Exxon Valdez Oil Spill
Restoration Project Annual Report

Otolith Marking of Pink Salmon in Prince William Sound Salmon Hatcheries, 1997

Restoration Project 97188
Annual Report

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

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Study History: Hatchery and wild stocks in Prince William Sound salmon fisheries have been assessed by an extensive coded wire tagging program administered through Exxon Valdez oil spill projects Fish/Shellfish Study Number 3, Restoration Study Number 60A, and Restoration Projects 93067, 94320B, 95320B, 96186, and 97186. As a result of the expense of applying coded wire tags and the need for assumptions pertaining to tag loss, a thermal mass marking technique has been developed. Thermal marking of otoliths is a relatively new technology in which specific patterns can be laid down on the otoliths of incubating fish. The technique promises to improve the precision and accuracy of estimation of hatchery contributions. The otolith thermal mark program was supported through Restoration Projects 95320C, 96188 and continued through 97188, the subject of this report. FY98 is the last field season for this project and final data analysis and reports will be written in FY99.

Abstract: In the fall of 1995, 1996, and 1997, base thermal marks were applied to the otoliths of all hatchery pink salmon in Prince William Sound, Alaska. Otolith marks were highly visible on voucher samples taken from hatchery fry in the spring of 1998. In 1996 and 1997, accessory thermal marks were applied after fry hatched and allowed identification of within-hatchery treatment groups. A double-blind test was conducted to assess the ability of laboratory personnel to correctly identify otolith marks laid down in 1996. The test indicated that the probability of a successful identification was about 0.994. Catch-sampling and estimation protocols, developed by projects R95320C and R96188, were used to estimate the contribution of hatchery fish to the Prince William Sound pink salmon commercial fisheries of 1997. Preliminary estimates of the stock composition of an area-time specific catch were available within 24 hours after a fishery closure.

Key Words: Commercial harvest, hatchery, *Oncorhynchus gorbuscha*, otolith, pink salmon, Prince William Sound, thermal mark, wild stock, voucher sample.

Project data: Data pertaining to the double blind test are stored in Microsoft Excel™ worksheets, ASCII files, and a Microsoft Access™ database. Data pertaining to hatchery contribution estimates are stored in Excel™ worksheets and an Access™ database. Software code used to analyze the data (SAS™, Gauss™) is available in ASCII format.

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EXECUTIVE SUMMARY

This report documents Restoration Study 97188, one of the projects designed to restore the pink salmon *Oncorhynchus gorbuscha* resource of Prince William Sound to its pre-spill status. Four objectives were outlined for this study. The first objective, to apply unique and distinct thermal marks to the otoliths of developing pink salmon embryos at all four pink salmon hatcheries in Prince William Sound, was met in the fall of 1997, using equipment purchased and installed in 1995. The second objective, to measure the quality and uniqueness of otolith marks applied in 1996 was met upon completion of the double-blind test in which laboratory personnel successfully identified the origin of otoliths from hatchery and wild fry 99.4% of the time. It is reasonable to assume that recovered otoliths can be identified with negligible error. The third objective, to estimate stock composition of commercial catches of pink salmon using thermal marks, was met during the 1997 season. The fourth objective, to evaluate the quality of stock estimation procedures, was met upon analysis of the precision of estimates of stock contribution, of the availability of the estimates to managers, and of the success of otolith identification methods. Usefully narrow confidence intervals for estimated hatchery contribution to an area-time stratum were obtained, and the estimates were made available to fishery managers within 24 hours of the closure of the fishery. The negligible error encountered upon reading recovered otoliths contributed significantly to the managers' acceptance of the method, and hence its use in management of the fishery.

INTRODUCTION

Between 1961 and 1976, when hatcheries were absent from Prince William Sound, the commercial seine harvest of wild pink salmon *Oncorhynchus gorbuscha* averaged about 3.4 million fish. In the early 1970's, run failures led to an aggressive enhancement program that included construction of hatcheries. By 1986, five hatcheries were operating: Solomon Gulch hatchery, producing pink salmon, and later, also chum *O. keta*, coho *O. kisutch* and chinook salmon *O. tschawytscha*; A. F. Koernig hatchery, producing pink salmon; W. H. Noerenberg hatchery, producing pink salmon, and later, also chum, coho and chinook salmon; Cannery Creek hatchery, producing pink salmon; and Main Bay hatchery which produced chum and presently raises sockeye salmon *O. nerka*. From the late 1980's to the present, returns to these facilities have contributed approximately 20 million pink salmon to the annual run.

Hatchery parent stocks were selected from populations indigenous to Prince William Sound, resulting in a similar migratory timing of adult hatchery and wild runs. Furthermore, all of these stocks migrate to their natal streams or hatcheries through corridors in the southwestern and western areas of Prince William Sound. Since both the timing and migratory corridors of the large hatchery runs and the much smaller wild runs are similar, there is a danger of overexploiting the latter. Indeed, shortfalls in wild escapements occurred in more than half of the 15 years prior to hatchery production, when the average exploitation rate was 42%, a figure considerably lower than the 80% considered appropriate for today's returning hatchery salmon.

To protect wild stocks in the mixed-stock fishery, managers needed information pertaining to the temporal and spatial distributions of hatchery and wild salmon. In 1986, a coded wire tagging program was initiated for hatchery releases of pink salmon, with the first recoveries of tagged, returning adults in the commercial and cost recovery fisheries beginning in 1987. Such tag recovery data enabled managers to obtain estimates of hatchery and wild contributions to catches from selected temporal and spatial strata within the fishery.

The March 24, 1989, *Exxon Valdez* oil spill exacerbated the problems faced by fishery managers. The spill contaminated tidal portions of streams where most wild pink salmon stocks in western Prince William Sound spawn as well as the marine waters traversed by juvenile salmon on their migration seaward. Detrimental effects have been found from oil contamination upon pink salmon embryos, pre-emergent fry, and juvenile salmon in wild populations (Bue et al.,1996, Willette and Carpenter, 1994). The decisions made by fishery managers suddenly became more complex since they now affected wild populations injured by the oil spill.

The coded wire tagging program was continued after the spill and was funded by Natural Resource Damage Assessment study F/S 3 through 1991 (Sharr et al., 1995a). During this period, the program continued to provide information pertaining to the stock composition of the commercial salmon catch. The pink salmon tagging program was supported from 1992 through 1996, by Restoration Studies R60A (Sharr et al. 1995b), R93067 (Sharr et al. 1995c), R94320B (Sharr et al. 1995d), R95320B (Riffe et al. 1996),and R96186 (Riffe and Evans, 1997), along with contributions from the Prince William Sound Aquaculture Corporation, Valdez Fisheries Development Association and the State of Alaska.

Coded wire tag hatchery contribution estimates are based on several assumptions. The most contentious of these pertain to an adjustment factor used to account for differential mortality and tag-shedding. Adjustment factors are calculated based on the assumptions that 1) brood ponds contain only salmon reared at the hatchery in question, and 2) for a given cohort, the tagging rate calculated for the brood stock is equal to that experienced in the commercial fishery. Immigration of wild fish into brood stocks may occur (Sharr et al. 1995c), which would inflate catch estimates of hatchery salmon, and tags may induce straying (Habicht, 1996), which would inflate estimates of wild stocks. In light of these studies, it became clear that hatchery contribution estimates based on coded wire tags may be flawed, and an alternative marking technology was sought.

Munk et al. (1993), Mosegard (1987) and Volk (1990) have demonstrated that chinook, coho, sockeye, chum, pink, and Atlantic salmon *Salmo salar* otoliths in embryos can be marked by carefully controlled changes in water temperature, while Hagan et al. (1995) have successfully incorporated the technology into a mixed stock fisheries assessment program. In 1995, 1996, and 1997 thermal marks were applied to the otoliths of all pink salmon incubating in Prince William Sound hatcheries, with support from R95320C, R96188, and R97188 respectively. Application of otolith marks is cheaper than that of coded wire tags, and use of otolith marks eliminates problems associated with tag loss and differential mortality. In 1997, simultaneous recovery of coded wire tags and thermally marked otoliths allowed us to examine some of the assumptions made in the coded wire tag program.

In the otolith program, every salmon receives a thermal mark, and the proportion of the catch that must be examined for a given level of precision is considerably smaller than that needed in a coded wire tag program, where only about 2% of released salmon are marked. However, when sample sizes are small, issues concerning representative random sampling and correct identification of otolith origins become very important. Aspects of the sampling methodology used for recovering marked otoliths from commercial harvests was tested by Joyce et al. (1996 and 1997) through assessment of tender-mixing capabilities and comparison of sample estimates of the proportions of externally marked salmon to known population proportions aboard tenders. The results of the studies were incorporated into the sampling methodology used to recover thermally marked otoliths from the 1997 fishery.

This report documents application of thermal marks for the 1997 brood year salmon, presents an early assessment of mark quality for those marks, reports results of a blind test of readability of marks laid down in 1996, and records the first use by fishery managers of otolith-generated estimates of pink salmon stock composition in Prince William Sound.

OBJECTIVES

1. To apply unique and distinct thermal marks to the otoliths of developing pink salmon embryos at all four pink salmon hatcheries in Prince William Sound.

2. To measure the quality and uniqueness of otolith marks applied in 1996, and to identify problems pertaining to specific mark assignments.

3. To estimate the stock composition of the commercial catches and hatchery brood stocks in 1997 using otolith thermal marks.

4. Evaluate the quality of stock-estimation procedures.

METHODS

Application of Thermal Marks to brood year 1997 pink salmon

Thermal base marks were laid down after the primordial stage of otolith development (approximately 275 TU) or, equivalently, at the 'eyed' stage, and before hatching. Methods followed those of Munk et al. (1993). Accessory marks were applied after hatching to a portion of the embryos to distinguish different release treatments. Each ring within a mark was created by a temperature-induced modification of the rate of deposition of otolith material. This modification was accomplished by raising the ambient temperature of the incubation water for 24 hours by 4 ^{o}C, and then rapidly returning it to its original value, where it remained for another 24 hours before instigation of the next ring. Later in the season as the ambient temperature dropped, 36-hour, alternating cycles were used at the Cannery Creek and W.H. Noerenberg hatcheries to insure proper spacing between rings. Marking schedules were staggered for pairs of incubators so that the oil-fired boilers ran continuously. This schedule marked the maximum number of embryos in the shortest time.

The thermal marks were classified according to a "Region, Band, and ring" (RBr) code, written numerically as 'R:B.r' (Munk *(in prep.)*). Thermal mark codes are shown in Table 1.

Table 1 Thermal mark codes and associated thermal schedules.

Hatchery	Schedule	R:B.r	Ring pattern	
A.F.Koernig	(4X)24H:24C Base	1:1.4	IIII	
	…(3X)24H:24C Accessory	1:1.4+2.3	IIII	III
Cannery Creek	(3X)24H:24C,(1X)72H: 36C,2(X)24H:24C	1:1.3,2.3	III III	
W.H. Noerenberg	(8X)24H:24C Base	1:1.8	IIIIIIII	
	…(3X)24H:24C Accessory	1:1.8+2.3	IIIIIIII	III
Solomon Gulch	(6X)24H:24C	1:1.6	IIIIII	

Prince William Sound hatchery base marks appear on the otolith before the hatch mark, and were chosen to distinguish hatchery of origin. The W.H. Noerenberg and A.F. Koernig facilities also applied accessory marks that differentiate size at release. The accessory marks were applied after the hatch mark.

Voucher samples were taken at the time of emergence from each lot at each hatchery so that thermal mark codes could be verified, and any confounding marks laid down during the remaining incubation period could be documented.

Determination of the Readability of Otoliths

Our ability to successfully determine the origin of otoliths extracted from brood year 1996 emergent pink salmon fry was measured through a double blind test conducted at the Alaska Department of Fish and Game (ADF&G) laboratory in Cordova. The extent to which readers agreed with each other regarding mark assignments was measured, and an identification matrix was constructed to highlight specific misclassification tendencies. Otoliths from returning adults were also examined (brood year 1995) and the agreement between Cordova and Juneau readers assessed. An identification matrix was also produced.

Brood Year 1996 Blind Test (Fry)

Sampling. In the spring of 1997, pink salmon fry were collected from incubators at the W.H. Noerenberg, A.F. Koernig, Cannery Creek and Solomon Gulch hatcheries, and from four streams located in Prince William Sound. The otoliths from approximately 400 hatchery and wild fry were extracted at the Cordova otolith laboratory, mounted on glass microscope slides with thermoplastic cement, and placed in slide boxes labeled by origin. Slide boxes were sent to personnel at the ADF&G Anchorage office, where slides were coded and mixed. Four boxes of one hundred coded slides were then shipped back to the Cordova otolith laboratory for identification. Coded information was not made available to Cordova personnel until after the test was concluded.

Experimental Design. In the original design, two inseason readers that will be identifying otoliths from returning adults in 1998 were to be assessed. Due to unforeseeable circumstances, one of the readers will not be available for testing until after the submission of this report. The test was administered to the one remaining inseason reader, and two other readers assigned to other projects. The latter two readers will not be identifying otoliths for inseason management purposes in 1998. The boxes of 100 slides were assigned in a random fashion to the inseason reader, who ground all otoliths. Once the inseason reader had completed the test, the boxes were assigned to the other readers. They were not permitted to grind the otoliths further. It was assumed that the inseason reader was capable of grinding an otolith to the degree that an interpretation was possible by any reader.

Along with determination of the origin of an otolith, each reader also recorded a measure of the confidence with which the determination was made. Upon completion of the readings, all determinations were sent back to the Anchorage office for analysis.

Data Analysis. The overall ability to correctly identify otoliths was determined for the tested inseason reader and the two additional readers.

The success rate for identification of a population of otoliths is defined as the probability that a reader will determine the origin of a randomly selected otolith without error. Success rates were estimated for six different populations. These consisted of the overall population of otoliths of hatchery and wild origin, the populations associated with each of the four hatcheries, and that associated with the wild population alone.

The estimated success rate for the tested reader for a population, $\hat{p}$, is calculated as

$$\hat{p} = \frac{\sum_{i=1}^{n} x_i}{n}$$

where x_i=1 if otolith i is identified correctly, and x_i=0 otherwise, and n is the number of otoliths in the test from the population in question.

To calculate an appropriate variance estimate for, $\hat{p}$, account must be taken of the variability encountered in the laboratory estimation process, and of sampling variability. The variance estimation method used in this report is somewhat different to that used in Joyce et al. (1997).

Since the tested reader will be responsible for decoding otoliths during the 1998 return, he may be considered a fixed quantity, in the statistical sense, and there is no need to incorporate a reader-to-reader variance component in the estimation of the variance of the success rate. The reader's ability is, however, likely to vary from one reading event to the next, and this should be accounted for in the estimation. The entire process was simulated using Gauss™ (1996) by first generating a binomial parameter, p^*, from a distribution describing the variability of the reader's ability to decode otoliths and then generating a success rate, $\hat{p}^*$ as X^*/n, where X^* is generated from a binomial(n,p^*) distribution. Confidence intervals for success rates are obtained using the percentile method.

Each iteration of the simulation for a given population was conducted as follows (simulated quantities are identified with '*'):

1) Simulation of inherent reader success rate. A binomial parameter p^* was generated as (1-q^*), where q^* was modeled as a lognormal($\hat{\mu},\hat{\sigma}$) distribution. The quantities $\hat{\mu},\hat{\sigma}$ were obtained from the method of moments. Nonlinear least squares was used to solve the following equations for $\hat{\mu},\hat{\sigma}$:

$$(1-\hat{p}) = e^{\hat{\mu}+\hat{\sigma}^2/2}$$

$$\hat{V}(\hat{p}) = e^{2\hat{\mu}+2\hat{\sigma}^2} - e^{2\hat{\mu}+\hat{\sigma}^2}$$

where $\hat{p}$ is the measured success rate, and $\hat{V}(\hat{p})$ is obtained from the within-reader variance component estimate made by Joyce et al. (1997).

The q^*= (1-p^*) variates were generated as $e^{\hat{\sigma}N(0,1)+\hat{\mu}}$.

2) Simulation of binomial sampling variability. A simulated number of successful determinations was generated from a binomial(n,p^*), and a simulated success rate calculated as $\hat{p}^* = X^*/n$.

For the overall simulated population, an empirical distribution function (EDF) was constructed, and 95% confidence intervals for the success rates were obtained as $EDF^{-1}(0.025)$ and $EDF^{-1}(0.975)$.

While perfect agreement between readers can occur simultaneously with complete failure in identification, the degree of consistency among readers is nevertheless an important parameter. Cohen's kappa will be used to assess agreement between the two inseason readers when both data sets are available. In the meantime, agreement between the inseason reader and the non-project readers will be assessed. This statistic compares the observed agreement to that expected if the ratings were independent, and thus accounts for agreement occurring by chance alone. For $\Gamma_o = \sum \hat{\pi}_{ii}$ and $\Gamma_e = \sum \hat{\pi}_{i+}\hat{\pi}_{+i}$, where π_{ii} is the probability of a classification in category i by both readers, and π_{+i} is the marginal probability for category i for one of the readers and π_{i+} for the other reader, Cohen's kappa is calculated as

$$\kappa = \frac{\Gamma_o - \Gamma_e}{1 - \Gamma_e}$$

The ratio is a measure of the agreement in excess of that expected by chance to the excess under perfect agreement. The distribution of κ is asymptotically normal for multinomial sampling , and 95% confidence intervals were calculated as κ +/1.96*standard error (see Agresti, 1990 for variance formula).

An identification matrix was produced in order to identify any trends in errors. A 5x5 matrix was constructed with true and observed origin describing rows and columns, respectively.

Brood Year 1995 Analyses (Adults)

A blind test in which the inseason reader was tested on adult pink salmon otoliths was attempted. Coded wire tags were to provide positive identification of adult otoliths. Pink salmon heads that contained coded wire tags were sent to the Statewide Coded Wire Tag and Otolith Laboratory (Statewide Laboratory) in Juneau where the tag and the otoliths were removed. The otoliths were then sent back to the inseason reader in Cordova, where they were to be read by the inseason readers. However, due to circumstances beyond our control, otolith identities were lost prior to slide-mounting and the test was abandoned.

Reader agreement (Cohen's kappa) was assessed between Cordova and Juneau readers using inseason and quality control second readings on adult otoliths. An identification matrix was also produced.

Reader agreement on adult otoliths was assessed between Cordova and Juneau readers from quality control second readings using Cohen's kappa. An identification matrix was also produced.

Catch-Sampling Methodology

Recovering otoliths

At the conclusion of a common property or cost recovery fishing period, otoliths were recovered by systematically sampling all available tender loads delivered to processors. The systematic samples were collected by removing otolith pairs from salmon removed from processor belts at set intervals. The time intervals used by technicians at each processor depended upon the number and speed that pink salmon were processed. Each technician used a timing device with a count-down feature that set off an audible alarm after a pre-set time had elapsed. The entire tender was sampled in this manner so that a sample was taken throughout the load. The otoliths gathered from each tender were placed in order of selection into a numbered plastic tray. If possible, all tenders participating in the district-period stratum were sampled. A weighted sample of 96 otoliths, culled from all otoliths collected after an opening, was formed using a proportional allocation scheme; each sampled tender contributed otoliths to the sample of 96 in proportion to its load. Another sample of 96 otoliths formed in a similar manner was taken and stored for possible postseason analysis using the Bayesian sampling algorithm of Geiger (1994). The total catch for that period and district, used in calculation of the weights was obtained from the ADF&G fish ticket system. The recovered sample of 96 otoliths were bar-coded and mounted for microscopic examination at the Cordova otolith laboratory. After the origin of an otolith was determined, a bar-code scanner was used to transfer the identity to an Access™ computer database. Upon completion of identification of the inseason sample, hatchery contributions were estimated. Otoliths were recovered in a similar manner from hatchery brood stocks and were identified as described above. A total daily count of the pink salmon spawned was used in place of the catch, and a weighted sampled of 300 - 500 otoliths was eventually taken from each hatchery brood stock.

Preliminary hatchery contribution estimates in a district-period stratum were generated from the first reading of the 96-otolith sample. A second reading was made on these otoliths blind to the first reading approximately two weeks later at the Statewide Laboratory in Juneau. In cases of discrepancy between the two readings, the Juneau laboratory supervisor made a third read to determine the correct identification. Any reading errors found in the quality control process were corrected in the database and the contribution number recalculated postseason.

Estimating Hatchery Contributions with Otoliths

The otolith-derived estimate of the contribution of hatchery *h* to district-period stratum *i*, C_{hi} was made as follows:

$$\hat{C}_{hi} = \frac{o_{hi}}{n_i} N_i$$

where,

o_{hi}	=	Number of otoliths from hatchery *h* in sample n_i
n_i	=	Number of otoliths sampled from stratum *i* (usually 96)
N_i	=	Number of fish caught in stratum *i*.

Otolith-derived estimates of the contribution of hatchery *h*, C_{Sh}, to all sampled common property, cost recovery, and special harvests and brood stocks, were calculated as follows:

$$\hat{C}_{Sh} = \sum_{i=1}^{Q} C_{hi}$$

where,

Q = Number of recovery strata associated with common property, cost recovery, brood stock, and special harvests in which otoliths from hatchery *h* were found.

An estimate of the contribution by hatchery *h* to unsampled strata (very few), $\hat{C}_{Uh}$, was made in a manner similar to that for the coded wire tagging program (Riffe et al., 1996).

An estimate of the contribution by hatchery *h* to all strata, sampled and unsampled, is given by

$$\hat{C}_h = \hat{C}_{Sh} + \hat{C}_{Uh}$$

A variance estimate for $\hat{C}_h$ is given by:

$$\hat{V}(\hat{C}_h) = \sum_{i=1}^{Q} \frac{N_i^2 o_{hi}}{n_i^2}\left(1 - \frac{o_{hi}}{n_i}\right)$$

There were very few unsampled strata and the variance associated with $\hat{C}_{Uh}$ is assumed negligible.

For any sampled stratum, the sample size was such that the estimate of the proportion of the catch comprised of hatchery fish was made such that there is at least a 95% chance that it is within 10% of the true proportion. When combined over strata, the precision of the estimated hatchery contribution improves.

Estimating Survival Rates with Otoliths

An estimate of the survival rate for hatchery *h*, S_h, was made from otolith recoveries as follows:

$$\hat{S}_h = \frac{\hat{C}_{Sh} + \hat{C}_{Uh}}{R_h}$$

where,

R_h = Number of pink salmon released from hatchery *h in 1996*..

An approximate variance of $\hat{S}_h$ is given by:

$$\hat{V}(\hat{S}_h) = \frac{\sum_{i=1}^{Q} \frac{N_i^2 o_{hi}}{n_i^2}\left(1 - \frac{o_{hi}}{n_i}\right)}{R_h^2}$$

There were very few unsampled strata and the variance associated with $\hat{C}_{Uh}$ is assumed negligible.

RESULTS

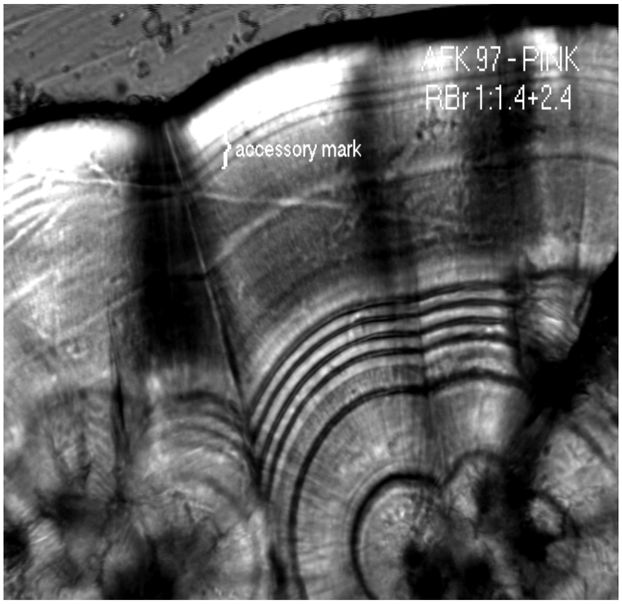
Application of Thermal Marks to Brood Year 1997 Pink Salmon

Incubation water temperatures were maintained at 3.8^o to 4.0^{o}C above ambient at all of the Prince William Sound hatcheries when required by the marking schedule. When marking system problems occurred, they were fully documented by hatchery staff and the Statewide Laboratory was notified. Modifications to mark schedules were made when appropriate, resulting in only minor variations to base marks. None of these modifications compromised mark integrity of any hatchery base mark.

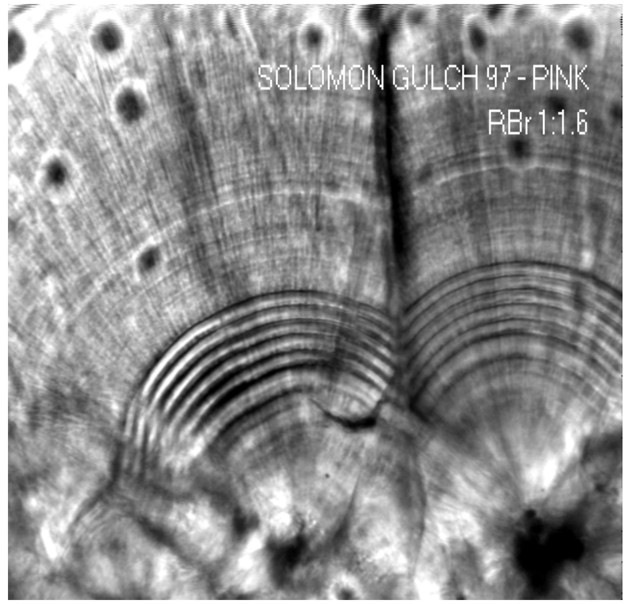
All of the embryos to be released at the A.F. Koernig hatchery were spawned at the W.H. Noerenberg hatchery. Once the embryos had reached the ‘eyed’ stage of development, they were transported by barge to the A.F. Koernig facility where they were immediately loaded into incubators and started on their thermal marking regime. Temperature fluctuations in the hold of the transporting barge led to additional rings being laid down on the otoliths. The result is an A.F. Koernig hatchery pink salmon with a base mark otolith pattern very similar to the Solomon Gulch hatchery base mark pattern. Subtle differences in the two patterns along with temporal and spatial separation between these two hatchery returns will provide a method for proper identification in the adult returns of 1998.

Samples taken three weeks after completion of the marking process revealed that high quality thermal marks had been laid down at each of the four hatcheries (Figure 1).

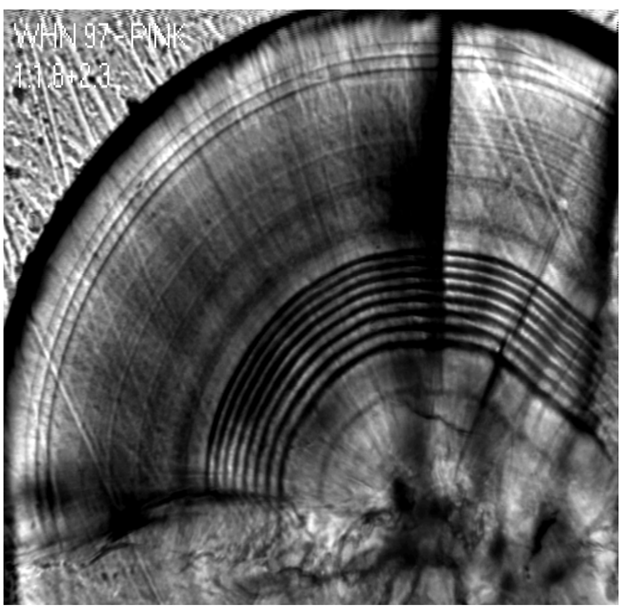
Figure 1 Thermally-marked pink salmon otoliths sampled from Prince William Sound hatcheries in 1997 (brood year 1997).



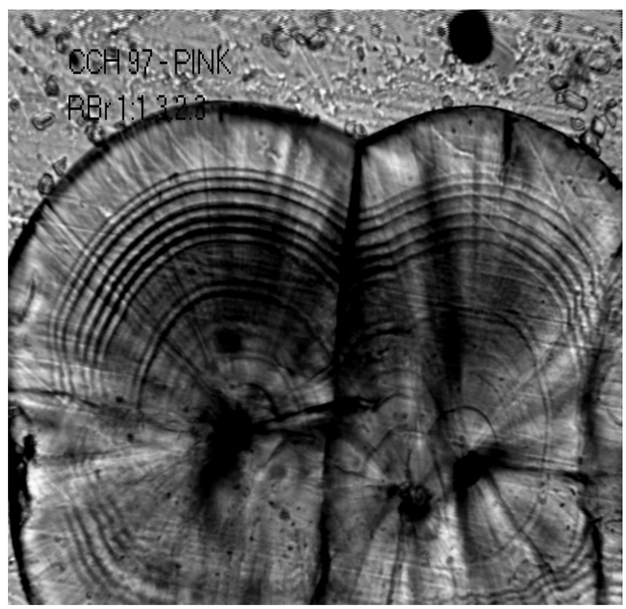
A.F.Koernig – 97 with accessory mark



Solomon Gulch – 97



W.H. Noerenberg – 97 with accessory mark



Cannery Creek - 97

Brood Year 1996 Blind Test (Fry)

The estimated overall success rate for the inseason reader was 0.995 (0.974, 1.000). For a reader having no ability to determine the origin of an otolith on a slide, the expected success rate is 0.20 (five choices for each slide). The overall success rates for the two readers not responsible for identifying otoliths in 1998 were 0.997 and 0.989.

The overall success rate improved when calculated on a hatchery-wild distinction, and reached 0.997 for the inseason reader. No confidence intervals were calculated for this measure.

Estimated success rates and 95% confidence intervals by origin of otolith ranged from 0.980{0.922, 1.000) for W.H. Noerenberg otoliths to 1.000 for A.F. Koernig and Cannery Creek otoliths. (Table 2).

Table 2 Measured success rates by origin of otolith.

Origin[a]	Lower 95%	Point Estimate	Upper 95%
AFK	NA	1.000	NA
CC	NA	1.000	NA
SG	0.957	0.989	1.000
WN	0.922	0.980	1.000
WILD	NA	1.000	NA

a AFK=A.F. Koernig; CC=Cannery Creek; SG=Solomon Gulch; WN=W.H. Noerenberg.

Measures of agreement between readers ranged from 0.982 (between non-project readers) to 0.989 (Table 3).

Table 3 Agreement between readers[a]. Single entries are values of Kappa.

Reader	B	C
A	0.986	0.989
B		0.982

a: A=Inseason reader; B,C=Non-project readers.

The identification matrix is almost diagonal, and reflects the high success rates. The matrix is shown in Table 4.

Table 4 Identification matrix for the blind test[a] (inseason reader).

		OBSERVED				
	ORIGIN	AFK	CC	SG	WN	WILD
	AFK	49	0	0	0	0
TRUE	CC	0	50	0	0	0
	SG	0	0	93	1	0
	WN	0	0	0	50	1
	WILD	0	0	0	0	148

a AFK=A.F. Koernig; CC=Cannery Creek; SG=Solomon Gulch; WN=W.H. Noerenberg.

Brood Year 1995 Analyses (Adults)

During the 1997 pink salmon season, 10,660 otoliths were identified at the Cordova otolith laboratory. Out of this total, 7,426 otoliths were read a second time at the Juneau Statewide Laboratory as a quality control measure. A total of 54 discrepancies (0.7%) were found and later confirmed by a third experienced reader. The most common error involved misidentification of a Cannery Creek hatchery otolith by Cordova readers as a W.H. Noerenberg hatchery otolith (Table 5). Cohen’s kappa for the Juneau-Cordova comparison is 0.991 (0.988, 0.993).

Table 5 Identification matrix for the Cordova *vs.* Juneau readers[a].

		Juneau				
	Origin	AFK	CC	SG	WN	WILD
	AFK	1033	2	1	2	0
Cordova	CC	0	1227	0	1	2
	SG	4	1	2390	5	2
	WN	0	19	3	2181	1
	WILD	2	0	7	1	542

a AFK=A.F. Koernig; CC=Cannery Creek; SG=Solomon Gulch; WN=W.H. Noerenberg.

Otolith-Derived Hatchery Contributions to the 1997 Pink Salmon Harvest

General

The estimated pink salmon return to Prince William Sound in 1997, including the Copper and Bering river districts was 28.31 million fish. The common property harvest was 15.98 million while the cost recovery fishery harvested another 9.82 million. In addition, 1.09 million were taken as brood stock and 1.42 million naturally escaped into index streams. The total harvest in Prince William Sound was 25.80 million fish.

The A.F. Koernig hatchery produced the largest pink salmon return this season (6.95 million fish). The Solomon Gulch facility was the second highest producing hatchery with a documented return of 6.79 million fish. However, because of a fishermen's strike towards the end of the Solomon Gulch return an estimated 300,000 pink salmon went unharvested and died near the Solomon Gulch hatchery. If these fish had been accounted for in the harvest then the Solomon Gulch hatchery production would have exceeded the return of the A.F. Koernig hatchery. The W.H. Noerenberg hatchery had a return of 6.19 million fish, followed by the Cannery Creek hatchery, which was responsible for a return of 5.78 million fish (Table 6). At the Cannery Creek facility, there were an additional 180,000 pink salmon which escaped into the stream adjacent to the hatchery because of flooding.

Common Property Harvest

All otolith-derived contributions to the common property harvest were calculated by district and period. In 1997, pink salmon produced by the Solomon Gulch hatchery comprised the largest portion of the common property harvest (Table 6). The remaining common property harvest was produced, in order of abundance, by the A.F. Koernig, Cannery Creek, and W.H. Noerenberg hatcheries. Production from wild systems was the smallest contingent of the return. In general, the largest contributor to a district was the nearest hatchery producing pink salmon. Appendix A lists the hatchery contribution to the common property catch by district and period.

The hatchery contribution estimates presented in all appendices include those adjusted with post season samples. In the common property fishery, 11 periods out of 68 were adjusted with post season samples. Six of these periods occurred in the Eastern District, one in the Northern district and four in the Southwestern district. The largest postseason change occurred in the ninth period of the Eastern District when the hatchery contribution increased five percent from the inseason estimate.

Cost Recovery Harvest

Cost recovery harvests were stratified by statistical week (Appendix B). Daily harvests were not sampled in all cases, so a number of daily strata had to be combined. In general, contributions to cost recovery harvests from hatcheries other than the one of origin were small. Main Bay hatchery was a notable exception. Since Main Bay hatchery produces only sockeye salmon, the 38.9 thousand pink salmon sold in their cost recovery operation originated from other locations. The pink salmon cost recovery harvest contribution by the A.F. Koernig hatchery was the highest at 3.21 million. The remaining hatchery cost recovery contributions of pink salmon are in the following order of abundance: Solomon Gulch, 2.42 million; W.H. Noerenberg, 2.21 million; Cannery Creek, 1.86 million and wild fish, 0.07 million (Table 6).

Brood Stock Harvest

Only three hatcheries used brood stocks in Prince William Sound in 1997. Embryos incubated at the A.F. Koernig hatchery were spawned at the W.H. Noerenberg hatchery and later transferred after reaching the “eyed” stage of development. Hatchery brood stocks included all fish that were processed at the hatchery, and included fish in which the roe was removed for sale rather than incubation. The W.H. Noerenberg hatchery processed the highest number of pink salmon for brood stock followed by Solomon Gulch and Cannery Creek (Table 6).

Table 6 Pink salmon contribution by hatchery to Prince William Sound fisheries and brood stocks (millions of fish)

Harvest	Estimate	Lower 95%	Upper 95%
Common Property			
Solomon Gulch	4.005	3.937	4.074
Cannery Creek	3.608	3.492	3.724
W.H. Noerenberg	3.464	3.326	3.603
A.F. Koernig	3.815	3.677	3.954
Wild	1.089	.986	1.192
Cost Recovery			
Solomon Gulch	2.428	2.408	2.448
Cannery Creek	1.852	1.827	1.878
W.H. Noerenberg	2.321	2.295	2.347
A.F. Koernig	3.139	3.104	3.174
Wild	0.075	.042	.107
Rack Return			
Solomon Gulch	0.356	0.354	0.359
Cannery Creek	0.319	0.316	0.323
W.H. Noerenberg	0.409	0.406	0.413
A.F. Koernig	0		
Wild	0.0029	0.0005	0.0053

Wild stock contributions were only found in the Solomon Gulch hatchery brood stock and comprised less than one percent of the number used at that hatchery (Appendix C). Table 7 indicates the proportion of fish used at a hatchery that originated from some other location.

Table 7 Brood Stock Composition

Origin[a]	Brood Stock SG(n=524)	CC(n=288)	WN(n=350)
AFK	0	0	0
CC	0	0.993	0.003
SG	0.992	0	0
WN	0	0.007	0.997
WILD	0.008	0	0

a AFK=A.F. Koernig; CC=Cannery Creek; SG=Solomon Gulch; WN=W.H. Noerenberg.

Survival Rates

Contrary to recent years, the pink salmon survival rate associated with the A.F. Koernig hatchery was the highest overall at 6.40% (6.27,6.53); that associated with the Cannery Creek hatchery was 4.12% (4.03,4.20), which was slightly higher than the 3.65% (3.57,3.74) survival rate associated with the W.H. Noerenberg hatchery. The survival rate of fish released from the Solomon Gulch hatchery was the lowest at 3.04% (3.01,3.08).

DISCUSSION

Application of Thermal Marks to brood year 1997 pink salmon

High quality marks are one of the prerequisites to the successful implementation of an otolith marking program intended to separate hatchery and wild stocks. Preliminary sampling of otoliths indicates that such marks were indeed placed on the otoliths of all brood year 1997 pink salmon embryos produced by Prince William Sound hatcheries. Further voucher samples, and a blind test to be conducted in 1998 will yield a more detailed view of the nature and success of the marking process.

Determination of the Readability of Otoliths

With regards to brood year 1996 pink salmon, it was reassuring to find that the inseason reader was able to correctly identify otoliths of unknown origin in a blind test 98% to 99% of the time, and that reader agreements between the inseason reader and two readers associated with other projects were in the range 0.982 to 0.989 (perfect agreement is 1.0). It is also interesting that the latter readers were considerably less experienced than the inseason reader and yet were still capable of successfully identifying otoliths 99.7% and 99.0% of the time.

Knowledge of thermal patterns that caused inaccurate determinations in the blind test will be used to help readers working on otoliths extracted from adults returning in 1998. If errors occur in identification of adult otoliths in the 1998 fishery, they are likely to consist of misidentification of W.H. Noerenberg otoliths as Cannery Creek otoliths. A similar type of prediction made from the blind test last year (Joyce et al., 1997), however, appears to have been pessimistic. Last year's blind test using brood year 1995 pink salmon indicated that in the 1997 fishery the most likely errors would be misidentification of Solomon Gulch fish for Cannery Creek fish, wild fish for A.F. Koernig fish and Cannery Creek fish for W.H. Noerenberg fish. Comparison of inseason readings (Cordova) with those made by more experienced readers (Juneau), suggested, however, that the Cannery Creek/W.H. Noerenberg error was the only one of any significance

The success rates for marks established in brood year 1996 were as high as those laid down in brood year 1995 (Joyce et al., 1997) and we expect success rates for identification of adult otoliths in the 1998 fishery to be similar to those seen for the 1997 fishery. The first-reader errors associated with the 1997 adults were less than predicted from the blind tests conducted with the same brood year fry. One possible explanation is that the readers became familiar with the marks and their permutations very quickly and were able to identify marks that were misidentified early in the season. In fact, a third of the errors in first-read identification, as determined from quality control readings, occurred in the first two fishing periods. Success rates better than indicated by blind test results are again expected in 1998, although to a lesser degree, as readers had considerable experience looking at the brood year 1996 otoliths prior to participating in the blind test.

The results of the blind test provide us with a high degree of confidence that accurate estimates of the contribution of hatchery pink salmon to the commercial fishery in 1998 can be made from identification of recovered otoliths. While success rates in identification have been very high to this point, there is no guarantee that this will always be the case, and it is stressed that blind testing of marks will be required each year.

Otolith–Derived Hatchery Contributions to the 1997 Pink Salmon Harvest

Estimates of hatchery contributions derived from otolith sampling in the common property and cost recovery fisheries were more precise, were available sooner, and were viewed with greater confidence than those provided by the coded wire tag program. For some important strata, information regarding the prevalence of hatchery fish was available prior to conducting a common property fishery. These factors, discussed in more detail below, enhanced the management biologist's knowledge, and enabled him to harvest excess hatchery stocks without impacting wild stocks with a greater efficiency than ever before.

The rapid turn-around time from the end of a fishing period to provision of an estimated hatchery contribution to the manager was largely a function of the proximity of the inseason otolith laboratory to the site of otolith collection. Otoliths sampled from a fishery were routinely read at the Cordova laboratory within a matter of hours. For the coded wire tag program, estimates formed from facility-specific expansions were only available after tags were shipped to Juneau and decoded in the Statewide Laboratory. Fully adjusted estimates from the coded wire program were only available postseason, when brood stocks had been sampled, and account taken of tag loss and differential mortality.

The high degree of confidence associated with otolith-derived estimates originates in large part from the assumption-free nature of the estimation procedure. The application of a nonintrusive, permanent mark to all of the fish released from a hatchery has eliminated the need for the much-maligned adjustment factor used in the coded wire tag program. Otolith thermal marks cannot be lost and the nonintrusive nature of the mark precludes the problem of differential mortality. Further, there are no concerns over mark-induced straying. An additional feature of the otolith program which enhanced its general appeal, and therefore the confidence in which generated estimates were held, is the highly efficient data-tracking mechanism built into the project. The data-management facilities, incorporated into the local system by personnel from the Statewide Laboratory in Juneau, functioned extremely effectively and data summaries and updates were executed with few problems. While there are few assumptions associated with the marking aspect of the program, it should be emphasized that the otolith program will only generate unbiased estimates if representative samples are taken from the fishery. Since estimates can be generated from as few as 100 fish, constant attention to the sampling methodology used to derive them is needed. Post season sampling had little effect on inseason estimates, and would have had no influence on management decisions. None of the post season estimates fell outside the original inseason confidence intervals, suggesting that the devised catch-sampling methodology provided representative samples.

Several times during the pink salmon fishery, test fisheries were used to gather otolith samples from areas that had historically been closed because of insufficient stock-identification data. The resulting hatchery contribution estimates allowed the fishery manager to open these areas to commercial fishing. The coded wire tag program could not furnish such estimates because test fishery catches are usually too small to yield sufficient tag recoveries, and hence usable contribution estimates. As emphasized above, while the otolith program is capable of providing estimates from relatively few fish, considerable effort must be expended to ensure a representative otolith sample is taken from the population of interest.

One area where the otolith program is inferior to the coded wire tagging program is in its ability to track many individual hatchery release groups. Under the coded wire tagging program, an almost unlimited number of codes were available to hatchery managers interested in experimenting with different rearing strategies. With the otolith program, such within-facility tracking is limited to the number of accessory marks available. Both the W.H. Noerenberg and A.F. Koernig hatcheries used an accessory mark to distinguish long-term from short-term reared fish released into the peak plankton bloom. It is anticipated that the recovery of the otolith marks in the returning adults will provide information on the survival of these different release strategies.

Besides their use in the management of adult returns in 1997, otolith thermal marks were also integral to the success of other projects conducted in Prince William Sound. The salmon predation study (97320E), part of the Sound Ecosystem Assessment program, used otolith-marked juvenile salmon to determine growth and condition of hatchery and wild fish. It is possible that information obtained from that study would eventually be used in a forecast model being developed by project 97320J. A small study which investigated the role of coded wire tags in straying also used otoliths to generate estimates of hatchery contributions to stream escapements; a comparison with coded wire tag generated estimates should give an idea of the extent, if any, of the degree of tag-induced straying. Study findings are still preliminary, but current indications are that no large tag-induced straying effects will be detected, and that recovered stray tags are, in large part, accompanied by untagged cohorts. Completed findings will be presented in the final report of the coded wire tag project.

CONCLUSIONS

The major objective of this project was to apply unique and distinct thermal marks to all pink salmon embryos produced in Prince William Sound hatcheries and then to use such marks to identify hatchery salmon in mixed harvests of hatchery and wild salmon. Samples taken three weeks after marking indicated that unique and distinct marks had been applied in 1997. Results of a double blind test on the readability of brood year 1996 otoliths indicated that laboratory readers had few problems in successfully differentiating hatchery otoliths from those obtained from wild populations, and also in differentiating hatchery-specific otoliths. Field recoveries of thermally marked adults occurred for the first time in the 1997 season and the sampling methodology developed in 1996 proved simple to use and provided a timely stock composition information to the management biologist. The postseason samples applied to some fishing periods did not result in any significant changes in estimates of hatchery contributions. After the first year of use, the otolith thermal marking stock identification method has become the tool of choice for managing the Prince William Sound pink salmon return

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LITERATURE CITED

Agresti, A. 1990. Categorical Data Analysis. John Wiley & Sons, Inc. 558pp.

Bue, B.G., S. Sharr, S.D. Moffitt and A.K. Craig. 1996. Effects of the Exxon Valdez oil spill on pink salmon embryos and preemergent fry. Pages 619-627 in S.D. Rice, R.B. Spies, D.A. Wolfe, and B.A. Wright, editors. Proceedings of the Exxon Valdez oil spill symposium. American Fisheries Society Symposium 18.

Gauss. 1996. Aptech Systems Inc., Maple Valley Washington.

Geiger, H.J. 1994. A Bayesian approach for estimating hatchery contribution in a series of salmon fisheries. Alaska Fishery Research Bulletin 1:66-73.

Habicht, C., Sharr, S. and J. Seeb. 1996. Coded Wire Tag Placement Affects Homing Precision of Pink Salmon. *In press.*

Hagan, P., Munk, K., Van Alen, B. and B. White. 1995. Thermal Mark Technology for Inseason Fisheries Management: A Case Study. Alaska Fishery Research Bulletin Vol. 2, No. 2.

Joyce, T., Evans, D. & R. Riffe. 1996. Otolith Marking of Pink Salmon in Prince William Sound Salmon Hatcheries, 1995. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project R95320C), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Cordova, Alaska.

Joyce, T., Evans, D. & R. Riffe. 1997. Otolith Marking of Pink Salmon in Prince William Sound Salmon Hatcheries, 1996. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project R96188), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Cordova, Alaska.

Mosegaard, H., N.G. Steffner, and B. Ragnarsson. 1987. Manipulation of otolith microstructure as a means of mass-marking salmonid yolk sac fry. Pages 213-220 in S.O.Kullander and B. Fernholm, editors. Proceedings: fifth congress of European ichthyologists. Swedish Museum of Natural History, Stockholm.

Munk, K., (*In Prep.*), Thermal Marking Manual: A Guideline to the Induction of Thermal Marks in Otoliths for the Purpose of Mass-Marking Hatchery Stocks. Alaska Department of Fish and Game, Special Publication, Juneau.

Munk, K., W. Smoker, Beard, D. and R. Mattson. 1993. A Hatchery Water-Heating System and its Application to 100% Thermal Marking of Incubating Salmon. The Progressive Fish-Culturist. 55:284-288.

Riffe, R., and D. Evans. 1997. Coded wire tag recoveries from Prince William Sound salmon fisheries, 1996. *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration

Project R96186), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Cordova, Alaska.

Riffe, R., Gehlbach, S., Evans, D. and B. Bue. 1996. Coded wire tag recoveries from Prince William Sound salmon fisheries, 1995. *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project R95320B), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Cordova, Alaska.

Sharr, S., Peckham, C., Sharp, D., Peltz, L., Smith, J., Willette, T., Evans, D. and B. Bue. 1995a. Coded wire tag studies on Prince William Sound salmon, 1989-1991. Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Project Final Report (Fish/Shellfish Study #3), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Cordova, Alaska.

Sharr, S., Peckham, C., Sharp, D., Smith, J., Evans, D., and B. Bue. 1995b. Coded wire tag studies on Prince William Sound salmon, 1992. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project R60A), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Cordova, Alaska.

Sharr, S., Peckham, C., Sharp, D., Evans, D. and B. Bue. 1995c. Coded wire tag recoveries from Prince William Sound salmon, 1993. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project R93067), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Cordova, Alaska.

Sharr, S., Riffe, R., Gehlbach, S., Evans, D. and B. Bue. 1995d. Coded wire tag recoveries from Prince William Sound salmon, 1994. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project R94320B), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Cordova, Alaska.

Volk, E.C., S.L. Schroder, and K.L. Fresh. 1990. Inducement of unique otolith banding patterns as a practical means to mass-mark juvenile Pacific salmon. American Fisheries Society Symposium 7: 203-215

Willette, T.M. and G. Carpenter. 1994. Early marine salmon injury assessment in Prince William Sound. Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Project Final Report (Fish/Shellfish Study Number 4), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Cordova, Alaska.

APPENDICES

Appendix A Pink salmon hatchery contribution to Prince William Sound common property fisheries

District: 212

Date	Period	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild	
5/15-5/16	1	0	0	0	0	0	
5/19-5/20	2	0	0	0	0	0	
5/23-5/23	3	0	0	0	0	0	
5/26-5/26	4	0	0	0	0	0	
5/29-529	5	0	0	0	0	0	
5/31-5/31	6	0	0	0	0	0	
6/2-6/3	7	0	0	0	0	0	
6/5-6/6	8	0	0	0	0	1	
6/9-6/10	9	0	0	0	0	1	
6/12-6/14	10	0	0	0	0	0	
6/16-6/17	11	0	0	0	0	1	
6/19-6/21	12	0	0	0	0	9	
6/23-6/25	13	0	0	0	0	10	
6/26-6/28	14	19	0	0	0	390	**
6/30-7/2	15	8	0	0	0	162	**
7/3-7/5	16	15	0	0	0	311	**
7/7-7/8	17	19	0	0	0	387	**
7/10-7/12	18	5	0	0	0	112	**
7/14-7/15	19	43	0	0	0	895	**
7/17-7/19	20	19	0	0	0	394	**
7/21-7/22	21	75	0	0	0	1,568	**
7/24-7/26	22	62	0	0	0	1,285	**
7/28-7/29	23	37	0	0	0	777	**
7/31-8/01	24	29	0	0	0	605	
8/4-8/5	25	29	0	0	0	605	*
8/7-8/8	26	22	0	0	0	451	*
8/11-8/12	27	6	0	0	0	133	*
TOTAL		388	0	0	0	8,097	

* Previous period used to apportion catch **Following period used to apportion catch

District: 221

Date	Period	Facility Solomon Gulch	Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild	
7/3	1	588,493	0	0	0	6,261	
7/7	2	715,587	5,148	0	0	20,592	
7/12	3	463,042	0	0	0	4,874	
7/15	4	449,429	0	0	0	33,403	
7/17	5	353,050	0	0	0	18,039	
7/19	6	306,881	4,910	2,455	0	39,281	
7/21	7	185,192	0	0	0	28,491	
7/23	8	184,634	5,430	1,810	1,810	65,165	
7/25	9	169,990	6,219	4,146	0	68,411	
7/28	10	190,396	2,164	0	0	15,145	
8/6	18	13,868	0	0	0	1,541	
8/7	19	24,191	0	0	0	255	
8/8	20	32,480	0	0	0	1,048	
8/9-8/10	21	69,164	2,280	0	0	1,520	
8/11-8/12	22	33,900	8,030	10,705	0	33,008	
8/13	23	18,060	1,389	1,042	0	12,850	
8/14	24	39,455	3,035	2,276	0	28,073	*
8/15	25	26,685	11,674	1,112	556	13,343	
8/16	26	7,847	3,433	328	163	3,923	*
8/17	27	11,369	13,762	2,393	0	8,975	**
8/18	28	18,713	22,653	3,940	0	14,774	
8/19	29	13,658	16,533	2,875	0	10,783	*
8/20	30	7,048	8,532	1,484	0	5,564	*
8/21	31	1,427	1,727	300	0	1,127	*
8/22	32	1,258	1,384	503	0	1,257	**
8/23	33	1,355	1,491	542	0	1,354	**
8/24	34	1,629	1,792	652	0	1,629	**
8/26	36	1,087	1,195	435	0	1,087	
8/29	39	73	80	29	0	72	*
8/31-9/2	41	41	45	16	0	40	*
TOTAL		3,930,002	122,906	37,043	2,529	441,885	

* Previous period used to apportion catch **Following period used to apportion catch

District: 222

Date	Period	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild	
7/28	1	2,645	232,733	5,289	0	13,223	
8/5	8	0	74,929	0	0	788	**
8/6	9	0	316,638	0	0	3,333	
8/7	10	0	318,151	0	0	3,349	
8/9	11	0	279,895	165,799	0	14,027	
8/10	12	0	0	173,617	0	0	
8/11	13	0	108,910	4,951	0	4,951	
8/13	14	0	3,186	144,951	1,593	3,186	
8/21	15	4,965	326,694	130,774	1,530	9,553	
8/22	16	0	310,870	13,665	0	3,416	
8/23	17	0	60,472	0	0	0	
8/24	18	0	95,563	7,351	0	2,100	
8/25	19	0	64,077	4,929	0	1,408	*
8/26	20	0	32,618	2,509	0	717	*
8/27	21	0	21,915	1,685	0	482	*
8/28-8/29	22,23,24	0	104,358	9,075	0	1,512	
9/10-9/13	25-29	0	74,440	0	0	0	
TOTAL		7,610	2,425,449	664,595	3,123	62,045	

* Previous period used to apportion catch **Following period used to apportion catch

District: 223

Date	Period	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
6/26-6/27	5	24	0	0	0	28
6/28-6/29	6	28	0	0	0	33
6/30-7/1	7	41	0	0	0	48
7/3-7/5	8	55	0	0	0	64
7/7-7/8	9	668	0	0	0	780
7/10-7/12	10	173	87	3,556	0	1,908
7/14-7/15	11	319	160	6,542	0	3,511
7/17-7/19	12	493	247	10,109	0	5,425
7/21-7/22	13	1,699	850	34,830	0	18,689
7/24-7/26	14	0	0	145,775	0	6,160
7/28-7/28	15,16	0	986	19,718	986	9,859
8/1	19	0	7,316	21,947	0	7,316
8/5	23	0	630	10,297	0	0
8/6	24	0	9,848	16,179	0	2,110
8/7	25	0	6,015	75,788	1,203	2,406
8/8	26	1,365	2,730	122,833	0	6,193
8/15	27	0	40,021	44,675	931	3,723
8/16	28	0	77,947	10,393	0	0
8/21	29	0	58,117	32,117	0	0
8/22	30	1,401	33,628	96,679	1,401	1,401
8/23	31	2,025	48,595	139,707	2,025	2,025
8/24	32	2,129	36,195	161,811	0	4,258
8/25	33	0	55,956	83,933	0	6,583
8/26	34	0	15,936	23,904	0	1,875
8/27	35	0	4,288	6,432	0	504
8/28	36	0	1,057	1,586	0	124
8/29	37		2,346	20,173	0	
8/30	38	0	62	537	0	0
8/31-9/2	39	0	17,715	152,349	0	0
9/3-9/6	40	0	4,150	195,029	0	0
9/7-9/9	41	0	865	59,691	0	0
9/10-9/13	42	0	89	6,162		
TOTAL		10,420	425,836	1,502,752	6,546	85,032

District: 225*

Date	Period	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
6/30-7/1	1	18	0	0	0	29
7/3-7/4	2	107	0	0	0	174
7/7-7/8	3	300	0	0	0	489
7/10-7/11	4	0	269	3,358	0	134
7/14-7/15	5	0	24	301	0	12
7/17-7/18	6	0	79	982	0	39
7/21-7/22	7	0	287	3,587	0	143
7/24-7/25	8	0	890	11,131	0	446
7/28-7/29	9	0	1,474	18,430	0	737
7/31-8/1	10	0	3,127	25,329	0	1,563
8/4-8/5	11	0	299	24,507	0	3,885
8/11-8/12	12	235	469	20,420	235	1,174
8/18-8/19	13	0	0	37,521	0	3,263
8/21-8/22	14	0	477	18,139	477	2,625
8/25-8/26	15	0	509	19,338	509	2,799
8/28-8/29	16	0	277	10,518	277	1,522
TOTAL		660	8,181	193,561	1,498	19,034

* 38% of catch prior to July 10 attributed to Solomon Gulch

District: 226

Date	Period	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
7/28	1	14,165	6,666	6,666	15,831	10,831
7/30	2	3,569	1,680	1,680	3,988	2,729 *
8/1	4	3,254	1,531	1,531	3,637	2,489 *
8/4	7	3,570	1,680	1,680	3,990	2,730 *
8/6	9	0	8,001	4,001	372,059	0
8/7	10	0	12,027	42,095	222,500	12,026
8/8	11	13,346	50,046	63,392	146,803	40,037
8/9	12	6,485	45,391	67,007	168,598	28,100
8/10	13	2,743	19,199	52,110	172,787	16,456
8/15	14	0	14,792	81,359	647,172	33,283
8/16	15	0	78,541	121,874	322,290	51,457
8/21	16	0	57,849	73,919	163,907	12,855
8/22	17	0	40,675	189,817	338,959	27,117
8/23	18	3,269	29,419	75,182	303,997	52,301
8/24	19	0	29,434	54,663	134,554	21,025
8/25-8/26	20,21	0	63,777	54,666	168,552	40,999
8/27	22	0	32,749	28,071	86,550	21,053 *
8/28	23	0	20,499	17,571	54,176	13,176 *
8/29	24	0	21,161	24,185	33,254	4,535 **
8/30-9/2	25,26	0	76,922	87,911	120,878	16,483
9/3-9/6	27	0	0	0	249,352	8,044
9/7-9/9	28				30,556	986 *
9/10-9/13	29				33,540	1,082 *
TOTAL		50,401	612,039	1,049,380	3,797,930	419,794

* Previous period used to apportion catch **Following period used to apportion catch

District: 227

Date	Period	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
6/16-6/17	7	39	0	0	0	81 **
6/23-6/24	10	163	0	0	0	340 **
6/25-6/27	11	160	0	0	0	335
6/30-7/1	13	25	0	0	0	52 *
7/2-7/4	14	124	0	0	0	261 *
7/5-7/6	15	70	0	0	0	147 *
7/7-7/8	16	27	0	0	0	55 *
7/9-7/11	17	20	0	0	0	42 *
7/12-7/13	18	58	0	0	0	122 *
7/14-7/15	19	348	0	0	0	729 *
7/21-7/21	22	0	0	0	0	6,389
8/11-8/12	23	550	3,852	3,852	550	3,303
8/13	24	101	710	710	101	608 *
8/14	25	1,038	7,260	7,260	1,038	6,224 *
8/17	28	461	307	769	154	1,077 **
8/18	29	1,805	1,203	3,009	602	4,212
8/19	30	794	529	1,323	265	1,853 *
TOTAL		5,783	13,861	16,923	2,710	25,830

* Previous period used to apportion catch **Following period used to apportion catch

District: 228

Date	Period	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
7/21	1	0	0	0	0	6,252
7/23	2	0	0	0	0	8,781
7/25	3	0	0	0	794	10,327
8/8	14	0	0	0	106	1,383 *
8/9-8/10	15	0	0	0	19	243 *
8/20	24	0	0	0	10	125 *
TOTAL		0	0	0	929	27,111

* Previous period used to apportion catch **Following period used to apportion catch

Appendix B Pink salmon hatchery contribution to Prince William Sound cost recovery fisheries

District 221

Dates	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
6/18-6/21	8,525	0	0	0	89
6/22-6/25	170,884	0	0	0	7,430
6/26-6/28	254,015	0	0	0	0
6/29-6/30	344,441	0	0	0	0
7/01-7/02	242,849	0	0	0	2,556
7/03-7/05	318,799	0	0	0	0
7/06-7/09	478,982	0	0	0	5,042
7/10-7/11	360,992	0	0	0	0
7/12-7/14	219,016	0	0	0	2,305
8/22-9/3R	14,808	0	0	0	274
TOTAL	2,413,311	0	0	0	17,696

District: 222

Dates	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
7/29-8/02	0	336,323	7,311	0	7,311
8/03-8/05	0	567,353	0	0	5,972
8/06-8/09	0	404,136	0	0	4,541
8/10-8/13	0	141,312	0	0	0
8/14-8/16	0	252,515	0	0	2,806
8/17-8/21	0	128,074	0	2,784	2,784
9/22	0	9,271	0	0	0
TOTAL	0	1,838,984	7,311	2,784	23,414

District: 223

Dates	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
7/13-7/26	0	0	8,792	0	0
7/27-7/28	2,038	0	46,885	0	2,038
7/29-8/02	3,525	0	296,126	0	3,525
8/03-8/05	0	0	290,363	0	0
8/06-8/09	0	0	260,776	0	0
8/10-8/13	0	0	555,901	0	0
8/14-8/16	0	0	247,148	2,686	0
8/17-8/19	0	0	261,302	0	0
8/19-8/21	0	2,378	225,931	0	0
9/16	0	0	8,896	0	0
9/18	0	0	12,996	0	0
9/19	0	0	13,335	0	0
9/22	0	0	14,021	0	0
9/23	0	0	7,460	0	0
TOTAL	5,563	2,378	2,249,932	2,686	5,563

District: 225+

Dates	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
6-Jul	0	0	0	0	23
27-Jul	0	0	1,107	0	0 **
31-Jul	0	0	672	0	0 **
8/3-8/9	0	0	13,894	0	0
16-Aug	0	0	22,560	301	301
TOTAL	0	0	38,233	301	324

+ Eshamy CPF used to apportion cost recovery catch
* Previous period used to apportion catch **Following period used to apportion catch

District: 226

Dates	Solomon Gulch	Facility Cannery Creek	W.H. Noeremberg	A.F. Koernig	Wild
7/24-7/26	0	0	0	206,374	0
7/27-7/29	0	0	0	412,332	0
7/30-8/02	0	0	0	430,845	9,167
8/03-8/09	0	0	0	560,772	0
8/10-8/13	0	4,126	4,126	387,814	0
8/14-8/16	0	3,447	0	324,082	3,447
8/17-8/18	3,382	3,382	10,145	287,439	3,382
8/19-8/22	5,754	0	11,508	523,624	11,508
TOTAL	9,136	10,955	25,779	3,133,282	27,504

Appendix C Pink salmon hatchery contribution to Prince William Sound brood stocks

District: 221

Period	Solomon Gulch	Facility Cannery Creek	W.H. Noeremberg	A.F. Koernig	Wild
7/21-7/25	52,093	0	0	0	548
7/28-8/01	81,361	0	0	0	855
8/3-8/8	55,937	0	0	0	589
8/10-8/16	45,972	0	0	0	0
8/17-8/23	57,911	0	0	0	950
8/7-8/9R	47,649	0	0	0	0
8/8R	14,311	0	0	0	0 *
8/20R	813	0	0	0	0 *
9/13R	224	0	0	0	0 *
TOTAL	356,271	0	0	0	2,942

* Previous period used to apportion catch **Following period used to apportion catch

District: 222

Period	Solomon Gulch	Facility Cannery Creek	W.H. Noeremberg	A.F. Koernig	Wild
8/24-9/6	0	94,499	995	0	0
9/7-9/13	0	131,740	1,387	0	0
9/14-9/17	0	91,692	0	0	0
TOTAL	0	317,931	2,382	0	0

District: 223

Period	Solomon Gulch	Facility Cannery Creek	W.H. Noerenberg	A.F. Koernig	Wild
8/22-8/30	0	0	40,150	0	0
8/31-9/6	0	1,398	132,842	0	0
9/7-9/13	0	0	159,889	0	0
9/14-9/15	0	0	42,541	0	0
9/16-9/28	0	0	31,651	0	0
TOTAL	0	1,398	407,073	0	0