Pristane Monitoring in Mussels

Project Number:	01195
Restoration Category:	Research and Monitoring
Proposer:	Jeffrey W. Short and Patricia M. Harris NMFS, Auke Bay Laboratory ABL Program Manager: Dr. Stan Rice NOAA Program Manager: Bruce Wright
Lead Trustee Agency:	NOAA
Cooperating Agencies:	None
Alaska Sea Life Center:	No
Duration:	Indefinite
Cost FY01:	$ 55,000
Cost FY02:	$ 55,000
Cost FY03:	$ 55,000
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pink Salmon

ABSTRACT

This project has focused on elucidating the transport mechanism of pristane from ***Neocalanus ssp*** copepods into mussels in PWS for the previous 5 years. Comparison of pristane concentration increases in mussels near hatcheries with marine survival of hatchery pink salmon shows a significant correlation, indicating that pristane monitoring is a candidate forecasting method for marine survival of these salmon. This project will now focus on (1) assessing the reliability of these forecasts, (2) examining whether survival forecasts for hatchery pink salmon may be extended to wild stocks and to other salmonids, (3) development of a formal model for the expected relationship between pristane concentrations in mussels and marine survival of hatchery pink salmon, and (4) further evaluation of the physical and biological features of the ecosystem that modulate the production of pristane and its accumulation by mussels.

INTRODUCTION

Predicting recruitment is a fundamental goal of fisheries management, but an adequate understanding of the factors modulating recruitment are rarely achieved. This project has been funded in the hope that it would elucidate recruitment factors during the early marine phase of salmon and herring in Prince William Sound (PWS). Project results, augmented by agency-sponsored research, indicate that monitoring pristane in mussels may provide a basis for predicting marine survival of pink salmon, which might also be applicable to other salmon species (especially chum salmon). This project is now ready to advance to a validation stage, comparing pink salmon survival forecasts with actual returns, to assess reliability. If validation is successful, fisheries managers will have a new tool to improve salmon and ecosystem management in PWS.

Comparison of pristane accumulated by mussels near PWS hatcheries following mass-releases of juvenile pink salmon with subsequent marine survival of the released salmon has shown a significant and potentially useful correlation. Prince William Sound Aquaculture Corporation (PWSAC) hatcheries in PWS have adopted a strategy of releasing juvenile salmon ***en masse*** in recent years to minimize predation. Numbers of released juveniles usually range from 20 to more than 100 million per release. Released juveniles immediately begin searching for adequate prey, and they become increasingly vulnerable to predation until prey adequate to support rapid growth are located.

By far the most available prey during spring in PWS are ***Neocalanus*** copepods, which contain pristane concentrations approaching 1% (dry weight basis). High-density patches of these copepods accumulate near shorelines in response to wind-driven and other surface currents, and juvenile pink salmon remain close to shorelines during their first few weeks of marine residence searching for prey. Abundant fecal material rich in pristane is produced when large numbers of released pink salmon encounter concentrated near-shore patches of copepods. This pristane-laden fecal material is readily incorporated by mussels, so monitoring the increase of pristane concentrations in mussels near PWSAC hatcheries 2 to 3 weeks following releases of juveniles provides an indication that the released fish have located adequate prey. Conversely, failure to detect pristane increases in mussels anywhere within 25 km of hatcheries following a mass release strongly suggests low prey availability, leading to high vulnerability to piscivorous predators.

Most aspects of the transport pathway linking pristane generation in copepods to consumption by mussels have now been validated by field and laboratory experiments. Field studies have demonstrated that high ***Neocalanus*** copepod abundance alone does not result in much pristane accumulation by mussels, hence direct incorporation of pristane dissolved into seawater from copepods, or of pristane in feces produced by these copepods, are negligible pathways to mussels. Other zooplanktivorous fishes may also produce pristane-laden feces during Spring, but are unlikely to cause significant confounding because compared with pink salmon they are not as abundant near hatcheries just after releases of pink salmon, and other these zooplanktivorous fishes are less closely associated with the shoreline. Shoreline association is important because both field and laboratory studies showed that effective incorporation of pristane by mussels requires production of feces just above mussel beds at higher tidal stages. Laboratory studies also showed that mussels accumulate pristane within hours when exposed to pristane-laden feces, attaining thousand-fold concentration increases within a few days, and that depuration occurs much more slowly over a period of a few weeks.

Last year, marine survival of juvenile pink salmon released ***en masse*** from PWS hatcheries was found to be significantly associated with pristane concentration increases in mussels near hatcheries 2 - 3 weeks following releases. Pristane concentrations have been monitored during Spring at a network of 30 stations for each of the last 5 years in PWS. Comparison of (1) the number of returning adults to a hatcheries, with (2) pristane concentration ***increases*** in mussels collected from sampling stations within 25 km of that hatchery 2 - 3 weeks following release of juveniles, showed that 62% of the interannual variability of returning adults is explained by pristane increases ($P < 0.001$, $df = 13$). These results strongly suggest that continued monitoring of pristane in mussels may have predictive value to forecast marine survival of hatchery-released pink salmon.

This proposal signals the transition of this project from a research project to more of a validation project. This transition exploits the results of the research phase to optimize the monitoring design. Six samplings are proposed, biweekly beginning early April through end of June, to address the temporal variability of the spring zooplankton production and hatchery release strategies. The network of sampling stations has been increased by 11 to optimize geographic coverage near the hatcheries. Two stations were dropped because of the difficulty of access. The current network of stations permits assessment of the relation of marine survival estimates for hatchery pink salmon to wild stocks in PWS.

NEED FOR THE PROJECT

A. Statement of Problem

Pink salmon are a recovering species in PWS. This project will assess feeding conditions for juvenile pink salmon during the critical period of initial marine residence, and will forecast survivals through this period. If these forecasts are sufficiently reliable, they may help improve management of salmonids in PWS. Improved management will aid the full recovery of this species.

B. Rationale

Pristane in PWS mussels has been monitored for the last 5 years to assess whether seasonal variability of tissue concentrations may be related to recruitment of salmon. Pristane is an environmentally persistent hydrocarbon naturally produced by ***Neocalanus*** copepods in PWS. These copepods account for nearly all of the planktonic biomass available as prey for zooplanktivorous fishes during early Spring, especially juvenile pink salmon during initial marine residence. Laboratory and field experiments have confirmed that these fishes excrete some of the pristane ingested with ***Neocalanus*** copepods in feces, and the feces are subsequently ingested by mussels. The time scale for pristane accumulation by mussels exposed to pristane-laden feces is a few days, and for depuration of accumulated pristane a few weeks. Monitoring pristane concentration increases in mussels during Spring thus indicates the conversion of nearby copepods into fish feces, implying growth of the zooplanktivorous predators. Rapid growth during early life history is essential for high survival. Verification of survival forecasts will permit more precise assessment of human impacts on this species.

C. Location

Mussel samples will be collected in Prince William Sound and will be analyzed for pristane concentrations at the Auke Bay Laboratory, Juneau, Alaska. Marine survival forecasts for pink salmon will help improve management of salmonids in PWS. Educational materials and the brochure will be most appropriate for residents and students of Prince William Sound, but will also be available for others.

COMMUNITY INVOLVEMENT

We will continue to involve Prince William Sound residents in this project to share knowledge and interest in PWS ecosystems and to reduce sampling costs. Since 1994, the Prince William Sound Aquaculture Association has collected mussels near their 4 hatcheries at the appropriate times and stored them until the end of the season for pick-up. This year students with Youth Area Watch (Project 00210) and independent students will again be collecting mussels near their hometowns, Tatitlek, Whittier, Chenega, Kenny Cove, Valdez, Cordova, and Seward, and may be assisting with collections at other sites. We will provide materials for each participating school that explains the rationale of the project, and compares specific results for each school with the results for the whole effort. The underlying biology of this project gets to the heart of how the sound turns sunlight into fish, which we believe can provide a very useful local teaching resource. Youth Area Watch students will also continue to participate in a 1 day workshop at Auke Bay Laboratory on laboratory analysis techniques for pristane in mussels.

PROJECT DESIGN

A. Objectives

In 2001 this project has 4 objectives:

1. Develop a formal model relating fecal production by pink salmon with the expected number of returning adults.

2. Forecast marine survival of hatchery-released pink salmon in PWS.

3. Evaluate the feasibility of extending pink salmon survival forecasts to other salmonids.

4. Explore the feasibility of relating the physical and biological features of the ecosystem to production of pristane and its accumulation by mussels.

B. Methods

Objective 1: Formal Model Development

Previous work indicates a surprisingly strong association between pristane increases in mussels near PWSAC hatcheries immediately following mass releases of juvenile pink salmon, and the number of adults returning to the hatcheries 16 months later. This association may be formally stated as follows. Let $\{m_{i,j,25}\}$ denote the set of j mussel sampling stations near the ith hatchery, where J(i) is the total number of stations within 25 km of the i^{th} hatchery, and the total number of hatcheries is I (=3). For each hatchery, assume mussels are collected and analyzed for pristane from all the stations $\{m_{i,j,25}\}$ just prior to a mass release of juvenile pink salmon, and again two to three weeks later. Pristane concentrations in mussels near hatcheries often increase substantially during this interval because of fecal production by the released salmon. From the analysis results, the change of the pristane concentration in mussels at each station may be calculated for this two to three week interval. Let $m_{i,j=j',25}$ indicate the station (j') within 25 km of the i^{th} hatchery where the ***maximum*** concentration increase of pristane is observed among the sampled mussels, and let $\Delta P(m_{i,j=j',25})$ denote the magnitude of this increase. Finally, let $N_{r,i}$ denote the number of adult survivors of the released cohort that return to the ith hatchery. The association of $N_{r,i}$ and $\Delta P(m_{i,j=j',25})$ is modeled simply as $N_{r,i} = a\,[\Delta P(m_{i,j=j',25})] + b + \epsilon_i$ (eq 1), that is the number of surviving pink salmon is related to the maximum increase of pristane in mussels collected anywhere within 25 km of a hatchery two to three weeks following release of juveniles, ϵ_i is the error for the i^{th} hatchery.

Regression of adult pink salmon returns with the associated $\Delta P(m_{i,j=j',25})$ at each of 3 PWSAC hatcheries for 5 brood years (1994-1998) produces a very highly significant association ($P<0.0003$, df = 13) wherein $\Delta P(m_{i,j=j',25})$ explains 62% of the variability of $N_{r,i}$ among hatcheries and across brood years. The strength of this association strongly suggests that survival through the early marine residence period largely determines recruitment to the returning adult cohort population.

The rationale for $\Delta P(m_{i,j=j',25})$ as a predictor variable derives from physical and biological constraints. After juvenile pink salmon commence marine residence, they must locate adequate prey densities to support rapid growth to avoid increasing vulnerability to predation or starvation. At 3 cm initial body length and swimming at 1 body length per second, these juveniles can travel a maximum of about 2.5 km per day, and hence are semi-planktonic. The pristane-producing ***Neocalanus sp.*** dominate the zooplankton of PWS are in early May when juvenile pink salmon begin marine residence, and concentrations of these zooplankters together with juvenile pink salmon may appear adjacent to shorelines in response to wind-, tidal- or density-driven surface currents. These concentrations of juveniles and their ***Neocalanus sp.*** prey therefore likely have a strong random component, hence the need for a network of stations surrounding the hatcheries. A large increase of pristane in mussels near a hatchery following release of juvenile hatchery pink salmon indicates that zooplankton prey were successfully located by a substantial portion of the released salmon. The maximum observed pristane increase $\Delta P(m_{i,j=j',25})$ is therefore used as an indicator of the most favorable feeding conditions in the vicinity of a hatchery. This is where growth and survival are likely greatest, and hence where the greatest contributions to numbers of returning adults occur.

The two to three week sampling interval is suggested by the uptake and depuration kinetics of pristane associated with fecal material produced by pink salmon and accumulated by mussels. Both laboratory and field experiments have shown that increased pristane concentrations appear in mussels within a few hours to a few days following introduction of pristane-laden fecal material to mussels, whereas the depuration half-life is two to three weeks. Also, juvenile pink salmon probably need to begin rapid growth within the first week of marine residence or face severe predation.

The 25 km radius criterion for identifying the mussel collection stations associated with a particular hatchery $\{m_{i,j,25}\}$ corresponds with the distance juvenile pink salmon can swim during their first 10 days of marine residence. Surface currents may well transport juveniles faster than this, but these are unlikely unidirectional across 25 km distances given the heavily indented shoreline characteristic of PWS. Failure to locate abundant prey within 25 km of a hatchery would likely result in substantial weakening and increased vulnerability to predation.

The absence of density dependence implicit in eq 1 may be a consequence of the factors integrated by the $\Delta P(m_{i,j=j',25})$. Intuitively, no fecal material will be produced by juveniles that are starving, or that are killed by predators. However, it is unclear at present what functional relationship is to be expected between the amount of fecal material produced by apopulation of juvenile salmon that are growing and also being killed by predators, and the number of survivors. From this perspective, eq 1 must be regarded as an empirical approximation. To better address this issue, a formal 3-parameter model for the expected relationship between $N_{r,i}$ and $\Delta P(m_{i,j=j',25})$ will be developed. The parameters will include instantaneous growth and mortality rates, and the variation of mortality rate with body size. Other relevant variables such as daily ration rate, assimilation efficiency, and the interaction of mortality with growth can be expressed in terms of these 3 independent parameters. Successful development of this model will help identify functional expectations for how sensitively fecal production would respond to food limitation compared with increased predation, and thus help to relate the $\Delta P(m_{i,j=j',25})$ to other physical and biological ecosystem processes.

Objective 2: Forecasting Marine Survival of Hatchery Produced Pink Salmon

Objective 2 will be addressed by applying eq 1 to pristane concentrations found in mussels from stations within 25 km of hatcheries. The number of stations near hatcheries has been increased to insure that possible migration routes are better represented. Application of eq 1 produces forecasts of numbers of adult pink salmon predicted to each hatchery, thus introducing geographic discrimination among hatchery environs. Comparison of predictions with subsequent returns of adults will permit on-going validation of the approach. Ths first set of predictions have been made in the FY99 annual report for this project, which will be compred with adults returns during fall 2000.

Objective 3: Forecasting Marine Survival of Non-Hatchery Salmon

Objective 3 will be addressed by comparing survival indicators for wild pink salmon and for other salmon species with the $\Delta P(m_{i,j=j',25})$, and with predictors analogous to $\Delta P(m_{i,j=j',25})$. The other survival indicators may include results from ADF&G surveys and fishery catch records.

An attempt will be made to evaluate possible stock or regional differences by using a predictor analogous to the $\Delta P(m_{i,j=j',25})$ for stock or geographic regions to be defined later. At a fairly gross level this approach is likely to be successful, because the ΔP values typical of eastern PWS mussel sampling stations during May have generally been much lower than western PWS throughout the life of this project, and wild pink salmon production in eastern PWS has been commensurately low.

Objective 4: Explore the feasibility of relating the physical and biological features of the ecosystem to production of pristane and its accumulation by mussels.

The large-scale ecosystem projects such as SEA may have models or data sets describing biological or physical processes that would be expected to modulate densities of zooplankton and pink salmon juveniles, and these could be compared with the pristane monitoring results of this project to evaluate possible linkages. The feasibility of evaluating such linkages will be explored over the next year, and compelling opportunities will be proposed in the DPD for FY02.

The specific methods for mussel collection, pristane analysis, dry weight determination, etc. have been described in DPDs for previous years of this project, and re not repeated here.

Because there is no other practical way of estimating energy conversion from ***Neocalanus*** to their near-shore predators over a broad geographic area such as PWS, there are no alternative methodologies to consider here.

C. Contracts and Other Agency Assistance

There will be no contracts under this project.

SCHEDULE

A. Measurable Project Tasks for FY01

FY01:

Apr 1 - June 30: Collect mussel samples.

Jul 1 - Sep 30: Analyze 2001 samples for pristane, summarize results in a report

B. Project Milestones and Endpoints

Write report by Dec. 31, 2001

C. Completion Date

Dec. 31, 2001

PUBLICATIONS AND REPORTS

An annual report will be produced by December 31, 2001.

NORMAL AGENCY MANAGEMENT

NOAA/NMFS has statutory stewardship for most living marine resources; however, if the oil spill had not occurred, NOAA would not be conducting this project. NOAA/NMFS proposes to make a significant contribution (as stated in the proposed budget) to the operation of this project, making it truly cooperative.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

We are cooperating closely with Youth Area Watch (01210), which is providing us with samples and to whom we are providing training and educational materials.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

The changes are the result of optimizing sampling to evaluate responses of pristane concentrations in mussels following mass-releases of pink salmon from PWS hatcheries.

PROPOSED PRINCIPAL INVESTIGATOR

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PRINCIPAL INVESTIGATOR

Jeffrey W. Short

Education:
BS, 1972, University of California, Riverside (Biochemistry & Philosophy)
MS, 1982, University of California, Santa Cruz (Physical Chemistry)

Relevant Experience:
1989- Present: Established and managed the hydrocarbon analysis facility at ABL to analyze hydrocarbon samples generated by the ***Exxon Valdez*** NRDA effort (about 20% of these samples

were analyzed at ABL).
1989 - 1992: Principal Investigator, Exxon Valdez project Air/Water #3: Determination of petroleum hydrocarbons in seawater by direct chemical analysis and through the use of caged mussels deployed along the path of the oil spill.
1991 - 1996: Principal Investigator, Exxon Valdez project Subtidal #8: Development of computer-based statistical methods for global examination of sediment and mussel hydrocarbon data produced for the Exxon Valdez NRDA effort for systematic bias, and for identification of probable sources of hydrocarbons. In addition, this project produced both hard-copy and computer display maps of all the sediment and mussel hydrocarbon data.
1994 - 1995: Initiated data analysis and pilot projects that established the role of pristane in Prince William Sound.
1996-1997 Principal Investigator 96195 and 97195

OTHER KEY PERSONNEL

Patricia M. Harris

Education: University of Alaska Fairbanks; B.S. Biological Science 1966
Graduate work at U of A Fairbanks, U of A Southeast, University of British Columbia

Relevant Experience:
1989-1992: Co-principal investigator of NRDA study Subtidal 3, was responsible for field logistics and sample collection and assisted in data analysis and report preparation; also assisted other NRDA projects in field collections.
1992 -1996: participated in study design, field work, proposal preparation, data analysis, and report preparation for mussel bed monitoring and restoration (R103-96090).
1994-1997 Participated in logistic planning, sampling, and community involvement coordination for the pilot pristane project ,96195, and 97195.

Relevant publications: Co-author of final reports for NRDA study Subtidal 3 and several publications pertaining to distribution of ***Exxon Valdez*** oil in mussels and underlying sediments. Several public presentations of oil-related scientific research.

Responsibilities: Coordinate sample collection logistics and collect mussel samples; data analysis; report and proposal preparation; and preparation of science educational materials, posters, and reports.

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2000 to September 30, 2001

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel	$16.6	$21.9						
Travel	$26.2	$26.2						
Contractual	$1.5	$1.0						
Commodities	$3.5	$2.5						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$47.8	$51.6			Estimated FY 2002	Estimated FY 2003		
General Administration	$2.6	$3.4						
Project Total	$50.4	$55.0			$55.0	$55.0		
Full-time Equivalents (FTE)		0.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources		23.3K						

Comments:

NOAA contribution: Principle Investigator, Senior Research Chemist Jeff Short 1.5 months@15 K, Zoologist Pat Harris 1.5 mo @ 9.5K for a total NOAA contribution of 23.3K.

FY00

Prepared: 4/13/00

Project Number: 01195
Project Title: Pristane Monitoring in Mussels
Agency: National Oceanic and Atmospheric Administration

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2000 to September 30, 2001

Personnel Costs:		GS/Range/	Months	Monthly		
Name	Position Description	Step	Budgeted	Costs	Overtime	
Pat Harris	Zoologist	11/4	1.0	6.4		
Josie Lunasin	Chemist	9/6	1.8	5.8		
Jeff Short	Senior Research Chemist	13/6	0.5	10.1		
	Subtotal		3.3	22.3	0.0	
					Personnel Total	

Travel Costs:	Ticket	Round	Total	Daily	
Description	Price	Trips	Days	Per Diem	
anchorage Workshop	0.4	1	3	0.2	
Cordova	0.4	6	24	0.2	
air charter 18 days @ 1K/day	1.0	18			
				Travel Total	

FY00

Prepared: 4/13/00

Project Number: 01195
Project Title: Pristane Monitoring in Mussels
Agency: National Oceanic and Atmospheric Administration

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2000 to September 30, 2001

Contractual Costs:	
Description	
Temporary labor to analyze pristane samples	
When a non-trustee organization is used, the form 4A is required. ***Contractual Total***	

Commodities Costs:	
Description	
Chemicals, glassware and chemistry laboratory supplies to analyze samples	
Commodities Total	

FY00

Prepared: 4/13/00

Project Number: 01195
Project Title: Pristane Monitoring in Mussels
Agency: National Oceanic and Atmospheric Administration

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2000 to September 30, 2001

New Equipment Purchases:	Number	Unit	
Description	of Units	Price	
Those purchases associated with replacement equipment should be indicated by placement of an R.		***New Equipment Total***	

Existing Equipment Usage:	Number	
Description	of Units	

FY00

Prepared: 4/13/00

Project Number: 01195
Project Title: Pristane Monitoring in Mussels
Agency: National Oceanic and Atmospheric Administration