Exxon Valdez Oil Spill
Restoration Project Final Report

Prince William Sound System Investigation: Experimental Manipulation

Restoration Project 94320L
Final Report

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Study History: 94320L was proposed by Prince William Sound Aquaculture Association in conjuction with 94320K (Experimental Fry Release) to study the effects of releases of large numbers of pink salmon smolts on the Prince William Sound ecosystem.

Abstract: Harvesting and processing of Pacific salmon is the economic, social, cultural, and recreational focal point for Prince William Sound (PWS) residents, but these have been threatened by aberrant adult salmon returns since the *Exxon Valdez* oil spill. Studies of pink salmon *Oncorhynchus gorbuscha* population dynamics and their role in the complex marine ecosystem of PWS is a central objective of the Sound Ecosystem Assessment program. The systems investigation component proposes that releases of hatchery-nurtured and marked pink salmon fry will test the influence of ocean-entry timing and fry size at ocean entry on losses to predators. Greater than 3.25×10^8 salmon fry were released from three pink salmon facilities in spring 1994. A significant number of fry (6.2×10^5) were marked and coded wire tagged. The rearing and release strategies included: 1) early fed, 2) direct release, 3) mid-release, 4) late fed. Predetermined numbers, sizes, and times allowed us to measure the influence of ocean-entry timing and fry size at ocean entry due to losses by predation. By utilizing multiple release sites for the ocean entry coordinates, an increase in the spatial differences at ocean entry point allows insight into the subtle effect of geographical influences on the interaction of apical predators.

Key Words: *Exxon Valdez* oil spill, hatchery, marine survival, *Oncorhynchus gorbuscha*, pink salmon, predation, Prince William Sound, Prince William Sound Aquaculture Corporation.

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TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

Harvesting and processing of Pacific salmon *Oncorhynchus sp.* is the economic, social, cultural, and recreational focal point for the residents of Prince William Sound (PWS). The aberrant adult salmon returns in evidence since the *Exxon Valdez* oil spill incident have threatened PWS communities as never before.

Knowledge is requisite in finding ways to restore as many of the impacted marine life forms injured by the spill as is possible. Studies of pink salmon, *Oncorhynchus gorbuscha* population dynamics and their role in the complex marine ecosystem of PWS is a central objective of The Sound Ecosystem Assessment program (SEA). The systems investigation SEA proposal states that releases of hatchery-nurtured and marked pink salmon fry "will provide a powerful test of the influence of ocean-entry timing and fry size at ocean entry on losses to predators".

Greater than 3.25×10^8 salmon fry were released from three Prince William Sound Aquaculture Corporation (PWSAC) pink salmon facilities in the spring of 1994. A significant number of fry (6.2×10^5) released were made recognizable by the labor intensive practice of marking and coded wire tagging (CWT), to allow SEA fellow researchers ready and precise identification. The rearing and release strategies included: 1) early fed, 2) direct release, 3) mid-release, 4) late fed.

Predetermined numbers, sizes, and times at ocean entry allowed SEA co-researchers to measure the influence of ocean-entry timing and fry size at ocean entry due to losses by predation. By being able to allocate variables of origin, time and size at ocean entry, SEA co-researchers can gain a level of precision otherwise economically and logistically virtually impossible if only unaided salmon stocks had to be relied upon.

Yet other related SEA research projects used PWSAC nurtured salmon fry to assess early marine growth and migration patterns. Additionally, by utilizing multiple release sites for the ocean entry coordinates of the subject salmon fry, an increase in the spatial differences at ocean entry point allows researchers insight into subtle effect of geographical influences on the interaction of apical predators and one of their main target species within the Sound.

Zooplankton collected by PWSAC personnel formed the basis for yet other SEA research projects.

The diverse impacts of various releases acting upon the multiple parameters studied will be described in other SEA project reports such as 94320-A (Sal. Growth and Mort.), 94320-E (Sal. Pred.), 94320-N (Nearshore Fish) and 94320-H (Zooplankton).

INTRODUCTION

Subsequent to the spill, it was immediately evident the knowledge base of the complex abiotic and biotic interactions occurring within and adjacent to the Sound was clearly inadequate for the immense task of restoration and rehabilitation of the spill induced damage. SEA, a multi-disciplinary, -faceted, -year, and -suite of studies was created.

Since the spill, erratic pink salmon returns to PWS, accompanied with deflated fish prices, have resulted in near financial disaster for coastal communities and for PWSAC. During the 1980's, commercial catches of pink salmon in the Sound reached record highs as a result of ever larger returns of stream and artificially spawned Pacific salmon. In 1991, an aberrant return of adult pink salmon, spawned in parent year 1989 (the year of the spill), came in late and approaching maturity. The direct consequence of their low intrinsic quality was virtual market rejection. Their economic value was essentially zero; coupled with limited processing capacity, millions went unsold. PWSAC cost recovery efforts plummeted while expenses continued to accrue.

In 1992, the pink salmon return was approximately one-third of the projected size; in 1993, one-fifth. PWSAC cost recovery efforts continued to plummet so fixed and variable costs went unfunded.

This year, 1994, returns in Prince William Sound were up dramatically in number. If it had not been for the general pink salmon run failure in other locations of the spill impacted area, PWS processing capacity, which has contracted significantly since the spill, would have been limiting. The waste of millions of additional fish was only narrowly avoided.

PWSAC, a non-profit corporation, is where the residents of PWS meet to plan and implement salmon resource restoration and development in the region. The restoration, supplementation and enhancement of PWS pink salmon populations is PWSAC's central mission. PWSAC now has another mandate, that of assisting with spill related restoration of pink salmon populations such that they will gradually return to pre-spill health. While the 1994, returns of pink salmon to PWS may be but an anomaly, restoring pink salmon productivity will improve opportunities for other injured fish, bird, and mammal populations whose survival is linked to the overall health of pink salmon.

OBJECTIVES

The goal of this project is, through collaboration with SEA program co-researchers, to assist "to develop an ecosystem level understanding of the natural and man-caused factors influencing the production of pink salmon in PWS". Specific objectives are:

A. Provide SEA researchers, in 1994, with certain of the tools needed to determine the effect of ocean-entry timing (i.e., ocean entry on losses to predators of pink salmon).

B. Provide, in 1994, through PWSAC facility releases of pink salmon fry, the support necessary to conduct PWS ecosystem investigations that will provide further information that will aid in understanding unaided and assisted spawning stock interactions.

C. Provide SEA researchers with the tools needed to determine the migratory path of pink salmon fry in PWS.

D. Monitor macrozooplankton abundance, ocean temperature, and meteorological conditions at three locations in PWS.

E. Prior to saltwater entry mark and CWT 1 x 10^6 pink salmon fry.

Project 94320-L, Experimental Manipulation, was to be an integral component of the Sound Ecosystem Assessment - Project 94230 - Prince William Sound System Investigation suite of studies.

METHODS

The project took place in PWS at three PWSAC facilities: Armin F. Koernig (AFK) located on Evans Island, Wally Noerenberg (WN) sited on Esther Island, and Cannery Creek (CC) in Unakwik Inlet.

Rearing/release strategies and fish culture procedures employed at AFK, WN, and CC were as per respective facility's *Procedures for Fish Culture and Harvest, Vols. I and II.* The rearing, release, and fish cultural strategies and procedures have been demonstrated during previous years to result in high - relative to unaided spawning stocks - but variable, fry to adult survivals.

Beginning in late February, 1994, pink salmon fry began exiting the incubators volitionally and were carried, via gravity flow, through plastic pipes through a bank of electronic fry counters (+/-0.5% accuracy). Following enumeration, fry were conveyed via flexible hose to 12 m x 12 m x 3 m (432 m^3) saltwater rearing pens.

Fry loading density per pen varies by location, ranging from 7.0 x 10^6 fry to 1.25 x 10^7 fry/pen, or 3.1 kg/m^3 - 5.3 kg/m^3. The higher densities are possible in deeper bays such as at the WN facility. All fry were fed a standard commercial diet of soft, semi-moist fish food for 3 - 30 days prior to release. Feeding rates range from 2.5%/body weight/day to 4.0%/body weight/day, depending upon stage of development, fry group, and water temperature.

A total of 3.25 x 10^8 pink salmon fry were supplied from the three facilities: AFK - 8.5 x 10^7, CC - 8.5 x 10^7, WN - 1.55 x 10^8. Within the total, in excess of 6.20 x 10^5 were marked by adipose fin removal and coded wire tagging (CWT) at a ratio of 600:1 un-:mark/tagged. This 600:1 ratio must be strictly adhered to as Alaska Department of Fish and Game fisheries

biologists also rely upon PWSAC facility produced, marked/CWT pink salmon fry as an integral component of their harvest management strategies.

Releases began on April 25, 1994 as calanoid copepods, a key prey item of pink salmon fry, moved into the upper 20 meters of the water column as verified by PWSAC plankton sampling. At all PWSAC salt water adjacent sites, near shore plankton abundance is monitored from mid-March through late June, twice weekly. Samples are taken in two preselected locations near each facility using a 1/2 m sample net hauled vertically from 20 m. Up to three replicates are made per sample location per sampling date. Samples are transferred to 250 ml graduated cylinders and allowed to settle 24 hours. The relative density of zooplankton and phytoplankton as well as their percent composition are determined. The samples are then preserved in a 10% buffered formalin solution for later taxonomic and other inquires by SEA researchers.

Plankton samples collected by PWSAC personnel are used extensively by fellow SEA researchers and other scientists such as those with the National Atmospheric and Ocean Administration's Alaska Fisheries Center located in Seattle, Washington.

All releases were done in concert with the ship board sampling carried out by SEA research teams. Fry release data from the hatcheries was communicated to biologists on board trawl and purse seine vessels to assure near shore and open water sampling targeted on released fry.

Fry were released in groups of 7.0×10^6 to 2.5×10^7 to assess the impact of number of fry released on predation and fry growth as well as other stated purposes. Fry were released at a size of between 0.21 and 0.35 g/ea. The wide geographic separation of each hatchery will test the influence of location of ocean entry point on growth, mortality, and migration patterns. Ocean entry dates typically fall within the ranges of ocean entry timing of parent, and local stocks.

The four release arrays were as follows:

Early Fed: Fry were held in saltwater rearing pens and fed for 10-20 days prior to release at the peak of the near shore macro-zooplankton biomass period (end of April - early May). The group was comprised of 2.674×10^8 fry or 82% of the total 1994 project releases.

Direct Release: Fry were held in saltwater rearing pens for no more than three days prior to release, thus synchronizing out migration with the macrozooplankton bloom. The direct release group was comprised of 1.3×10^6 fry or 0.4% of total 1994, project release.

Late Fed: These last to be released fry out migrate after the macro-zooplankton bloom. They are held in saltwater pens until late May/early June, and fed on a programmed basis. This late group was comprised of 2.76×10^7 fry or 8.5% of the 1994, total releases.

A fourth group was added at CC to test the performance of fry fed for about 20 days and released in mid-May. CC was chosen to test this late release strategy because out migration

typically follows the other two sites. The mid-May release group was comprised of 2.87 x 10^7 fry or 9.1% of the total.

A sub-project of the SEA program for 1994 addressed the influence of fry size at ocean entry on predation by looking at the growth and mortality of large fry (1.5 gram) released late in the season. A separate project report has been prepared for this program.

RESULTS

Principal milestones were met as a total of approximately 3.25 x 10^8 pink salmon fry were released at predetermined times and sizes (Table 1). In addition, 620,217 pink salmon fry were marked by the removal of the adipose fin, and CW tagged, making identification possible. In total PWSAC facilities released some 4.73 x 10^8 salmon fry of all species (Table 2).

The parent broodstock were the worst quality fish PWSAC personnel have ever dealt with. Returning adult pink salmon were considerably smaller than average, had a lower fecundity, and smaller eggs. Prespawning mortalities of adult fish at CC were the highest ever recorded at a PWSAC facility. As a direct consequence only 8.5 x 10^7 pink salmon eggs were taken at CC, vs: a normal of 1.52 x 10^8.

Fry number, size, fitness, and survivals were also reduced. Average weight of emergent pink salmon fry at PWSAC facilities averages 0.23 grams each (n >1 x 10^{10}). Emergent fry weights were as much as 13.4% lower (range 0.199-0.208 g) than average.

Higher than expected mortalities occurred during the saltwater rearing phase at AFK and CC hatcheries. Samples have been sent to several university and agency laboratories. Approximately 2.28x 10^7 fry more than average perished from an as yet unknown cause. Preliminary evidence indicates that many fry were not osmocompetent.

As a direct consequence of the poor quality of parent stock and resultant progeny, the number of fry that PWSAC personnel released, and consequently could mark/tag, was considerably reduced. The ratio of marked to unmarked fish must remain constant as it is relied on in fisheries management procedures.

Close coordination and communication occurred between PWSAC personnel and SEA researchers. To further assist SEA co-researchers each pen of fry contained a unique code. As a consequence CWT fry are integral to tracking migration patterns of pink salmon, as well as in estimating growth and mortality rates.

CONCLUSIONS

Project 94320-L, Experimental Manipulation, was an integral component of, and a very powerful tool used by the Sound Ecosystem Assessment (SEA) - Project 94320 - Prince William Sound System Investigation suite of studies. Its milestones described as numbers of released fry were achieved as was well as was possible given the post-spill biological anomalies suffered.

PWSAC recognizes its scientific, technical, and political assets are vital to spill restoration. PWSAC supports the notion expressed by Dr. George Rose that "experimental management can be done in PWS using hatcheries in collaboration with the SEA research proposal". PWSAC has been and will continue to be heavily involved in the ecosystem research envisioned by the Trustee Council as necessary for restoration of PWS.

The *Exxon Valdez* oil spill incident, however, has threatened the corporate existence of PWSAC as well as many, many other corporations, businesses, and persons in PWS. As a direct consequence, PWSAC cannot continue to be the focal point for fisheries restoration and development in PWS if it allocates its very finite resources inadvisably.

One of the most important keys, then, to rehabilitating the pink salmon of PWS is understanding the complex species interactions that occur during critical early marine life stages. As was addressed in the SEA proposal, releases of hatchery produced pink salmon fry "will provide a powerful test of the influence of ocean-entry timing and fry size at ocean entry on losses to predators". By using hatchery-nurtured pink salmon, important variables such as release timing and location, number of fry released, fry age and size can be controlled. In addition, a portion of all hatchery pink salmon fry released are marked, making assessments of early marine growth, life stage mortality and migration patterns possible at a highly reasonable cost.

Humans have harvested and altered the habitat of Pacific salmon populations for a considerable period of time, during the past two centuries in particular. As a consequence, all known populations of Pacific salmon are anthropogenitic; impacted by humans. It is inevitable that harvesting and/or habitat disturbances must exert selective pressures. Impacts on the scale of the spill are, however, very rare, hence restoration efforts must proceed concomitantly with increases in our basic understanding of the functioning of an ostensibly healthy ecosystem. The SEA program is developing the tools which will eventually allow prudent and sustainable ecosystem management. Inherent with the tenets of ecosystem management is the preservation of biodiversity.

As fry quality, and size at time of ocean entry have a dramatic effect upon marine survivals, PWSAC has the gravest concern that returning adult pink salmon (in 1995) will continue to demonstrate the aberrant return characteristics of the post-spill years.

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TABLE 1
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PRINCE WILLIAM SOUND AQUACULTURE CORPORATION
TRUSTEE COUNCIL PROJECT 94320-L
PINK SALMON RELEASE GROUP REPORT

09/26/94

EVOS PROJECT NO.	HATCHERY	TREATMENT GROUP	NO. FISH RELEASED	NO. FISH TAGGED	RATIO TAGGED: UNTAGGED	PERCENT OF TOTAL REL.
94320-L	AFK	EARLY FED	85,700,000	146,107	587	
94320-L	CCH	EARLY FED	28,300,000	47,400	597	
94320-L	WNH	EARLY FED	153,400,000	255,506	600	
94320-L	TOTAL	EARLY FED	267,400,000	449,013	596	78.7%
94320-L	AFK	DIRECT REL.	0	0	0	
94320-L	CCH	DIRECT REL.	0	0	0	
94320-L	WNH	DIRECT REL.	1,300,000	2,229	583	
94320-L	TOTAL	DIRECT REL.	1,300,000	2,229	583	0.4%
94320-L	AFK	MIDDLE REL.	0	0	0	
94320-L	CCH	MIDDLE REL.	28,700,000	47,740	601	
94320-L	WNH	MIDDLE REL.	0	0	0	
94320-L	TOTAL	MIDDLE REL.	28,700,000	47,740	601	8.4%
94320-L	AFK	LATE FED	0	0	0	
94320-L	CCH	LATE FED	27,600,000	45,964	600	
94320-L	WNH	LATE FED	0	0	0	
94320-L	TOTAL	LATE FED	27,600,000	45,964	600	8.1%
94320-K	AFK	1.5 GRAM	7,000,000	36,812	190	
94320-K	WNH	1.5 GRAM	7,700,000	38,459	200	
			14,700,000	75,271	195	4.3%
TOTAL 94320-L + 94320-K			339,700,000	620,217	548	

TABLE 2

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PRINCE WILLIAM SOUND AQUACULTURE CORPORATION
1994 JUVENILE SALMON RELEASES

DATE	WALLY NOERENBER HATCHERY PINK	CHUM	COHO	CHINOOK	A.F.K. PINK	C.C.H. PINK	MAIN BAY HATCHERY SOCKEYE	GULKANA HATCHERY SOCKEYE	TOTAL PINKS	TOTAL FISH
22-Apr					644,630				644,630	644,630
23-Apr									0	0
24-Apr									0	0
25-Apr	22,752,250		----						22,752,250	22,752,250
26-Apr		11,695,066	|		6,618,697				6,618,697	18,313,763
27-Apr		11,899,423	|						0	11,899,423
28-Apr	25,212,438		|						25,212,438	25,212,438
29-Apr			| E. Chum		6,324,498				6,324,498	6,324,498
30-Apr			|		11,372,138				11,372,138	11,372,138
01-May			|			9,485,711			9,485,711	9,485,711
02-May		10,033,597 *	|		5,507,274				5,507,274	15,540,871
03-May	24,218,697	6,017,654 **	|		6,125,031				30,343,728	36,361,382
04-May			----		5,142,018				5,142,018	5,142,018
05-May	24,454,963				4,946,477	9,329,671			38,731,111	38,731,111
06-May					12,822,714				12,822,714	12,822,714
07-May	24,320,537								24,320,537	24,320,537
08-May									0	0
09-May	24,347,238				6,685,569				31,032,807	31,032,807
10-May					6,270,226	9,492,115			15,762,341	15,762,341
11-May	9,371,637				6,821,127				16,192,764	16,192,764
12-May									0	0
13-May									0	0
14-May									0	0
15-May									0	0
16-May									0	0
17-May			----		6,398,894				6,398,894	6,398,894
18-May		12,178,163	| M. Chum			18,923,551			18,923,551	31,101,714
19-May		11,975,827 **	|						0	11,975,827
20-May		9,756,819 *	|						0	9,756,819
21-May			----						0	0
22-May									0	0
23-May						9,767,701			9,767,701	9,767,701
24-May									0	0
25-May				394,606	WNH				0	394,606
26-May				99,334	CDV				0	99,334
27-May				50,318	CHG				0	50,318
28-May				98,302	WHT.		691,633 RR. ESHAMY		0	789,935
29-May			----				761,797 MBH/ESH		0	761,797
30-May		11,937,899	|				90,358 EYAK		0	12,028,257
31-May			| L. Chum				889,158 RR. COGHILL		0	889,158
01-Jun			|			27,617,865	2,400,666 MBH/COG		27,617,865	30,018,531
02-Jun			|						0	0
03-Jun		14,528,105 *	|						0	14,528,105
04-Jun			----						0	0
05-Jun									0	0
06-Jun			1,281,837 WNH						0	1,281,837
07-Jun									0	0
08-Jun			103,471 WHT.						0	103,471
09-Jun			98,628 CDV.						0	98,628
10-Jun								10,000,000 PAXSON L.	0	10,000,000
11-Jun	7,709,008 *							6,300,000 SUMMIT L.	7,709,008	14,009,008
12-Jun								10,000,000 CROSSW L.	0	10,000,000
13-Jun					7,044,288 *				7,044,288	7,044,288
14-Jun									0	0
15-Jun									0	0
TOTAL	162,386,768	100,022,553 ***	1,483,936	642,560	92,723,581	84,616,614	4,833,612	26,300,000	339,726,963	473,009,624

* 1.5 Gram fry release
** Port Chalmers chum release

* 1.5 Gram fry release