3.35	40	660	6856	0	0	14
			03-Oct-93	6.1	60	763	6738	0	4	14
630	Bainbridge Creek	1	14-Oct-93	2.13	20	196	159	0	0	14
			14-Oct-93	2.74	30	535	2772	0	165	14
			14-Oct-93	3.35	40	497	6918	0	1322	14
			14-Oct-93	6.1	60	542	4619	0	726	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
632	Claw Creek	1	14-Oct-93	2.13	20	44	817	0	3	14
			14-Oct-93	2.74	30	27	801	0	213	14
			14-Oct-93	3.35	40	721	6189	0	1498	14
			14-Oct-93	6.1	60	3	531	0	1	7
637	Pt. Countess	2	13-Oct-93	2.13	20	1311	4637	0	0	14
			14-Oct-93	2.74	30	969	4673	0	0	14
			14-Oct-93	3.35	41 and 42	472	3827	0	0	14
			14-Oct-93	6.1	61 and 62	1171	4813	0	0	14
653	Hogg Creek	1	13-Oct-93	2.13	20	306	2087	0	0	14
			13-Oct-93	2.74	31 and 32	104	2311	0	0	14
			13-Oct-93	3.35	40	221	4160	1	204	14
			13-Oct-93	6.1	60	545	3540	0	3	14
656	Halverson Creek	1	13-Oct-93	2.13	20	95	1675	0	0	14
			13-Oct-93	2.74	30	5	171	0	3	14
			13-Oct-93	3.35	40	215	3438	0	199	14
			13-Oct-93	6.1	60	510	5164	0	5	14
663	Shelter Bay	2	11-Oct-93	2.13	20	0	1	0	0	12
			11-Oct-93	2.74	30	6	13	0	0	12
			11-Oct-93	3.35	40	303	924	0	0	12
			11-Oct-93	6.1	60	5	19	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
665	Bjorne Creek	2	11-Oct-93	2.13	20	289	337	0	0	14
			11-Oct-93	2.74	30	46	116	0	0	14
			11-Oct-93	3.35	40	479	3121	0	0	14
			11-Oct-93	6.1	60	795	9312	0	0	14
666	O'Brien Creek	1	11-Oct-93	2.13	20	0	0	0	0	14
			11-Oct-93	2.74	30	3	3	0	0	14
			11-Oct-93	3.35	40	238	1134	0	0	14
			11-Oct-93	6.1	60	55	1119	0	0	14
673	Falls Creek	1	12-Oct-93	2.13	20	41	634	0	0	14
			12-Oct-93	2.74	30	391	1759	0	0	14
			12-Oct-93	3.35	40	17	167	0	0	14
			12-Oct-93	6.1	60	2	6	0	0	14
677	Hayden Creek	2	11-Oct-93	2.13	21 and 22	270	2075	0	0	14
			11-Oct-93	2.74	31 and 32	196	1218	0	0	14
			12-Oct-93	3.35	41 and 42	39	160	0	0	14
			12-Oct-93	6.1	61 and 62	3	30	0	0	14
678	Sleepy Bay	2	11-Oct-93	2.13	20	3	0	0	0	12
			11-Oct-93	2.74	30	46	237	0	0	12
			11-Oct-93	3.35	40	39	824	0	0	12
			11-Oct-93	6.1	60	22	199	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
681	Hogan Bay	1	08-Oct-93	2.13	20	254	1050	0	0	14
			08-Oct-93	2.74	30	1045	4719	0	0	14
			08-Oct-93	3.35	40	1510	6655	0	0	14
			08-Oct-93	6.1	60	400	2159	0	0	14
682	Snug Harbor	2	08-Oct-93	2.13	20	987	1832	0	0	14
			08-Oct-93	2.74	30	1437	4239	0	8	14
			06-Oct-93	3.35	40	1745	7888	2	79	14
			06-Oct-93	6.1	60	2174	11094	0	89	14
692	Herring Bay	2	05-Oct-93	2.13	20	189	640	0	0	14
			05-Oct-93	2.74	30	1490	3745	0	0	14
			05-Oct-93	3.35	40	766	3769	0	0	14
			05-Oct-93	6.1	60	836	4685	0	0	14
695	Port Audrey	1	06-Oct-93	2.13	21 and 22	311	2006	0	0	14
			06-Oct-93	2.74	30	1038	5858	0	0	14
			06-Oct-93	3.35	40	796	3219	0	2	14
			05-Oct-93	6.1	60	235	2413	0	0	14
699	Cathead Bay	1	06-Oct-93	2.13	20	731	4063	0	0	14
			06-Oct-93	2.74	30	650	3821	0	0	14
			05-Oct-93	3.35	40	288	574	0	0	14
			05-Oct-93	6.1	60	188	1467	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
480	Mink Creek	1	01-Oct-94	2.13	20	2308	412	0	0	14
			01-Oct-94	2.74	30	6911	1088	0	0	14
			01-Oct-94	3.35	40	4748	1781	0	1	14
			01-Oct-94	6.1	60	2017	3078	1	12	14
485	W. Finger Creek	1	30-Sep-94	2.13	20	1249	1823	0	0	14
			30-Sep-94	2.74	30	2119	3431	0	0	14
			30-Sep-94	3.35	40	1320	5531	57	139	14
			30-Sep-94	6.1	60	5554	9698	27	158	14
498	McClure Creek	1	09-Oct-94	2.13	20	4308	286	0	7	14
			30-Sep-94	2.74	30	5574	2215	0	1	14
			30-Sep-94	3.35	40	9267	4531	0	65	14
			30-Sep-94	6.1	60	5342	4503	4	192	14
506	Loomis Creek	2	04-Oct-94	2.13	20	1347	239	0	0	14
			04-Oct-94	2.74	30	2330	616	0	0	14
			04-Oct-94	3.35	40	1915	529	0	0	14
			04-Oct-94	6.1	60	3106	921	0	0	14
604	Erb Creek	1	03-Oct-94	2.13	20	986	1260	0	0	14
			03-Oct-94	2.74	30	2455	650	0	0	14
			03-Oct-94	3.35	40	735	1318	0	11	14
			03-Oct-94	6.1	60	478	829	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
618	Junction Creek	2	03-Oct-94	2.13	20	1	0	0	0	12
			03-Oct-94	2.74	30	25	10	0	0	12
			03-Oct-94	3.35	40	106	294	0	0	12
			03-Oct-94	6.1	60	8	8	0	0	12
621	Totemoff Creek	1	02-Oct-94	2.13	20	3771	814	0	0	14
			02-Oct-94	2.74	30	977	201	0	0	14
			06-Oct-94	3.35	40	3277	2254	0	8	14
			06-Oct-94	6.1	60	7281	3337	0	28	14
623	Brizgaloff Creek	1	02-Oct-94	2.13	20	1394	714	0	0	14
			02-Oct-94	2.74	30	615	918	0	0	14
			02-Oct-94	3.35	40	962	923	0	0	14
			02-Oct-94	6.1	60	2511	1288	0	0	14
628	Chenega NE	2	04-Oct-94	2.13	20	107	21	0	0	14
			04-Oct-94	2.74	30	1656	718	0	0	14
			04-Oct-94	3.35	40	1034	1224	0	0	14
			04-Oct-94	6.1	60	360	994	0	1	14
630	Bainbridge Creek	1	11-Oct-94	2.13	20	1233	4	0	0	14
			13-Oct-94	2.74	30	6818	1792	0	0	14
			13-Oct-94	3.35	40	6209	9190	0	55	14
			13-Oct-94	6.1	60	2629	4814	0	338	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
632	Claw Creek	1	12-Oct-94	2.13	20	1644	5469	0	206	14
			12-Oct-94	2.74	30	766	4122	14	318	14
			12-Oct-94	3.35	40	2873	8510	0	61	14
			12-Oct-94	6.1	60	130	379	0	0	10
637	Pt. Countess	2	05-Oct-94	2.13	20	1442	655	0	0	14
			05-Oct-94	2.74	30	1748	605	0	0	14
			05-Oct-94	3.35	41 and 42	1295	137	0	0	14
			06-Oct-94	6.1	61 and 62	530	623	0	0	14
653	Hogg Creek	1	14-Oct-94	2.13	20	760	3751	0	434	14
			14-Oct-94	2.74	31 and 32	56	771	0	0	14
			14-Oct-94	3.35	40	193	2785	0	355	14
			14-Oct-94	6.1	60	187	970	0	41	14
656	Halverson Creek	1	13-Oct-94	2.13	20	1609	417	0	0	14
			13-Oct-94	2.74	30	665	407	0	0	14
			13-Oct-94	3.35	40	1822	1196	0	0	14
			13-Oct-94	6.1	60	1622	1653	0	0	14
663	Shelter Bay	2	12-Oct-94	2.13	20	351	13	0	1	12
			12-Oct-94	2.74	30	477	330	0	0	12
			12-Oct-94	3.35	40	432	1137	0	0	12
			12-Oct-94	6.1	60	1518	1219	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
665	Bjorne Creek	2	14-Oct-94	2.13	20	176	24	0	0	14
			14-Oct-94	2.74	30	168	53	0	0	14
			15-Oct-94	3.35	40	66	481	0	0	14
			15-Oct-94	6.1	60	215	1066	0	0	14
666	O'Brien Creek	1	15-Oct-94	2.13	20	0	0	0	0	14
			15-Oct-94	2.74	30	168	53	0	0	14
			15-Oct-94	3.35	40	66	481	0	0	14
			15-Oct-94	6.1	60	215	1066	0	0	14
673	Falls Creek	1	16-Oct-94	2.13	20	53	586	0	0	14
			16-Oct-94	2.74	30	31	149	0	1	14
			17-Oct-94	3.35	40	418	1182	0	32	14
			17-Oct-94	6.1	60	157	1127	0	0	14
677	Hayden Creek	2	16-Oct-94	2.13	21 and 22	91	872	0	0	14
			16-Oct-94	2.74	31 and 32	198	1517	0	23	14
			16-Oct-94	3.35	41 and 42	355	893	0	117	14
			16-Oct-94	6.1	61 and 62	146	262	0	0	14
678	Sleepy Bay	2	17-Oct-94	2.13	20	217	52	0	0	12
			17-Oct-94	2.74	30	455	945	0	0	12
			17-Oct-94	3.35	40	136	542	0	0	12
			17-Oct-94	6.1	60	99	592	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
681	Hogan Bay	1	10-Oct-94	2.13	20	1423	1133	0	2	14
			10-Oct-94	2.74	30	1292	2337	0	16	14
			10-Oct-94	3.35	40	4715	4065	0	54	14
			10-Oct-94	6.1	60	650	1103	0	1	14
682	Snug Harbor	2	10-Oct-94	2.13	20	4367	2131	0	20	14
			10-Oct-94	2.74	30	5913	2260	0	71	14
			10-Oct-94	3.35	40	4090	3331	0	662	14
			10-Oct-94	6.1	60	3814	3579	0	393	14
692	Herring Bay	2	01-Oct-94	2.13	20	293	597	0	0	14
			01-Oct-94	2.74	30	1496	185	0	0	14
			01-Oct-94	3.35	40	2332	1699	0	0	14
			01-Oct-94	6.1	60	815	1434	0	37	14
695	Port Audrey	1	05-Oct-94	2.13	21 and 22	937	429	0	0	14
			05-Oct-94	2.74	30	1112	2045	0	6	14
			05-Oct-94	3.35	40	1132	899	0	0	14
			05-Oct-94	6.1	60	878	677	0	3	14
699	Cathead Bay	1	04-Oct-94	2.13	20	477	16	0	0	14
			04-Oct-94	2.74	30	368	356	0	0	14
			04-Oct-94	3.35	40	43	1	0	0	14
			05-Oct-94	6.1	60	352	1341	0	101	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
480	Mink Creek	1	09-Oct-95	2.13	20	5	1	0	0	14
			09-Oct-95	2.74	30	127	1175	0	0	14
			09-Oct-95	3.35	40	50	371	0	0	14
			09-Oct-95	6.1	60	6	3	0	0	14
485	W. Finger Creek	1	08-Oct-95	2.13	20	5	373	0	0	14
			08-Oct-95	2.74	30	135	117	0	0	14
			08-Oct-95	3.35	40	234	3025	0	2	14
			08-Oct-95	6.1	60	198	4171	0	1	14
498	McClure Creek	1	08-Oct-95	2.13	20	221	1641	0	0	14
			08-Oct-95	2.74	30	1190	3543	0	0	14
			08-Oct-95	3.35	40	762	4581	0	2	14
			08-Oct-95	6.1	60	284	725	0	0	14
506	Loomis Creek	2	10-Oct-95	2.13	20	188	896	0	0	14
			10-Oct-95	2.74	30	1500	1866	0	0	14
			10-Oct-95	3.35	40	3364	1187	0	0	14
			09-Oct-95	6.1	60	622	768	0	0	14
604	Erb Creek	1	18-Oct-95	2.13	20 and 23	18	28	0	0	14
			18-Oct-95	2.74	30	1	3	0	0	14
			18-Oct-95	3.35	40	294	887	0	0	14
			18-Oct-95	6.1	60	5	38	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
618	Junction Creek	2	11-Oct-95	2.13	20	3	1	0	0	12
			11-Oct-95	2.74	30	5	0	0	0	12
			10-Oct-95	3.35	40	0	0	0	0	12
			10-Oct-95	6.1	60	7	24	0	0	12
621	Totemoff Creek	1	18-Oct-95	2.13	20	908	148	0	3	14
			17-Oct-95	2.74	30	404	894	0	4	14
			17-Oct-95	3.35	40	124	179	0	4	14
			17-Oct-95	6.1	60	1092	2015	0	180	14
623	Brizgaloff Creek	1	18-Oct-95	2.13	20	393	442	0	6	14
			17-Oct-95	2.74	30	179	704	0	2	14
			17-Oct-95	3.35	40	114	356	0	0	14
			17-Oct-95	6.1	60	2178	1217	0	3	14
628	Chenega NE	2	10-Oct-95	2.13	20	16	15	0	0	14
			10-Oct-95	2.74	30	93	246	0	0	14
			10-Oct-95	3.35	40	350	3271	0	0	14
			10-Oct-95	6.1	60	364	1397	0	0	14
630	Bainbridge Creek	1	13-Oct-95	2.13	20	3	2	0	0	14
			13-Oct-95	2.74	30	247	457	0	0	14
			12-Oct-95	3.35	40	581	1807	0	213	14
			12-Oct-95	6.1	60	556	3188	0	8	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
632	Claw Creek	1	12-Oct-95	2.13	20	6	6	0	0	14
			12-Oct-95	2.74	30	22	829	0	2	14
			12-Oct-95	3.35	40	493	3823	0	1	14
			12-Oct-95	6.1	60	3	221	0	0	10
637	Pt. Countess	2	12-Oct-95	2.13	20	1643	567	0	0	14
			12-Oct-95	2.74	30	672	282	0	0	14
			12-Oct-95	3.35	41 and 42	384	909	0	0	14
			12-Oct-95	6.1	61 and 62	383	428	0	0	14
653	Hogg Creek	1	15-Oct-95	2.13	20	5	21	0	0	14
			15-Oct-95	2.74	31 and 32	5	4	0	0	14
			14-Oct-95	3.35	40	0	1	0	0	14
			14-Oct-95	6.1	60	71	486	0	0	14
656	Halverson Creek	1	14-Oct-95	2.13	20	163	1148	0	0	14
			14-Oct-95	2.74	30	67	860	0	0	14
			14-Oct-95	3.35	40	838	2223	0	0	14
			14-Oct-95	6.1	60	380	2141	0	1	14
663	Shelter Bay	2	13-Oct-95	2.13	20	19	317	0	0	12
			13-Oct-95	2.74	30	0	9	0	0	12
			13-Oct-95	3.35	40	128	489	0	0	12
			13-Oct-95	6.1	60	164	3281	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
665	Bjorne Creek	2	19-Oct-95	2.13	20	67	327	0	0	14
			19-Oct-95	2.74	30	402	453	0	0	14
			19-Oct-95	3.35	40	316	692	0	0	14
			19-Oct-95	6.1	60	292	1267	0	0	14
666	O'Brien Creek	1	15-Oct-95	2.13	20	1	3	0	0	14
			15-Oct-95	2.74	30	11	52	0	0	14
			15-Oct-95	3.35	40	29	370	0	0	14
			15-Oct-95	6.1	60	140	317	0	0	14
673	Falls Creek	1	20-Oct-95	2.13	20	181	706	0	0	14
			20-Oct-95	2.74	30	18	87	0	0	14
			20-Oct-95	3.35	40	27	291	0	85	14
			20-Oct-95	6.1	60	136	1472	0	0	14
677	Hayden Creek	2	20-Oct-95	2.13	21 and 22	16	458	0	1	14
			20-Oct-95	2.74	31 and 32	30	365	0	0	14
			20-Oct-95	3.35	41 and 42	27	22	1	0	14
			20-Oct-95	6.1	61 and 62	1	8	0	0	14
678	Sleepy Bay	2	14-Oct-95	2.13	20	2	38	0	0	12
			14-Oct-95	2.74	30	35	1354	0	0	12
			13-Oct-95	3.35	40	15	41	0	0	12
			13-Oct-95	6.1	60	69	640	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
681	Hogan Bay	1	21-Oct-95	2.13	20	58	675	0	0	14
			21-Oct-95	2.74	30	648	2691	0	0	14
			21-Oct-95	3.35	40	1248	3581	0	0	14
			21-Oct-95	6.1	60	295	2658	0	0	14
682	Snug Harbor	2	21-Oct-95	2.13	20	1341	2754	0	0	14
			21-Oct-95	2.74	30	1145	2648	0	0	14
			21-Oct-95	3.35	40	1648	6693	0	0	14
			21-Oct-95	6.1	60	4927	7972	0	3	14
692	Herring Bay	2	09-Oct-95	2.13	20	613	1138	0	0	14
			09-Oct-95	2.74	30	722	907	0	0	14
			09-Oct-95	3.35	40	1492	2277	0	0	14
			09-Oct-95	6.1	60	162	790	0	0	14
695	Port Audrey	1	11-Oct-95	2.13	21 and 22	159	256	0	0	14
			11-Oct-95	2.74	30	876	1023	0	0	14
			11-Oct-95	3.35	40	503	564	0	0	14
			11-Oct-95	6.1	60	27	517	0	0	14
699	Cathead Bay	1	11-Oct-95	2.13	20	1043	578	0	0	14
			11-Oct-95	2.74	30	465	464	0	0	14
			11-Oct-95	3.35	40	429	1186	0	0	14
			11-Oct-95	6.1	60	598	2859	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
480	Mink Creek	1	07-Oct-96	2.13	20	658	4804	0	74	14
			07-Oct-96	2.74	30	706	3579	0	120	14
			06-Oct-96	3.35	40	661	2676	0	51	14
			06-Oct-96	6.1	60	623	4921	0	5	14
485	W. Finger Creek	1	06-Oct-96	2.13	20	197	3855	0	65	14
			06-Oct-96	2.74	30	1044	6198	0	101	14
			07-Oct-96	3.35	40	1152	11220	0	1046	14
			07-Oct-96	6.1	60	580	4331	0	1145	14
498	McClure Creek	1	06-Oct-96	2.13	20	434	1975	0	0	14
			06-Oct-96	2.74	30	1330	4927	0	0	14
			06-Oct-96	3.35	40	1881	6176	0	146	14
			06-Oct-96	6.1	60	147	842	0	3	14
506	Loomis Creek	2	08-Oct-96	2.13	20	948	776	0	0	14
			08-Oct-96	2.74	30	3623	2790	0	0	14
			08-Oct-96	3.35	40	6225	2267	0	0	14
			08-Oct-96	6.1	60	2491	4427	0	0	14
604	Erb Creek	1	12-Oct-96	2.13	20 and 23	307	1466	0	2	14
			12-Oct-96	2.74	30	78	1530	0	0	14
			12-Oct-96	3.35	40	47	89	0	5	14
			12-Oct-96	6.1	60	15	0	0	1	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
618	Junction Creek	2	09-Oct-96	2.13	20	10	0	0	0	12
			09-Oct-96	2.74	30	58	1581	0	0	12
			09-Oct-96	3.35	40	107	1810	0	0	12
			09-Oct-96	6.1	60	118	1301	0	0	12
621	Totemoff Creek	1	12-Oct-96	2.13	20	148	723	0	1	14
			12-Oct-96	2.74	30	415	1530	0	62	14
			11-Oct-96	3.35	40	723	3842	0	209	14
			12-Oct-96	6.1	60	90	238	0	0	14
623	Brizgaloff Creek	1	12-Oct-96	2.13	20	183	549	0	6	14
		1	12-Oct-96	2.74	30	111	1736	0	2	14
		1	12-Oct-96	3.35	40	67	459	0	0	14
		1	12-Oct-96	6.1	60	295	1333	0	3	14
628	Chenega NE	2	08-Oct-96	2.13	20	14	436	0	0	14
			09-Oct-96	2.74	30	374	1133	0	0	14
			09-Oct-96	3.35	40	2089	2821	0	0	14
			09-Oct-96	6.1	60	983	5532	0	0	14
630	Bainbridge Creek	1	11-Oct-96	2.13	20	867	3812	0	0	14
			11-Oct-96	2.74	30	941	6134	0	203	14
			11-Oct-96	3.35	40	443	7203	0	1349	14
			11-Oct-96	6.1	60	1550	4471	0	325	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
632	Claw Creek	1	11-Oct-96	2.13	20	0	0	0	0	14
			11-Oct-96	2.74	30	10	0	0	0	14
			11-Oct-96	3.35	40	249	1782	0	0	14
			11-Oct-96	6.1	60	3	45	0	0	10
637	Pt. Countess	2	10-Oct-96	2.13	20	1634	1892	0	0	14
			10-Oct-96	2.74	30	844	2039	0	0	14
			10-Oct-96	3.35	41 and 42	1875	2691	0	0	14
			10-Oct-96	6.1	61 and 62	2617	1663	0	0	14
653	Hogg Creek	1	20-Oct-96	2.13	20	35	103	0	15	14
			20-Oct-96	2.74	31 and 32	13	8	0	1	14
			20-Oct-96	3.35	40	38	758	0	1230	14
			20-Oct-96	6.1	60	162	1175	0	87	14
656	Halverson Creek	1	21-Oct-96	2.13	20	693	904	0	0	14
			21-Oct-96	2.74	30	12	470	0	0	14
			28-Oct-96	3.35	40	630	3381	0	0	14
			28-Oct-96	6.1	60	576	5558	0	12	14
663	Shelter Bay	2	18-Oct-96	2.13	20	60	857	0	0	12
			18-Oct-96	2.74	30	73	1386	0	0	12
			18-Oct-96	3.35	40	651	1405	0	0	12
			18-Oct-96	6.1	60	1464	6609	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
665	Bjorne Creek	2	18-Oct-96	2.13	20	3608	3328	0	0	14
			18-Oct-96	2.74	30	2766	2707	0	0	14
			18-Oct-96	3.35	40	1602	613	0	0	14
			17-Oct-96	6.1	60	836	5231	0	0	14
666	O'Brien Creek	1	19-Oct-96	2.13	20	88	5	0	0	14
			19-Oct-96	2.74	30	719	1615	0	0	14
			19-Oct-96	3.35	40	253	3224	0	0	14
			19-Oct-96	6.1	60	506	2412	0	0	14
673	Falls Creek	1	19-Oct-96	2.13	20	76	1039	0	0	14
			20-Oct-96	2.74	30	13	853	0	0	14
			20-Oct-96	3.35	40	41	251	0	0	14
			20-Oct-96	6.1	60	69	536	0	0	14
677	Hayden Creek	2	19-Oct-96	2.13	21 and 22	214	2897	0	0	14
			19-Oct-96	2.74	31 and 32	377	3230	0	0	14
			19-Oct-96	3.35	41 and 42	428	2530	0	1	14
			19-Oct-96	6.1	61 and 62	174	1562	0	0	14
678	Sleepy Bay	2	19-Oct-96	2.13	20	0	4	0	0	12
			19-Oct-96	2.74	30	2	169	0	0	12
			19-Oct-96	3.35	40	168	423	0	0	12
			19-Oct-96	6.1	60	23	163	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
681	Hogan Bay	1	17-Oct-96	2.13	20	54	2483	0	0	14
			17-Oct-96	2.74	30	446	6600	0	7	14
			17-Oct-96	3.35	40	828	6053	0	1	14
			17-Oct-96	6.1	60	594	4130	0	0	14
682	Snug Harbor	2	17-Oct-96	2.13	20	1458	4138	0	295	14
			17-Oct-96	2.74	30	1033	5872	14	1450	14
			17-Oct-96	3.35	40	1111	5566	1	603	14
			17-Oct-96	6.1	60	1463	3947	0	745	14
692	Herring Bay	2	07-Oct-96	2.13	20	831	3056	0	0	14
			08-Oct-96	2.74	30	484	4370	0	0	14
			08-Oct-96	3.35	40	520	2681	0	0	14
			08-Oct-96	6.1	60	340	5160	0	0	14
695	Port Audrey	1	10-Oct-96	2.13	21 and 22	61	1027	0	17	14
			10-Oct-96	2.74	30	566	2548	0	19	14
			10-Oct-96	3.35	40	363	1134	0	18	14
			10-Oct-96	6.1	60	114	958	0	128	14
699	Cathead Bay	1	09-Oct-96	2.13	20	31	100	0	0	14
			09-Oct-96	2.74	30	4	0	0	0	14
			09-Oct-96	3.35	40	13	24	0	0	14
			09-Oct-96	6.1	60	173	0	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
480	Mink Creek	1	29-Sep-97	2.13	20	177	494	0	2	14
			29-Sep-97	2.74	30	277	781	0	0	14
			29-Sep-97	3.35	40	143	492	0	3	14
			29-Sep-97	6.1	60	1059	3431	0	0	14
485	W. Finger Creek	1	28-Sep-97	2.13	20	0	2	0	0	14
			28-Sep-97	2.74	30	74	1310	13	119	14
			28-Sep-97	3.35	40	487	2864	0	159	14
			28-Sep-97	6.1	60	255	1870	0	5	14
498	McClure Creek	1	28-Sep-97	2.13	20	3098	3121	0	0	14
			28-Sep-97	2.74	30	1380	2456	0	0	14
			28-Sep-97	3.35	40	2866	9533	0	0	14
			28-Sep-97	6.1	60	1686	1095	0	0	14
506	Loomis Creek	2	30-Sep-97	2.13	20	1471	374	0	0	14
			30-Sep-97	2.74	30	4050	725	0	0	14
			30-Sep-97	3.35	40	5048	824	0	0	14
			30-Sep-97	6.1	60	2119	4578	0	0	14
604	Erb Creek	1	02-Oct-97	2.13	20 and 23	716	3060	0	0	14
			02-Oct-97	2.74	30	807	2251	0	0	14
			02-Oct-97	3.35	40	127	347	0	0	14
			02-Oct-97	6.1	60	511	2894	0	0	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
618	Junction Creek	2	02-Oct-97	2.13	20	17	0	0	0	12
			02-Oct-97	2.74	30	28	293	0	0	12
			02-Oct-97	3.35	40	1300	1335	0	0	12
			02-Oct-97	6.1	60	756	691	0	0	12
621	Totemoff Creek	1	02-Oct-97	2.13	20	873	430	0	0	14
			02-Oct-97	2.74	30	733	881	0	11	14
			02-Oct-97	3.35	40	699	3538	0	0	14
			02-Oct-97	6.1	60	1426	2559	0	0	14
623	Brizgaloff Creek	1	03-Oct-97	2.13	20	543	1840	0	0	14
			03-Oct-97	2.74	30	278	970	0	0	14
			03-Oct-97	3.35	40	2520	2423	0	0	14
			03-Oct-97	6.1	60	2996	5044	0	0	14
628	Chenega NE	2	30-Sep-97	2.13	20	702	573	0	0	14
			30-Sep-97	2.74	30	832	675	0	0	14
			30-Sep-97	3.35	40	4140	2490	0	0	14
			30-Sep-97	6.1	60	3577	5926	0	0	14
630	Bainbridge Creek	1	03-Oct-97	2.13	20	393	1012	0	0	14
			03-Oct-97	2.74	30	607	2504	0	1	14
			03-Oct-97	3.35	40	1005	6767	0	2	14
			03-Oct-97	6.1	60	1271	8505	3	123	14

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
632	Claw Creek	1	04-Oct-97	2.13	20	38	173	0	0	14
			04-Oct-97	2.74	30	37	121	0	0	14
			04-Oct-97	3.35	40	2426	12126	0	2	14
			04-Oct-97	6.1	60	3	209	0	0	10
637	Pt. Countess	2	04-Oct-97	2.13	20	1165	1987	0	0	14
			04-Oct-97	2.74	30	3290	2685	0	0	14
			04-Oct-97	3.35	41 and 42	4162	4811	0	0	14
			04-Oct-97	6.1	61 and 62	3274	4542	0	0	14
653	Hogg Creek	1	05-Oct-97	2.13	20	814	2163	0	2	14
			05-Oct-97	2.74	31 and 32	185	648	0	0	14
			05-Oct-97	3.35	40	219	507	0	0	14
			05-Oct-97	6.1	60	250	2421	0	0	14
656	Halverson Creek	1	05-Oct-97	2.13	20	1566	1534	0	0	14
			05-Oct-97	2.74	30	699	560	0	0	14
			05-Oct-97	3.35	40	2039	5371	0	0	14
			05-Oct-97	6.1	60	744	3665	0	0	14
663	Shelter Bay	2	08-Oct-97	2.13	20	305	1112	0	0	12
			08-Oct-97	2.74	30	185	947	0	0	12
			08-Oct-97	3.35	40	677	3762	0	0	12
			08-Oct-97	6.1	60	1665	3665	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
665	Bjorne Creek	2	07-Oct-97	2.13	20	1404	1500	0	0	14
			07-Oct-97	2.74	30	3785	2235	0	0	14
			07-Oct-97	3.35	40	3766	1134	0	0	14
			07-Oct-97	6.1	60	1025	4210	0	0	14
666	O'Brien Creek	1	06-Oct-97	2.13	20	495	67	0	0	14
			06-Oct-97	2.74	30	866	2832	0	0	14
			06-Oct-97	3.35	40	572	4633	0	3	14
			06-Oct-97	6.1	60	2920	3185	0	0	14
673	Falls Creek	1	08-Oct-97	2.13	20	892	1386	0	0	14
			08-Oct-97	2.74	30	688	4796	0	0	14
			08-Oct-97	3.35	40	933	2234	0	0	14
			08-Oct-97	6.1	60	1395	4261	0	0	14
677	Hayden Creek	2	08-Oct-97	2.13	21 and 22	1175	3443	0	1	14
			08-Oct-97	2.74	31 and 32	1278	4535	0	0	14
			06-Oct-97	3.35	41 and 42	1499	2457	0	0	14
			06-Oct-97	6.1	61 and 62	1062	3244	0	0	14
678	Sleepy Bay	2	06-Oct-97	2.13	20	228	483	0	0	12
			06-Oct-97	2.74	30	186	390	0	0	12
			06-Oct-97	3.35	40	489	1346	0	0	12
			06-Oct-97	6.1	60	894	2085	0	0	12

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples
681	Hogan Bay	1	21-Oct-97	2.13	20	179	911	0	0	14
			21-Oct-97	2.74	30	811	1089	0	0	14
			21-Oct-97	3.35	40	1188	58	0	0	14
			21-Oct-97	6.1	60	926	2450	0	0	14
682	Snug Harbor	2	09-Oct-97	2.13	20	856	1488	0	0	14
			09-Oct-97	2.74	30	2879	5330	0	0	14
			09-Oct-97	3.35	40	2984	5709	0	56	14
			09-Oct-97	6.1	60	2398	6636	0	104	14
692	Herring Bay	2	29-Sep-97	2.13	20	2031	823	0	0	14
			29-Sep-97	2.74	30	5807	1195	0	0	14
			29-Sep-97	3.35	40	2330	3464	0	0	14
			29-Sep-97	6.1	60	2159	6313	0	0	14
695	Port Audrey	1	01-Oct-97	2.13	21 and 22	1455	1905	0	0	14
			01-Oct-97	2.74	30	676	3386	0	0	14
			01-Oct-97	3.35	40	1452	4883	0	0	14
			01-Oct-97	6.1	60	721	1567	0	0	14
699	Cathead Bay	1	01-Oct-97	2.13	20	2266	687	0	0	14
			01-Oct-97	2.74	30	512	3100	0	0	14
			01-Oct-97	3.35	40	1568	3121	0	0	14
			01-Oct-97	6.1	60	1243	2890	0	0	14

Appendix A. Continued (page 79 of 79).

Stream #	Stream Name	Oil Status	Date	Height in Tidal Zone(m)	Location	Embryos Dead	Embryos Live	Fry Dead	Fry Live	No. of Samples

Appendix B. Summary of adult pink salmon counted in streams bordering Prince William Sound, 1989-1997.

Appendix B. Numbers of adult pink salmon counted in streams bordering PWS, 1989-1997. Data from ground surveys conducted by Exxon are indicated in bold type and ADF&G aerial data in normal type.

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
# 604	07-Jul	0								
Erb	08-Jul									
	09-Jul									
	11-Jul									
	12-Jul									
	13-Jul									
	14-Jul									
	15-Jul									
	16-Jul									
	17-Jul									
	18-Jul									
	19-Jul		**3036**							
	20-Jul						60			
	21-Jul	600								
	22-Jul									
	23-Jul								0	
	24-Jul						400			
	25-Jul									
	26-Jul	600						0		
	27-Jul									
	28-Jul									
	29-Jul						700		150	0
	30-Jul									
	31-Jul									
	01-Aug	**2143**	**2592**							
	02-Aug	**2047**								
	03-Aug	**2281**					1000			
	04-Aug	**1966**							850	
	05-Aug	**1441**								
	06-Aug	**690**						250		
	07-Aug	**2153**								
	08-Aug	**2590**	**5095**							
	09-Aug	**2061**					800			
	10-Aug	**3025**					**2220**			
	11-Aug	**2492**			**518**					
	12-Aug	**2573**								0
	13-Aug	**2077**							400	
	14-Aug	**2758**								
	15-Aug	**3021**		**3392**	**841**			2100		**257**
	16-Aug	**2126**					**1475**		**423**	
	17-Aug	**1940**	**3661**					**980**		
	18-Aug	**2130**			**907**					
	19-Aug	**1638**							**387**	
	20-Aug	**1555**								**337**
	21-Aug	**1941**								
	22-Aug	**961**					**2868**	**763**		
	23-Aug	**1509**		**4464**	**371**				**725**	
	24-Aug	**1252**	**4034**							
	25-Aug	**862**								
	26-Aug	**1066**								
	27-Aug	**2026**								**1665**
	28-Aug	**1536**		**4048**	**518**				**980**	
	29-Aug	**1706**	**2664**					**1465**		
	30-Aug	**1559**					**5475**			
	31-Aug	**1611**								
	01-Sep	**951**								
	02-Sep	**812**			**558**				**1205**	
	03-Sep	**1155**								**4360**
	04-Sep	**857**								
	05-Sep	**681**								
	06-Sep	**505**	**2928**		**408**				**817**	
	07-Sep	**469**					**1268**			
	08-Sep	**299**						**2280**		
	09-Sep									
	10-Sep	**106**								**2815**
	11-Sep	**50**	**1446**						**392**	
	12-Sep	**25**					**2325**			**1434**
	13-Sep	**10**								
	14-Sep									
	15-Sep							**15**		

Appendix B. Continued(page 82 of 10)

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
# 618	19-Jul	0								
Junction	20-Jul									
	21-Jul									
	22-Jul									
	23-Jul									0
	24-Jul									
	25-Jul									
	26-Jul									
	27-Jul									
	28-Jul									
	29-Jul								0	0
	30-Jul		0							
	31-Jul		0							
	01-Aug									
	02-Aug									
	03-Aug									
	04-Aug								0	0
	05-Aug									
	06-Aug				0			0		
	07-Aug									
	08-Aug									
	09-Aug									
	10-Aug						0			
	11-Aug		33							
	12-Aug				13					
	13-Aug								0	
	14-Aug									
	15-Aug		22					75		8
	16-Aug				12		0			
	17-Aug	0						41		
	18-Aug									
	19-Aug			584					19	
	20-Aug				0					0
	21-Aug		116						77	
	22-Aug	289					101	92		
	23-Aug									
	24-Aug				52					
	25-Aug			2167						
	26-Aug								765	
	27-Aug									144
	28-Aug		113						995	
	29-Aug	1578			33			321		
	30-Aug			1642			660			
	31-Aug									
	01-Sep									690
	02-Sep								945	
	03-Sep	1665			47					862
	04-Sep		858							
	05-Sep									
	06-Sep	964							89	
	07-Sep				36		152			
	08-Sep							845		
	09-Sep									
	10-Sep									2688
	11-Sep			1534					59	
	12-Sep		600				72			1887
	13-Sep									
	14-Sep	24								
	15-Sep							181		
	16-Sep									
	17-Sep									
	18-Sep									
	19-Sep									

Appendix B. Continued(page 83 of 10)

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
# 621	14-Jul						0			
Totemoff	15-Jul									
	16-Jul									
	17-Jul									
	18-Jul								0	
	19-Jul									
	20-Jul						50			
	21-Jul	0								
	22-Jul									
	23-Jul								0	0
	24-Jul						2900			
	25-Jul									
	26-Jul	100						0		
	27-Jul									
	28-Jul									
	29-Jul						1400		150	
	30-Jul									
	31-Jul									
	01-Aug									
	02-Aug									
	03-Aug						1100			
	04-Aug	1500							250	
	05-Aug	**3778**								
	06-Aug							100		1400
	07-Aug									
	08-Aug									
	09-Aug						1500			**1421**
	10-Aug						**5402**			
	11-Aug									
	12-Aug									
	13-Aug								400	
	14-Aug									**2585**
	15-Aug							1850	**295**	
	16-Aug						**2425**			
	17-Aug	**4062**						**2839**		
	18-Aug									
	19-Aug								**215**	
	20-Aug									
	21-Aug									**4440**
	22-Aug	**3145**					**6495**	**3235**		
	23-Aug								**405**	
	24-Aug									
	25-Aug									
	26-Aug									**5615**
	27-Aug									
	28-Aug								**985**	
	29-Aug	**2173**						**3738**		
	30-Aug						**3860**			
	31-Aug	**993**								
	01-Sep									
	02-Sep								**1450**	
	03-Sep	**821**								
	04-Sep									
	05-Sep									
	06-Sep	**515**							**1495**	**1944**
	07-Sep						**2960**			
	08-Sep							**1190**		
	09-Sep									
	10-Sep									
	11-Sep								**398**	
	12-Sep						**895**			
	13-Sep									
	14-Sep	**2**								
# 628	24-Jul						300			

Appendix B. Continued(page 84 of 10)

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
Chenega	25-Jul									
	26-Jul									
	27-Jul									
	28-Jul									
	29-Jul		3152				500		200	
	30-Jul									
	31-Jul		767							
	01-Aug									
	02-Aug									
	03-Aug	233					500			
	04-Aug									
	05-Aug									
	06-Aug									
	07-Aug									
	08-Aug									
	09-Aug						1400			
	10-Aug						5402			
	11-Aug		4407							
	12-Aug				497					
	13-Aug									
	14-Aug									
	15-Aug		2306							1110
	16-Aug				848		334		714	
	17-Aug	768						1389		
	18-Aug									1250
	19-Aug			7915					587	
	20-Aug				1041					
	21-Aug		4069						810	
	22-Aug	1830					2068	974		2730
	23-Aug									
	24-Aug									
	25-Aug			12742						
	26-Aug								5050	
	27-Aug				3845					
	28-Aug		3830						6670	
	29-Aug	3540						3621		
	30-Aug			13291			8500			
	31-Aug									
	01-Sep				5929					
	02-Sep								10555	
	03-Sep	3653								12395
	04-Sep		7099							
	05-Sep				2253					
	06-Sep	5350							4825	
	07-Sep						6383			
	08-Sep							8830		
	09-Sep									
	10-Sep				1123					14305
	11-Sep			7840					6230	
	12-Sep		3958				5760			13405
	13-Sep								2541	
	14-Sep	1370								
	15-Sep									7818
	16-Sep									
	17-Sep									
	18-Sep							419		
	19-Sep						0			
# 656	14-Jul	0					0			

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
Halverson	15-Jul									
	16-Jul									
	17-Jul									
	18-Jul									
	19-Jul			0						
	20-Jul						900			
	21-Jul	200								
	22-Jul									
	23-Jul									
	24-Jul									
	25-Jul			0						
	26-Jul	200						0		
	27-Jul									
	28-Jul			200						
	29-Jul						600			0
	30-Jul									
	31-Jul									
	01-Aug									
	02-Aug			800						
	03-Aug						1000			
	04-Aug	1200		1100					0	
	05-Aug	**1156**								
	06-Aug							100		
	07-Aug									
	08-Aug									
	09-Aug			970			1000			
	10-Aug						**1385**			
	11-Aug									
	12-Aug	**731**								1200
	13-Aug								120	
	14-Aug			1550						
	15-Aug							500	**30**	
	16-Aug	**546**					**1491**		**37**	
	17-Aug									
	18-Aug							**175**		**454**
	19-Aug			3500						
	20-Aug									
	21-Aug	**1005**					**1659**		**860**	
	22-Aug			**3410**						**1150**
	23-Aug							**237**	**2510**	
	24-Aug									
	25-Aug									
	26-Aug									
	27-Aug									
	28-Aug	**2130**		**4505**					**5490**	
	29-Aug									
	30-Aug						**9350**		**6620**	
	31-Aug									
	01-Sep									
	02-Sep	**3369**								
	03-Sep									
	04-Sep			**9560**				**6220**	**2978**	
	05-Sep									**6970**
	06-Sep									
	07-Sep						**3210**			
	08-Sep	**1420**								
	09-Sep									
	10-Sep									**10778**
	11-Sep								**4857**	
	12-Sep						**4955**			**9702**
	13-Sep			**2180**					**1939**	
	14-Sep									
	15-Sep							**577**		**4267**
	16-Sep									
	17-Sep	**37**								
	18-Sep									
	19-Sep									

Stream	Date	1989
# 663 Shelter	14-Jul	0
	15-Jul	
	16-Jul	
	17-Jul	

Appendix B. Continued(page 86 of 10)

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
	18-Jul									
	19-Jul			0						
	20-Jul									
	21-Jul	200								
	22-Jul									
	23-Jul									
	24-Jul									
	25-Jul			0						
	26-Jul	200						0		
	27-Jul		**2**							
	28-Jul			200						
	29-Jul									0
	30-Jul				0					
	31-Jul									
	01-Aug									
	02-Aug		**56**	800						
	03-Aug									
	04-Aug	1200		1100						
	05-Aug	**1156**								
	06-Aug		**3**		350			100		
	07-Aug									
	08-Aug									
	09-Aug			970						
	10-Aug						**0**			
	11-Aug									
	12-Aug	**731**								1200
	13-Aug									
	14-Aug			1550	**9**					
	15-Aug		**1**					500		
	16-Aug	**546**					**0**		**0**	
	17-Aug				**25**					
	18-Aug							**175**		**454**
	19-Aug			3500					**0**	
	20-Aug									
	21-Aug	**1005**			**2**		**0**			
	22-Aug			**3410**						**1150**
	23-Aug		**26**					**237**	**199**	
	24-Aug						10			
	25-Aug				**378**					
	26-Aug								**1265**	
	27-Aug									
	28-Aug	**2130**		**4505**						
	29-Aug		**8**							
	30-Aug				**261**		**2990**		**1815**	
	31-Aug									
	01-Sep									
	02-Sep	**3369**								
	03-Sep									
	04-Sep			**9560**	**286**			**6220**	**1386**	
	05-Sep									**6970**
	06-Sep		**1117**							
	07-Sep						**997**			
	08-Sep	**1420**			**237**					
	09-Sep								**329**	
	10-Sep		**1747**							**10778**
	11-Sep									
	12-Sep						**2130**			**9702**
	13-Sep			**2180**	50				**2115**	
	14-Sep									
	15-Sep							**577**		**4267**
	16-Sep									
	17-Sep	**37**								
	18-Sep									
	19-Sep									
	20-Sep									
# 673 Falls	14-Jul	0								
	15-Jul									
	16-Jul									
	17-Jul									
	18-Jul									
	19-Jul			0						
	20-Jul									

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
	21-Jul	200								
	22-Jul									
	23-Jul									
	24-Jul									
	25-Jul			0						
	26-Jul	200						0		
	27-Jul									
	28-Jul			200						
	29-Jul						0			0
	30-Jul									
	31-Jul									
	01-Aug									
	02-Aug			800						
	03-Aug						100			
	04-Aug	1200		1100						
	05-Aug	1156								
	06-Aug							100		
	07-Aug									
	08-Aug									
	09-Aug			970			300			
	10-Aug						442			
	11-Aug									
	12-Aug	731								1200
	13-Aug									
	14-Aug			1550	966					
	15-Aug							500		
	16-Aug	546					414		0	
	17-Aug				932					
	18-Aug							175		454
	19-Aug			3500						
	20-Aug									
	21-Aug	1005			610		513		83	
	22-Aug			3410						1150
	23-Aug							237	276	
	24-Aug									
	25-Aug									
	26-Aug									
	27-Aug				697					
	28-Aug	2130		4505					983	
	29-Aug									
	30-Aug						2790		1115	
	31-Aug									
	01-Sep				855					
	02-Sep	3369								
	03-Sep									
	04-Sep			9560				6220	1673	
	05-Sep									6970
	06-Sep				484					
	07-Sep						3025			
	08-Sep	1420								
	09-Sep								1013	
	10-Sep				372					10778
	11-Sep									
	12-Sep						880			9702
	13-Sep			2180					202	
	14-Sep									
	15-Sep							577		4267
	16-Sep									
	17-Sep	37								
# 678	09-Aug									
Sleepy	10-Aug						0			
	11-Aug									
	12-Aug				0					
	13-Aug									
	14-Aug									

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
	15-Aug		0							
	16-Aug				0		0		0	
	17-Aug									
	18-Aug									
	19-Aug									
	20-Aug				0					
	21-Aug						5		43	
	22-Aug				0					
	23-Aug								92	
	24-Aug		38							
	25-Aug									
	26-Aug									
	27-Aug				129					
	28-Aug								340	
	29-Aug									
	30-Aug		510				1230		495	
	31-Aug									
	01-Sep				301					
	02-Sep									
	03-Sep									
	04-Sep				350				825	
	05-Sep									
	06-Sep									
	07-Sep		1117				880			
	08-Sep				265					
	09-Sep								1049	
	10-Sep		1405							
	11-Sep									
	12-Sep						695			
	13-Sep								83	
	14-Sep									
	15-Sep									
	16-Sep									
	17-Sep									
	18-Sep									
	19-Sep									

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
# 682	10-Jul									
Snug Harbor	11-Jul		0							
	13-Jul									
	14-Jul						1200			
	15-Jul									
	16-Jul		1400							
	17-Jul				600					

Appendix B. Continued(page 89 of 10)

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
	18-Jul		0							
	19-Jul									
	20-Jul						1750			
	21-Jul									
	22-Jul									
	23-Jul		2500		1600				900	
	24-Jul						3000			
	25-Jul									
	26-Jul		5623							
	27-Jul									
	28-Jul									
	29-Jul						8000		1400	
	30-Jul									
	31-Jul				1400					
	01-Aug		5453							
	02-Aug									
	03-Aug						3000			
	04-Aug								1900	
	05-Aug									
	06-Aug		3071							
	07-Aug				3400					
	08-Aug									
	09-Aug						7000			
	10-Aug						6717			
	11-Aug									
	12-Aug									
	13-Aug				2363				2100	
	14-Aug		6456							
	15-Aug								2472	
	16-Aug				3247		4965			
	17-Aug									
	18-Aug									
	19-Aug								2410	
	20-Aug				1364					
	21-Aug						6485		2675	
	22-Aug		6049							
	23-Aug									
	24-Aug									
	25-Aug									
	26-Aug								5530	
	27-Aug				3333					
	28-Aug		5294							
	29-Aug									
	30-Aug						7470		5390	
	31-Aug									
	01-Sep				3891					
	02-Sep								4287	
	03-Sep									
	04-Sep									
	05-Sep		5847		1740					
	06-Sep									
	07-Sep						6880			
	08-Sep									
	09-Sep		2698						1734	
	10-Sep				1694					
	11-Sep									
	12-Sep						3570			
	13-Sep								543	
	14-Sep				100					
	15-Sep									
	16-Sep									
	17-Sep									
	18-Sep									
	19-Sep									
# 695 Port Audrey	23-Jul						0		0	
	24-Jul									
	25-Jul									
	26-Jul									
	27-Jul									
	28-Jul									
	29-Jul						0		250	
	30-Jul									
	31-Jul									

Appendix B. Continued(page 90 of 10)

Stream	Date	1989	1990	1991	1992	1993	1994	1995	1996	1997
	01-Aug									
	02-Aug									
	03-Aug						500			
	04-Aug								350	
	05-Aug									
	06-Aug									
	07-Aug									
	08-Aug									
	09-Aug						2000			
	10-Aug						**2612**			
	11-Aug									
	12-Aug									
	13-Aug								480	
	14-Aug									
	15-Aug									
	16-Aug						**1632**		**329**	
	17-Aug									
	18-Aug									
	19-Aug								**177**	
	20-Aug									
	21-Aug						**2894**		**405**	
	22-Aug									
	23-Aug									
	24-Aug									
	25-Aug									
	26-Aug								**1239**	
	27-Aug									
	28-Aug									
	29-Aug									
	30-Aug						**4225**		**1377**	
	31-Aug									
	01-Sep									
	02-Sep								**795**	
	03-Sep									
	04-Sep									
	05-Sep									
	06-Sep								**250**	
	07-Sep						**1810**			
	08-Sep									
	09-Sep									
	10-Sep									
	11-Sep								**2**	
	12-Sep						**975**			

Appendix C. Evidence of damage to pink salmon populations inhabiting Prince William Sound, Alaska, two generations after the *Exxon Valdez* oil spill.

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Evidence of Damage to Pink Salmon Populations Inhabiting Prince William Sound, Alaska, Two Generations after the *Exxon Valdez* Oil Spill

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Abstract.—Our investigations into the effects of the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska, suggest that chronic damage occurred to some populations of pink salmon *Oncorhynchus gorbuscha.* Significantly elevated embryo mortalities were observed from 1989 through 1993 in populations inhabiting streams previously contaminated by oil. No statistically detectable difference in embryo mortality was observed in 1994 and 1995. We assessed the possible influence of the natural environment on these findings by collecting gametes from adults returning to contaminated and to uncontaminated streams, transporting the gametes to a hatchery where intrastream crosses were made, and incubating the resulting embryos under identical environmental conditions. Significantly increased embryo mortality was detected for embryos originating from the oil-contaminated lineages in 1993 but not in 1994, which indicated that the significant differences detected in the field in 1989–1993 were not induced by naturally occurring environmental variables.

On March 24, 1989, the supertanker *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, Alaska, spilling approximately 41 million liters of crude oil (Bragg et al. 1994). The resulting slick moved through western Prince William Sound and the western Gulf of Alaska, contaminating approximately 2,000 km of coastal habitat (Bragg et al. 1994), killing an estimated 250,000 seabirds (Piatt and Ford 1996) and 4,000 sea otters *Enhydra lutris* (Garrott et al. 1993; Degange et al. 1994). Sublethal effects were also documented (Hose et al. 1996; Wiedmer et al. 1996; Marty et al. 1997). Despite a US$2 billion cleanup and restoration effort, subsurface oil remains in some of the beaches (Wolfe et al. 1994; Babcock et al. 1996; Spies et al. 1996).

One of the most abundant vertebrate species in the area is pink salmon *Oncorhynchus gorbuscha* of both wild and hatchery origin. Up to 75% of wild pink salmon that spawn within the Sound do so in intertidal areas (Helle et al. 1964). Unfortunately, their extensive use of intertidal spawning areas and the use of nearshore marine areas by juveniles made pink salmon vulnerable to oil exposure from the spill.

Mortality of pink salmon embryos was examined annually in 10 oil-contaminated (oiled) and 15 nearby, uncontaminated (reference), streams from 1989 through 1992 (Bue et al. 1996). In that work, stream oiling was assessed through visual observations of the stream and the adjacent area during the spring of 1989. The observations were reviewed and adjusted if needed according to the results of anadromous stream surveys conducted in southwestern Prince William Sound by the Alaska Department of Fish and Game, Habitat Division (Middleton et al. 1992). The oiling classifications of the streams correlated with the findings of the fall of 1989 shoreline surveys (ADEC–SRS 1989; Neff et al. 1995) and similar pink salmon work by Brannon et al. (1995). Each fall, live and dead embryos were collected from the stream gravel along transects established in three intertidal zones (1.8–2.4 m, 2.4–3.0 m, and 3.0–3.7 m above mean low water) and the area above mean high water (>3.7 m above mean low water). More than 2,500

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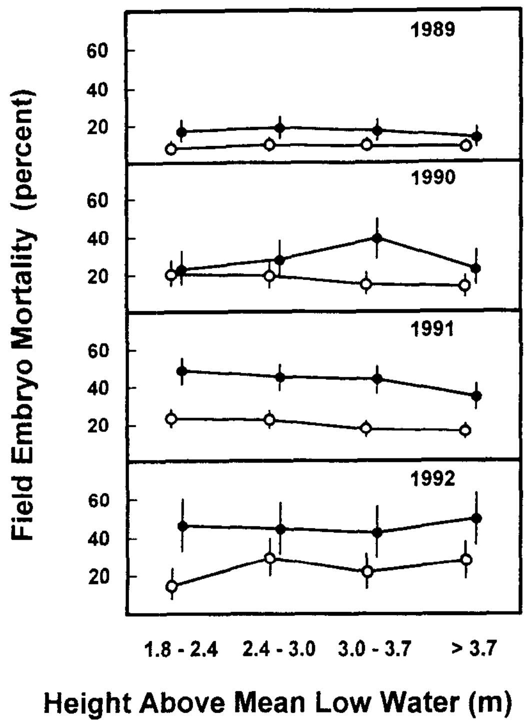

FIGURE 1.—Mean pink salmon embryo mortality observed during fall field sampling in 1989 through 1992 (Bue et al. 1996). Solid circles indicate oil-contaminated streams ($N = 10$); open circles identify reference streams ($N = 15$); error bars represent 90% confidence intervals.

embryos were examined on average from each stream zone to estimate embryo mortality.

Bue et al. (1996) measured significantly greater embryo mortality in oiled streams than in reference streams in 1989 ($P = 0.004$) and 1990 ($P = 0.023$); significant differences were recorded in all intertidal areas in 1989 and in the upper intertidal zone in 1990 (Figure 1). These results were consistent with the observed patterns of oil contamination and the results of controlled oiling experiments. Wolfe et al. (1994) found that among oiled streams, the intertidal areas were contaminated in 1989, and much of the remaining oil was deposited in the upper intertidal zone in 1990. In controlled oiling experiments, Marty et al. (1997) and Heintz et al. (1995) found that pink salmon embryos experienced significantly higher mortality when incubated in oiled gravel than in clean gravel. Heintz et al. (1995) also detected significantly elevated mortalities in pink salmon embryos incubated in oiled gravel that had weathered for a year.

In 1991 we observed a larger difference in embryo mortality between oil-contaminated and reference streams than was previously recorded ($P = 0.003$; Figure 1); this dissimilarity was observed across all stream zones, even in the area above that directly influenced by oil. A similar, but less extreme, pattern of embryo mortality was observed again in 1992 ($P = 0.010$; Figure 1). Evidence of oil contamination in the intertidal areas was dramatically reduced by 1991 (Wolfe et al. 1996), yet elevated mortality of embryos in oiled streams continued (Bue et al. 1996).

The 1991 and 1992 evaluations demonstrated significant differences in embryo mortality between oil-contaminated and reference streams in both the intertidal and upstream zones. These findings were unexpected because the presence of oil was dramatically reduced in all areas for these years. We developed three hypotheses that could explain these findings: (1) that oil-induced damage to the 1989 and 1990 broods included deleterious mutations in the germ line, (2) that incubating embryos continued to be damaged in a physiological manner by an oiled environment even after visually observable oil was gone and that this impact was expressed as functional sterility, (3) that the observed differences in embryo mortality were due to naturally occurring environmental factors that differed between oiled and reference streams.

All three hypotheses were supportable. Both the genetic-damage and physiological-damage hypotheses seemed credible. Past studies had confirmed that pink salmon embryos take up polycyclic aromatic hydrocarbons (PAHs; Moles et al. 1987), a major component of crude oil, and that these compounds were capable of inducing chromosomal lesions (McBee and Bickham 1988) and influencing endocrine function (Thomas and Budiantara 1995). Pink salmon have an obligate 2-year life cycle that results in two genetically isolated lineages, one produced during odd years and the other during even years (Heard 1991). Therefore, genetic or physiological damage induced in one brood year would be expressed in that lineage 2 years later. The environmental-difference hypothesis seemed credible because environmental factors (wind and currents) determined the distribution of the oil, and such factors might also influence the survivability of salmon embryos incubating intertidally.

In this study we continued to monitor pink salmon embryo mortality in oiled and reference streams and tested the environmental-difference hypothesis with a controlled incubation experiment.

Methods

Field monitoring.—We followed methods for pink salmon embryo sampling described by Bue et al. (1996), which were modeled after procedures described by Pirtle and McCurdy (1977). The 10 oil-contaminated and 15 reference streams sampled for pink salmon embryos each fall from 1993 through 1995 were the same ones studied by Bue et al. (1996) from 1989 through 1992.

On each study stream, four zones, three intertidal (1.8–2.4 m, 2.4–3.0 m, 3.0–3.7 m above mean low water) and one that was above most tidal influence (>3.7 m) were measured from the mean low tide mark and marked with stakes. A linear transect approximately 30.5 m in length was established in each zone. The transect ran diagonally across the stream, and its location was staked to ensure continuity of transects between years. Fourteen 0.3-m^2, circular digs were systematically made along each transect with a high-pressure hose and a specially designed net to flush and capture embryos. Numbers of live and dead embryos and recently hatched alevins were used to estimate embryo mortalities by stream zone.

Differences in embryo mortality were evaluated with a mixed-effects two-factor experiment with repeated measures on one factor (Neter et al. 1990). The two factors were (1) extent of oiling (two levels: oil-contaminated and reference) and (2) the height in the intertidal zone (four levels). The data were blocked by stream, a random effect nested within extent of oiling.

Controlled incubation experiment.—Intrastream crosses were made from gametes from 30 male and 30 female pink salmon collected from each of eight oiled and eight reference streams in southwestern Prince William Sound in 1993 and 1994 (Figure 2). The resulting embryos were incubated in a common environment, after which mortality was assessed. Care was taken to select oil-contaminated and reference streams with similar geographic locations, physical characteristics, and pink salmon spawning times. Streams selected for this study were a subset of those included in the field sampling described in Bue et al. (1996, Figure 1).

Before the experiment, we estimated that gamete collection and the subsequent crosses for four streams would constitute 1 d of work; consequently, we estimated it would take 4 d to complete the experiment. Therefore, the experiment was designed in a blocked fashion in which each day of gamete collection and fertilization constituted a block. All gamete collections, matings, and incubator loadings were conducted in an identical fashion for all streams.

Adults were captured in the stream mouth by means of a beach seine and held in shallow water. Only gametes from ripe individuals (adults that readily extruded eggs or sperm when gently massaged) were taken. Eggs (approximately 1,500) from each female were removed by excising the abdominal wall and allowing them to flow directly into a 1-L Zip-Lock plastic bag. The 30 bags of eggs were then sealed and packed on cotton towels over a 10-cm layer of wet ice in insulated ice chests. Sperm samples from each male (2–3 mL) were placed into a 15-mL plastic centrifuge tube and capped; the 30 tubes were placed on ice in the same chest as the eggs for that stream. When all gametes were collected from a stream, the ice chest was flown to the Armin F. Koernig Hatchery (an average 10-min flight time; Figure 2).

Construction of a stream-specific embryo pool consisting of all single-pair crosses ($30 \times 30 = 900$) began immediately after the gametes arrived at the hatchery. Crosses were made by first placing 5-mL of eggs (approximately 30 eggs) from each female into each of 30 cups (0.47 L each). After this step, each cup contained approximately an equal number of eggs from each female. Each cup of eggs was fertilized by a different male with 1-mL of sperm, followed by 100-mL of freshwater to initiate fertilization. This procedure provided each male an equal opportunity to fertilize eggs from each female. The fertilized eggs were allowed to sit for approximately 3-min, after which they were recombined into a 3-L plastic container and gently rinsed and mixed with freshwater three times.

Embryos from each day of stream sampling were placed into one of four vertical stacks of incubator trays (one stack for each day of collection). Six trays within each stack were divided into 16 equal compartments each with plastic strips (four rows by four columns). Each strip was sealed to the tray to prevent mixing of eggs and larvae between compartments. Twenty-four 100-mL samples of embryos (approximately 580 embryos) were randomly collected from each stream-specific embryo pool and loaded into separate compartments by using a randomized loading scheme.

Dead eggs in each compartment were counted and removed 36 h postfertilization, after which the trays were undisturbed for 4 weeks. Water flow to each of the four incubator stacks was maintained at 15 L/min. Each incubator stack received a so-

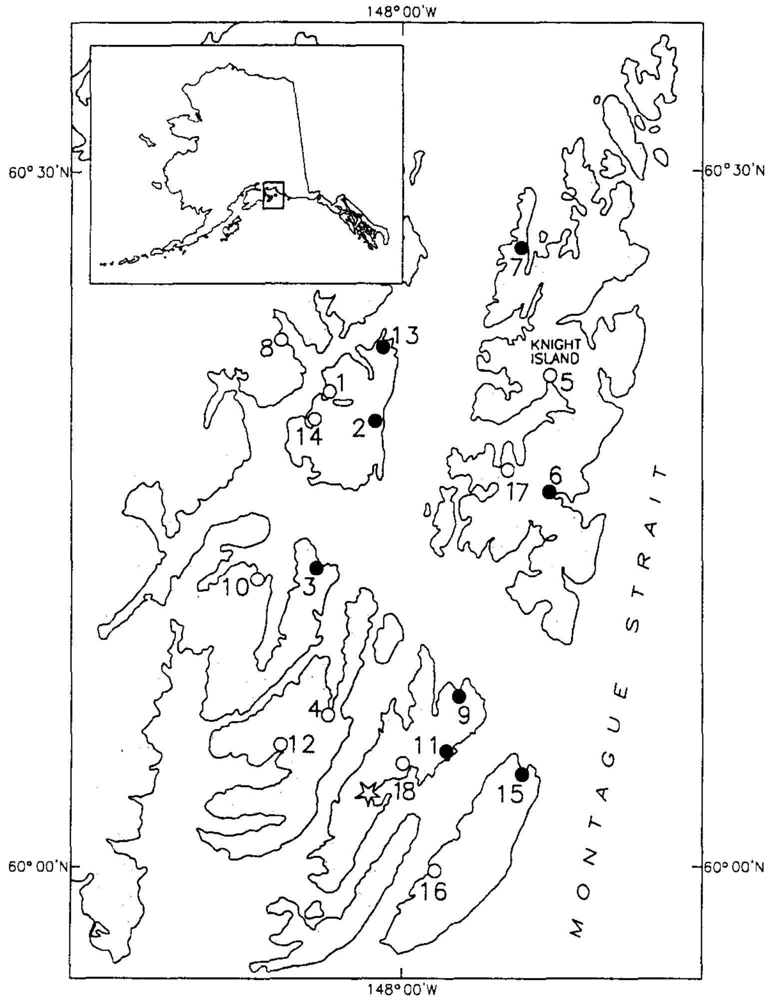

FIGURE 2.—The study area in southwestern Prince William Sound, Alaska, including approximate positions of oil-contaminated (solid circles) and reference (open circles) streams and the Armin F. Koernig Hatchery (open star).

dium chloride bath (20‰) for 20 min twice per week to control fungus.

Mortality of eyed embryos was determined and recorded when a distinct embryo eye could be seen through the chorion. Embryos at this stage were siphoned out of their compartments with clear flexible tubing (10-mm inside diameter) and allowed to drop 10–12 cm into a container of freshwater. The resulting physical shock caused coagulation of yolk material in dead embryos that allowed easier identification and removal. Live and dead embryos were gently placed back into their original compartments after siphoning. Both live and dead embryos were counted; the dead were removed and discarded. All larvae were destroyed after hatching.

A technician, who was stationed at the hatchery during the 3 months of the experiment, performed normal fish culture duties and collected mortality data. The technician was made aware of the day of collection for record keeping but did not know which incubator compartments represented oiled or unoiled streams. The statistical difference in mortality due to oil contamination was evaluated with a blocked analysis of variance.

Results

Field Monitoring

Elevated embryo mortalities were detected in oiled streams in 1993 (P = 0.010; Figure 3). A significant stream zone effect was also evident (P = 0.006), although no oil-by-zone interaction was found (P = 0.320). Estimated contrasts indicated

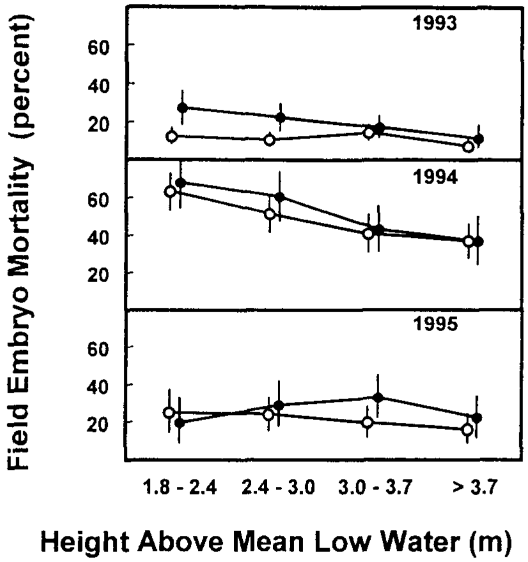

FIGURE 3.—Mean pink salmon embryo mortality observed during fall field sampling in 1993 through 1995. Solid circles indicate oil-contaminated streams ($N = 10$); open circles identify reference streams ($N = 15$); error bars represent 90% confidence intervals.

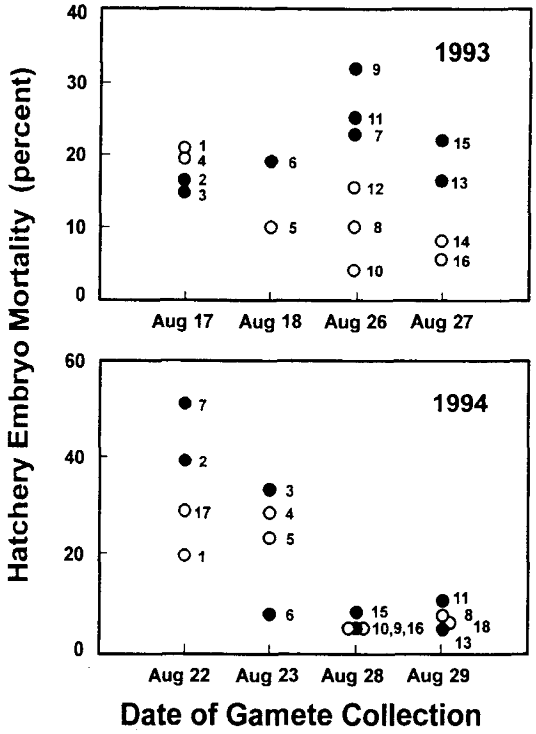

FIGURE 4.—Mean mortality of pink salmon embryos observed in the controlled incubation experiment in 1993 and 1994. Embryos were from oil-contaminated streams (solid circles) and reference streams (open circles); the number next to the circle identifies the stream location (see Figure 2).

the differences were in the two lower intertidal zones. No statistically significant difference in embryo mortality was detected in 1994 or 1995 between the oiled and reference streams ($P = 0.675$ and 0.4894, respectively; Figure 3). A significant zone effect was detected in 1994 ($P = 0.001$) but not in 1995 ($P = 0.280$), and there was no evidence of an oil-by-zone interaction for either year ($P =$ 0.801 and 0.318, respectively).

Controlled Incubation Experiment

In 1993, gamete collection and subsequent fertilizations began on August 17, when four streams were sampled. Only two streams were sampled the following day due to the low number of ripe fish in the remaining study streams. Sampling was postponed until August 26, at which time ripe fish were plentiful, and six streams were sampled. Four streams were sampled the following day to complete the mating scheme. A modification of the incubator loading scheme was made for the August 26 sampling to accommodate the change from four streams to six streams. The randomized loading design was maintained, but only 18 replicate samples from the embryo pool were collected for four streams and 12 replicate samples for two streams. Embryo mortality was scored at the eyed stage on September 17, 20, 28, and October 2 for the 4 d of sampling, respectively.

Significantly elevated embryo mortalities were observed for the oil-contaminated streams ($P =$ 0.012; Figure 4). Stream-specific estimates of embryo mortality were precise (Table 1), and average mortalities were 0.21 for oiled and 0.12 for reference streams.

In 1994, four streams were sampled each day (August 22, 23, 28, and 29), and embryo mortality was scored at the eyed stage on September 22, 25, 27, and 29, respectively. No significant difference in embryo mortality was observed ($P = 0.308$; Figure 4). Stream-specific estimates of embryo mortality were again precise (Table 1), and average mortalities were 0.20 for oiled and 0.15 for reference streams.

Discussion

The lack of an accurate and precise estimate of oil exposure was common to many field studies designed to evaluate the effect of the *Exxon Valdez* oil spill on animal populations. Streambed oiling was patchy rather than uniform. This observation

TABLE 1.—Estimated mean embryo mortality and corresponding SE for pink salmon embryos incubated at the Armin F. Koernig hatchery in 1993 and 1994; N is the number of embryo samples (about 580 embryos/sample).

Date of collection	Stream[a]	Treatment[b]	Embryo mortality Mean	SE	N
		1993 incubation experiment			
Aug 17	1	R	0.20	0.005	24
	2	O	0.16	0.006	24
	3	O	0.15	0.029	24
	4	R	0.20	0.036	24
Aug 18	5	R	0.10	0.006	24
	6	O	0.19	0.009	24
Aug 26	7	O	0.22	0.005	18
	8	R	0.11	0.006	18
	9	O	0.32	0.010	18
	10	R	0.04	0.004	18
	11	O	0.25	0.013	12
	12	R	0.16	0.007	12
Aug 27	13	O	0.17	0.011	24
	14	R	0.08	0.005	24
	15	O	0.12	0.023	24
	16	R	0.06	0.005	24
		1994 incubation experiment			
Aug 22	7	O	0.51	0.004	24
	17	R	0.29	0.005	24
	2	O	0.39	0.005	24
	1	R	0.20	0.003	24
Aug 23	3	O	0.33	0.004	24
	4	R	0.28	0.005	24
	5	R	0.23	0.004	24
	6	O	0.08	0.003	24
Aug 28	16	R	0.04	0.002	24
	15	O	0.08	0.003	24
	10	R	0.04	0.002	24
	9	O	0.04	0.002	24
Aug 29	13	O	0.05	0.002	24
	8	R	0.07	0.003	24
	11	O	0.10	0.004	24
	18	R	0.06	0.003	24

[a] Stream locations are depicted by stream number from Figure 2.
[b] Treatment R indicates reference streams; treatment O indicates oil-contaminated streams.

is supported by the results of Brannon et al. (1995), in which measured PAHs fluctuated dramatically over time within oiled streams. Although they attempted to do so, Brannon et al. (1995) did not obtain a reliable estimate of field exposure. Such a measurement would have been difficult and extremely expensive to obtain.

We dealt with the lack of a quantitative estimate of streambed oiling by assigning streams to either oil-contaminated or reference categories. While our classifications were initially based on visual observations, they were reevaluated in the fall of 1989 with the results of the anadromous stream surveys conducted in southwestern Prince William Sound (Middleton et al. 1992) as well as with the data collected by the Alaska Department of Environmental Conservation–Spill Response Staff (ADEC–SRS 1989; Neff et al. 1995). With one exception, our characterization of contamination is identical to that of Brannon et al. (1995) for the nine streams present in both studies.

Field Monitoring

Elevated pink salmon embryo mortality observed in oil-contaminated streams in 1993 was consistent with previous significant differences observed annually from 1989, the year of the oil spill, through 1992 (Bue et al. 1996). No statistically detectable difference in embryo mortality was observed in 1994 or 1995, suggesting that the influence responsible for the elevated mortality was reduced.

Controlled Incubation Experiment

In our controlled incubation experiment, we detected elevated embryo mortalities in 1993 but not in 1994 for populations of pink salmon from oil-contaminated lineages. Because the field data agree with data from the controlled incubation, we concluded that naturally occurring variation in the environment could not explain the systematic significant differences in embryo mortality that persisted in post–oil spill generations.

Embryo mortalities observed in the controlled incubation experiment were slightly higher than would be expected in a production hatchery (average mortalities for the controls in 1993 and 1994 of 12% and 15%, respectively). We attributed this higher mortality to the increased handling of gametes required to make the crosses. Both oiled and reference groups were treated identically and replicated. Consequently, the difference between oiled and reference groups was of interest rather than the level of overall mortality.

Long-Term Effects

Pink salmon that spawned during the fall of 1991 were from the 1989 brood year, the brood year that incubated in oiled gravels during the fall of 1989 and spring of 1990. The 1993 and 1994 embryos were the progeny of the 1991 and 1992 broods, respectively. Continuing embryo mortality through 1993 suggests that exposed pink salmon either experienced damage to their germ line in 1989 and 1990 or that the toxicity of the oil persisted through 1991 at a level capable of causing physiological dysfunction.

That genetic damage to pink salmon populations may have occurred as a result of the *Exxon Valdez* oil spill should not be surprising. Major chromosomal aberrations were observed in rodents inhabiting a petrochemical-polluted site (McBee and Bickham 1988). Polycyclic aromatic hydrocarbons are known to cause a variety of genotoxic responses in a variety of organisms including teleosts (Kocan and Powell 1985; Fong et al. 1993; reviewed in Van Beneden and Ostrander 1994). The link between oil pollution and damage to somatic genes is of concern for the immediate generation of the oiled population (Longwell 1977; Daniels and Means 1989; Brown et al. 1996; Hose et al. 1996). But until now, the connection has not been made between the detection of somatic damage and the possible occurrence of germ line genetic damage that may affect the viability of affected populations generations after a pollution event.

Interestingly, germ line genetic damage would probably persist in populations of pink salmon for more generations than it would in other vertebrates. Salmonids share a recent tetraploid ancestry through a gene duplication event approximately 25–100 million years ago (Ohno et al. 1969; Allendorf and Thorgaard 1984). Although some duplicate loci in salmon have been lost (Allendorf 1978; Allendorf et al. 1984), many loci are redundant, thereby masking deleterious recessive alleles. Putative lesions caused by crude-oil constituents might fail to express phenotypically until genetic assortment occurs in subsequent generations (Ohno 1970).

The possibility that the elevated embryo mortalities were due to physiological changes in pink salmon exposed to crude oil remaining in sediments in and around streams has not been assessed. Oil has been shown to have adverse effects on fish reproduction (Truscott et al. 1983; Thomas and Budiantara 1995), although these studies were conducted by treating mature fish with oil and then evaluating for differences in sexual maturation, levels of reproductive hormones, and oocyte development between treated and control fish. We found no completed studies in which embryos were treated and later evaluated for reproductive success. There is evidence that oil was in the intertidal environment in Prince William Sound in 1991 (Babcock et al. 1996), and cytochrome P-450 induction in pink salmon alevins was detected during the spring of 1991 in areas of streams oiled in 1989 (Wiedmer et al. 1996). These two studies indicate that oil was available to pink salmon in 1991 and that some exhibited a physiological response to an oiled environment (Tuvikene 1995).

We would like to reiterate that the field work described in this study and in Bue et al. (1996) was based on observational data, and we cannot definitively prove that crude oil was directly responsible for the elevated mortalities in oil-contaminated streams. We do believe there is strong evidence to suggest that the significant differences in embryo mortalities observed in 1993 were due to a parental effect. This work raises many questions concerning the effect of crude oil on reproductive potential that should be evaluated through controlled experiments. Finally, we also believe this work points to the need for long-term monitoring, beyond the generation immediately affected by a pollution event.

Acknowledgments

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