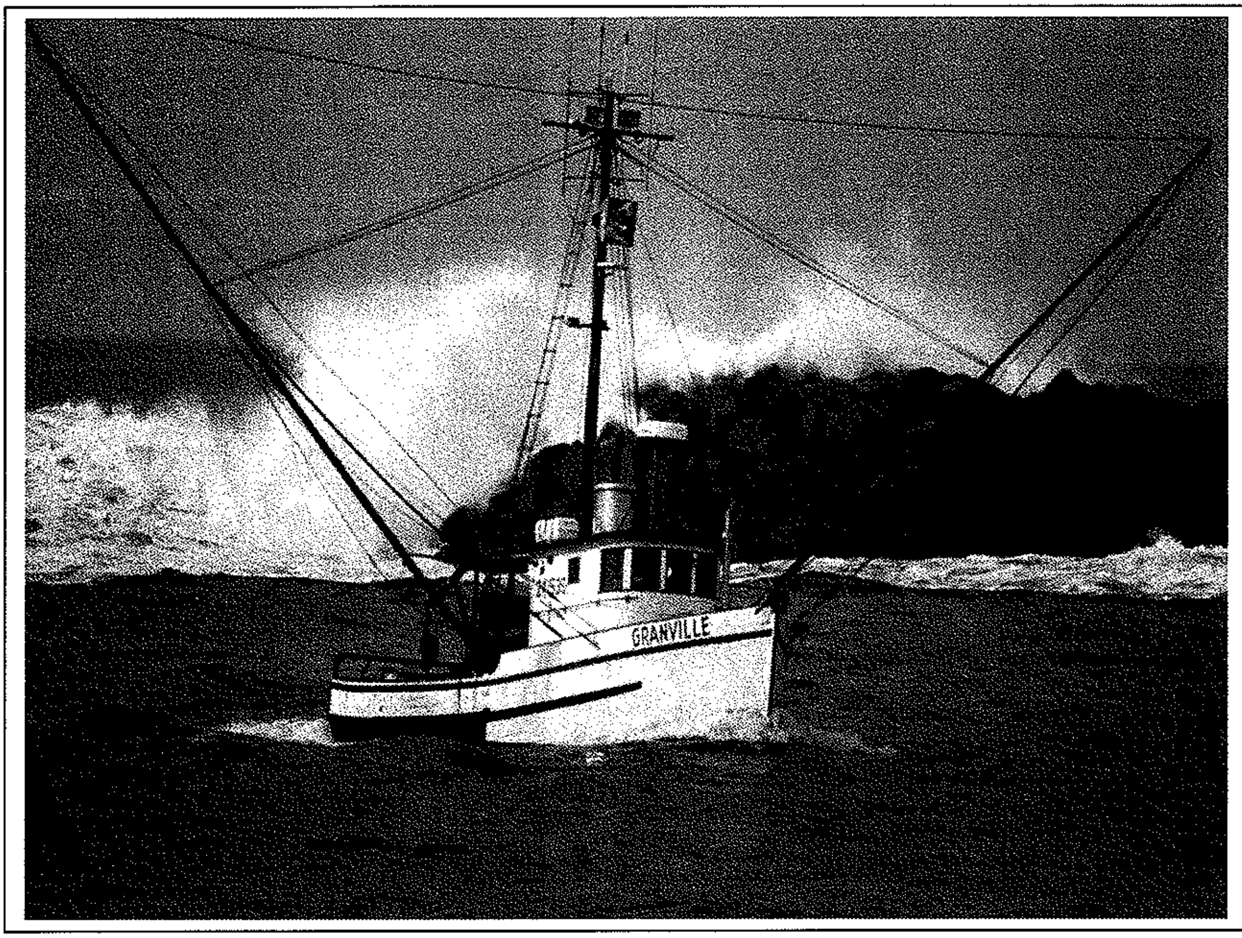
PROJECT CROOS
Collaborative Research on Oregon Ocean Salmon



Final Report

Project Funded by the Oregon Watershed Enhancement Board
To the Oregon Salmon Commission

OREGON TROLL SALMON — QUALITY IS KING — OREGON SALMON COMMISSION | OSU Oregon State University — Coastal Oregon Marine Experiment Station | Sea Grant Oregon | NOAA — National Oceanic and Atmospheric Administration — U.S. Department of Commerce | Oregon Fish & Wildlife

March 2007

PROJECT CROOS
Collaborative Research on Oregon Ocean Salmon

Using "Real Time" Genetic Information to Address the Klamath 'Weak' Stock Crisis for Oregon's Ocean Salmon Fishery

EXECUTIVE SUMMARY

Background

Low escapement levels of Klamath River stocks and harvest limits on ESA listed salmon have substantially constrained harvests of Oregon and West Coast salmon troll fisheries. This has resulted in the loss of 100's of jobs and millions of dollars in annual coastal income. Presently, salmon ocean managers have no access to "real time" data on stocks and are unable to differentiate stocks at local spatial and temporal scales. The result has been large area closures for entire seasons. New science and management tools are needed that can differentiate stocks in "real time" at refined spatial areas, protect weak stocks, and increase access to healthy stocks.

Objectives

The project goal was to conduct collaborative research and develop protocols using genetic stock identification (GSI) in "real time" that improves science, management, and marketing of West Coast salmon. Specific objectives included 1) providing financial assistance to salmon fishermen, 2) developing protocols for fishermen and fleet coordinators/managers, 3) conducting near "real time" GSI analysis, 4) developing digital technologies, bar codes, and "traceability" systems, 5) developing a comprehensive web site, 6) developing methods for collecting oceanographic information, and 7) considering potential of GSI technologies for improving salmon management.

Findings and Results

Financial Assistance The project provided financial assistance to 20% of the active Oregon fleet. More than 72 vessels participated in at least 1 opener (72 operators, 54 crew members). Over 4,270 fish were sampled which represented 17% of the Oregon commercial salmon harvest South of Cape Falcon in 2006. A total of $332,100 was distributed to operators and crew.

Protocols Project managers developed detailed protocols for biological sampling, data collection, fleet management, fishermen training, and project coordination.

Genetic Stock Identification (GSI) Over 4,200 tissue samples were delivered to the genetics laboratory along with digital or manual paper logs. A total of 2,097 fish were assigned probabilities $\geq 90\%$ to a specific hatchery or reporting region.

Stock Mixture Proportions The majority of sampled fish were from California's Central Valley (59.08%). The Rogue River contributed the second greatest proportion (7.61%), followed by the Mid Oregon Coast (7.11%) and the Klamath basin (6.58%). The California Coast and Northern California Coast/Southern Oregon Coast regions contributed 2.17% and 1.89%, respectively. The Upper Columbia River summer/fall run was estimated to contribute 3.03% of the total. Twenty other stocks contributed less than 2% each.

100% Assignment of Coded Wire Tag (CWT) Fish Thirty-one of the 2,097 fish that met the 90% probability criteria contained coded wire tags. All 31 CWT fish assigned to the correct hatchery of origin.

Near "Real Time" Analysis Real time genetic analysis was delayed (conducted between 48-96 hours) during the initial project due to inadequate resources. By September/October, fish were successfully assigned to individual genetic stock estimates in near "real time" (within 24-48 hours of laboratory receiving the sample).

Geographic Information Systems (GIS) Maps GIS-based maps were developed that include information on each harvested fish and include pull down menus for exploring relational data.

Dataloggers Digital datalogging devices for fishing vessels proved to be successful and were easier to use than "manual" sampling protocols.

Website Development A working "prototype" website was developed capable of reporting information to multiple audiences using a variety of tools, maps and statistical analysis. The working website will be accessible by mid-late April 2007 at www.ProjectCROOS.com.

Oceanographic Data Collection by Autonomous Vessels A successful pilot test was conducted which showed that autonomous underwater gliders could be used in conjunction with commercial fishing vessels for collecting a wide range of oceanographic data.

Recommendations and Next Steps

Improving Project Protocols Many protocols will need adjustment in response to changing fishing and sampling conditions. CROOS project members can work with other West Coast states, industries, and agencies to design, implement, and refine protocols.

Improving the GAPS Database The GAPS database requires continual improvement. Further characterization of stocks within and adjacent to the Klamath basin are recommended.

Expanding GSI Data Collection Coast Wide Implementing GSI for salmon management will require expanded data collection along the West Coast. Expanded data should be used to identify stock distribution patterns, test relevant hypotheses, and integrate oceanographic information.

Collecting and Integrating Oceanographic Information Oceanographic data will be critical for understanding salmon behavior. We recommend projects that combine vessel-based data collection with autonomous underwater gliders.

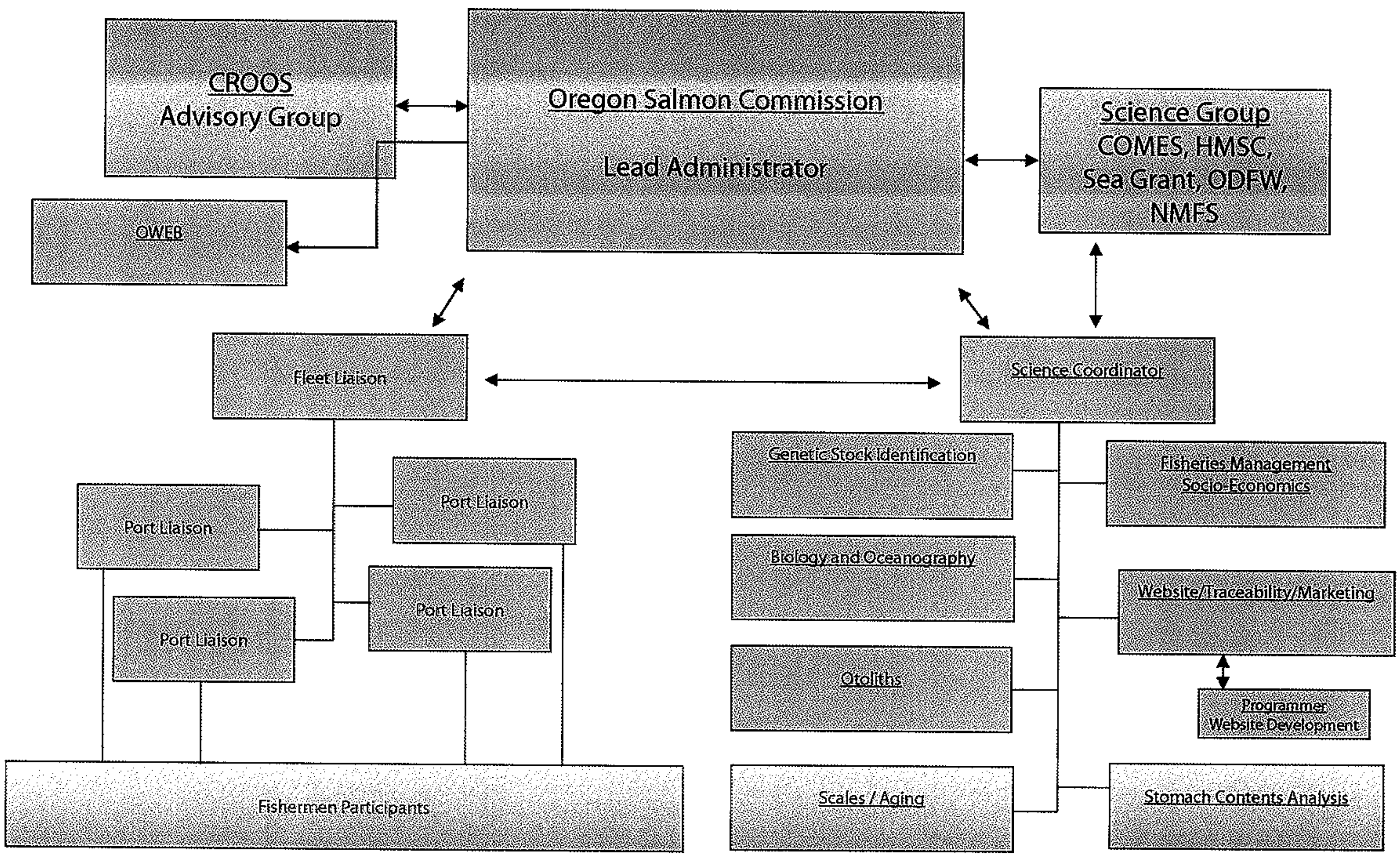
Improving the Design of Vessel Dataloggers Commercial digital dataloggers are inadequate given the needs for a tough, waterproof, relatively inexpensive, portable and reprogrammable logger. A national workshop should be conducted to examine digital-based data collection from commercial fishing vessels. Partnerships with private manufacturers should be evaluated.

Designing a Multiuse "Real Time" Website The prototype GIS-based website should be developed and tested to ensure security, privacy, reliability, and accommodate multiple users.

Using Barcodes, Traceability, and the Website to Improve Salmon Marketing Test markets should be conducted that "link" individual harvest information from producers to consumers, enhance market development, and minimize fraud.

Developing and Testing GSI-based Salmon Management Models Management models should be developed that incorporate GSI information. Management simulations should be conducted with salmon managers in "real time" to evaluate in-season management approaches. Bioeconomic models should evaluate GSI information and potential incentives for improving management of the salmon fishery.

Organizational Chart for CROOS Project



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INTRODUCTION

By almost any standard, managing West Coast ocean salmon fisheries poses extraordinary challenges. Hundreds of stocks migrate 1000's of ocean miles across two national and seven provincial and state boundaries. Some stocks migrate 100's of miles up freshwater rivers to spawn and reproduce. Their progeny remain in freshwater before they become juvenile smolts and return to the sea. Some stocks are raised in hatcheries until they become smolts and then are released into the natural habitat. In the face of reduced natural freshwater habitat, man-made obstacles limiting migration routes, and natural changes in the environment, providing commercial, recreational, and cultural-based fishing opportunities has become a daunting problem.

One of the major tasks in managing salmon fisheries is ensuring access to healthy stocks while protecting weak stocks and meeting stock escapement goals. Because these stocks commingle in ocean, estuarine and freshwater habitats, it is difficult to manage each stock as a distinct unit. The Pacific Fishery Management Council (PFMC) sets opening and closing dates for the commercial troll and recreational seasons, and bases their decisions on a combination of factors including the projected abundance of fish expected to be encountered in a region and the expected stock mixture compositions by area. Current management practices are aimed at reducing impacts to the weakest stock, and seasons and fishable areas are often limited by the "weakest stock" present in an otherwise healthy fishery.

In 2005 and subsequent years, concerns over the Klamath River fall run was the most constraining factor limiting fisheries harvest between Cape Falcon South to the Mexico/US Border (Pacific Fishery Management Council 2006). A fishery resource disaster was declared in 2006 by the Secretary of Commerce, and a complete closure spanning from Cape Falcon, Oregon to Point Sur, California was only avoided in a collaborative effort by the National Marine Fisheries Service (NMFS), Council, state and tribal representatives to identify a scientific basis to allow a limited fishing season. Nevertheless fishing opportunities were severely curtailed resulting in the loss of 100's of jobs and millions of dollars in annual coastal income.

Currently, the estimated contribution of Klamath stock to commercial troll and recreational fisheries is based on a complex model that uses, among other parameters, coded wire tag (CWT) data obtained from current and previous seasons. To date, detailed and specific information on timing of return and oceanic distribution of this and other stocks encountered off the Coast of Oregon and California are unknown. However, recent development of a genetic database known as GAPS (Genetic Analysis of Pacific Salmonids) provides new opportunities to identify the *genetic stock composition* (GSI) of a mixed stock fishery throughout the season, and to monitor when a particular stock moves in or out of an area being fished. With adequate resources this analysis can be performed rapidly (24-48 hours), allowing for near "real time" monitoring of stocks being impacted by harvesters. Availability of such "real time" data could enable fisheries managers to apply in-season adjustments to areas -- closing areas when impact levels of stocks of concern are exceeded and re-directing fishery efforts towards stocks of harvest intent. It may also provide new opportunities for new longer term management alternatives if there are discernable patterns of stock movement and migration over time.

Development of Project CROOS

In the summer of 2005, members of Oregon's Congressional delegation became concerned about the Klamath crisis and impacts on coastal communities. They asked Oregon State University (OSU) for help in finding science-based solutions to this complex problem. Faculty of the multidisciplinary Coastal Oregon Marine Experiment Station (COMES), in collaboration with the Oregon Salmon Commission and federal and state scientists co-located at the Hatfield Marine Science Center, organized a series of meetings through the fall and winter of 2005-2006 to begin scoping out research ideas. Dr. Michael Banks, a COMES faculty member, fisheries geneticist, and one of the contributors to the GAPS database, suggested designing a project founded on GSI techniques. By early spring 2006 Project CROOS (Collaborative Research on Oregon Ocean Salmon) was born. This informal group included members of the Oregon Salmon Commission (OSC), COMES and other OSU faculty, NOAA fisheries scientists, Oregon Sea Grant (OSG) faculty, members of the Community Seafood Initiative (CSI), faculty from OSU's Astoria Seafood Laboratory, and staff from the Oregon Department of Fish and Wildlife (ODFW). By mid spring a proposal was developed to fund a pilot project and seek out competitive and non-competitive grant funding.

The pilot project was designed to combine basic and applied interdisciplinary science, genetic and oceanographic research, industry and scientist collaboration, and data technology and website development -- while also providing financial assistance to the fleet. This required a high degree of adaptive learning and a fundamental commitment to day-to-day communication and coordination. The CROOS Group adopted a core set of principles to guide their project:

- Authentic collaborative research between industry and scientists based on mutual learning and respect
- Integrated fishing and research activities benefiting fishermen, scientists, and resource managers
- Integrated research and project management using digital technologies
- Creating and managing "real time" data for diverse audiences and uses including fishery science, fishery business management, resource management, seafood marketing, and education.

In mid-Spring of 2006, the Oregon Watershed Enhancement Board asked the CROOS group to develop a research proposal for funding consideration as part of their commitment to assist the Governor's office in providing salmon disaster assistance. In late June 2006 a nine-month pilot project was approved by the Oregon Legislative Emergency Board and funded by the Oregon Watershed Enhancement Board. Given the narrow window of time, the CROOS group began planning for the project in May and fishermen volunteered their own time to assist in developing the sampling protocols and providing data during the mid-June openers. When the project was formally approved in the last week of June, training sessions were being held, contracts with fishermen signed, and operational protocols already being refined.

Based substantially on the results of the pilot CROOS project during the summer of 2006, a two-day meeting was convened in early October by the Pacific States Marine Fisheries Commission. The meeting included over forty participants from federal and state agencies for salmon science and management, and representatives from the Oregon, Washington, and California salmon troll industries. The participants agreed to: 1) develop a five-year Experimental Fishing Permit (EFP) for the West Coast that would direct research on ocean salmon science and management using GSI techniques; 2) coordinate research between NMFS laboratories, state agencies, and fishing industries from the three West Coast states; and 3) use the protocols developed by the CROOS project to direct and facilitate cooperative fishery GSI-based science. In order to provide for sampling in otherwise closed areas and times, PFMC discussed and determined that, if needed, an EFP could be issued on an emergency basis. In addition, during the fall-winter of 2006/2007 the CROOS group began coordinating with the California Salmon Council and assisting them in developing a similar project.

OWEB Project Goal and Objectives

Goal

Conduct collaborative and interdisciplinary research that develops protocols using genetic stock identification (GSI) in near "real time" to 1) improve science, management, and marketing of West Coast salmon, 2) minimize harvests of "weak stocks," and 3) enhance economic value of the ocean salmon fishery.

Objectives

- Provide financial assistance to salmon fishermen in exchange for their participation in collecting biological, oceanographic, and fisheries information.
- Develop protocols for fishermen and fleet coordinators/managers for effectively collecting scientific samples and information, supplying and exchanging equipment, and coordinating fleet behavior.
- Conduct near "real time" GSI analysis (24-48 hours after samples and data received) on a minimum of 2,000 harvested salmon.
- Conduct salmon "otolith" chemistry analysis to determine if, and when, Chinook salmon from different stocks resided in waters with similar chemical characteristics.
- Develop digital technologies, bar codes, and "traceability" systems for recording, transmitting, storing, analyzing, and displaying scientific data in near "real time" using "datalogging" equipment, Geographic Information System (GIS) maps, and the internet.
- Develop a comprehensive website for salmon managers, fishermen, scientists, seafood marketers, consumers, and the public for accessing project information in near "real time."
- Develop methods for collecting oceanographic information and integrate with spatial and temporal fish location and GSI information.

- Consider implications/potential of GSI technologies for improving salmon management.
- Make recommendations for future research and management based on project findings.
- Produce Final Report

Guide to Report

This comprehensive report summarizes the 2006-2007 OWEB sponsored CROOS research project. The report describes project management and protocols, GSI sampling results, website development, oceanographic research, otolith analysis, scale analysis, and discussion of resource management. The concluding section summarizes results and makes recommendations for future research and development. A series of technical appendices provide key supporting and background information. The document is comprehensive and should prove valuable to salmon scientists, managers, and industry conducting similar projects.

FLEET MANAGEMENT

Organization and Planning

Planning for managing the fleet operations for the CROOS project began in January of 2006, six months before the project was funded.

The CROOS Team met on a number of occasions to define the roles and responsibilities for a fleet liaison/coordinator and several port liaisons who would report to that person. Tentative contractual arrangements were discussed with the candidates for those positions and were offered conditional to the approval of funding for the project.

The roles of the port liaisons were modified during the course of the project as specific communication and logistical needs were better defined. The liaison functions proved to be best covered on a week-by-week contractual basis by individuals who were chosen to best fit the fleet distribution for that opening period.

Information about the job opportunities for fishermen/vessels for the at-sea research data collection and the port liaison positions were advertised in various locations:

- The OSC June 2006 *Tagline* newsletter that is mailed to all licensed salmon troll permit holders who landed fish in 2005 (565);
- 2006 licensed wholesale first purchasers of troll salmon (73)
- Coastal ports (14)
- Coastal gear/tackle stores (30)
- Sea Grant Extension Agents (4)

From this notification, fishermen responded and were put on a list. Contracts were created for everyone on this list so that if and when they were selected to fish, the paperwork would be complete and they would be ready to go.

Selection of an "optimum compensation level" for the participating fishermen was critical to getting the maximum amount of data while attracting the largest portion of the active fleet to participate. It was determined that each vessel participating would receive $400 per day of charter, plus an additional $100 per day if a crewman was employed. This was intended to encourage fishermen to employ deckhands so that the economic benefits from the project would be spread as far as possible within the industry.

The original plan was to contract with approximately 50 vessels to fish up to 4 openers each (12 days maximum). An opener was defined as the open periods and locations as regulated by the Pacific Fishery Management Council (PFMC) - June 25-28, July 9-11, 16-18, 23-25, August 1-3, September 17-30, and October 17-31 (with each calendar week being an opener in September and October).

Selection of participating fishermen was on a "first come-first served" basis. An original application deadline of June 30 was set, but with the expectation of extending it if available funding allowed more vessels to participate.

Prior to formal project funding approval, four fishermen volunteered to pre-test some of the actual data collection protocols at sea. They fished and collected samples during regular fishery openers, and worked with team members to incorporate their experiences into the initial set of data collection protocols which would be presented to the fishers at a series of training meetings.

Three separate fishermen training sessions were conducted in Newport on June 24, July 8, and September 15. Fishermen traveling from other ports to attend these sessions were paid a mileage allowance.

At these sessions, a brief description of project goals and the science of Genetic Stock Identification were presented. Data collection techniques and protocols were explained. Supplies were distributed, reporting instructions were explained, and the operation of the datalogging equipment was demonstrated. Contracts were explained and signed, and instructions were given for submitting a billing invoice to OSC for each employed fishing period.

Those fishermen selected to use and test electronic dataloggers (four to six fishermen at any one time) were given separate individual training sessions, which involved actual installation and testing of the units on their vessels.

Fleet Sampling Activities and Performance

Contracted data collection began on June 25, immediately after the Grant approval was finalized.

Experimental fish permits were not acquired for this season and therefore all fishing occurred during regulated seasons.

The fishermen were required to record their "fishing track" for the time when their gear was in the water. When each fish was caught and landed, fisherman were required to:

- collect several scale samples and a small clip of a fin for DNA analysis
- enclose both in a piece of blotter paper and enclose in a pre-marked envelope
- measure the length of the fish
- attach a pre-barcoded metal tag to the fish
- record fisherman's name, the date, time, and location of capture in latitude/longitude, the length of the fish, its depth of capture, the presence of any fin clip markings, and other remarks on the envelope
- record pertinent oceanographic data
- record the "track" of the vessel during fishing operations

Although not a formal part of the CROOS project, two or three fishermen in each opener were asked to collect salmon stomach samples on the last day of their trip for NMFS scientists conducting feeding studies.

All oceanographic and track-log recordkeeping was initially accomplished by manual entry into a paper logbook on all vessels not equipped with an electronic datalogger. Data were supposed to be recorded at a minimum of 30 minute intervals by the fishermen. This requirement was cumbersome and not uniformly followed by all fishermen. In addition, difficulties in standardizing and recording the data seriously affected the time and effort required to analyze the data in the laboratory. By late July, each of the chartered fishermen was provided a handheld GPS unit to automate vessel track logging and to standardize some of the other recordkeeping protocols (the location and time of capture of each fish were also recorded and stored electronically). Using these units eliminated the need to manually record this information on a paper log, which simplified the data recording duties of the fishermen, as well as expediting data entry in the laboratory. Additional training sessions were held to familiarize the fishermen with these units.

In general, the fishermen participants were able to collect samples and record the required data with minimal interruption of their normal fishing operations. Some fishermen were initially concerned that data sampling would negatively impact their production, especially at higher catch rates, but as sampling became more routine, there was little if any impact on fishing production. Several of the original techniques for sampling and recording data were modified based on feedback from the participating fishermen.

The fleet managers maintained daily records of participation and contact information and shared this information with the liaisons and the lab. Communication between liaisons and charter vessels was sometimes limited due to physical proximity and communications equipment limitations, but was generally not required on a daily basis. Since each of the fishery openings for the 2006 season was limited to less than a week in duration (essentially one fishing trip per opener), it was possible to accurately account for total and individual participation by opener.

When each chartered vessel returned to port to deliver fish, the samples and records were dropped off at pre-arranged locations (a drop box at the Port of Newport office building, by using pre-paid mailers for out-of-Newport vessels, and by hand delivery in some cases), and were then delivered to the lab. Invoices were sent to the OSC.

The logistics involved with these activities proved to be much greater than anyone anticipated. In addition to gathering the samples, reports, and invoices, it was necessary to re-supply the fishermen between trips with tags, envelopes, batteries, etc. and to download the track logs and waypoints from the GPS or datalogger units and to reset these devices between each trip. As the project progressed, many of these problems were addressed and improvements made. In Newport, a convenient drop box, a central supply distribution site, and a check distribution site were all incorporated into the project to accomplish these tasks. By mid August, it was obvious that a single liaison at one central, convenient location would work more efficiently than a handful of fleet coordinators who were also fishing or engaged in other activities.

In late August, the OSC contracted with the Newport Port Outreach Specialist to assist with the logistics of the project. Fishermen were able to take their samples and GPS units to the local Outreach Specialist's office and attend to all responsibilities at one location and time. In addition to downloading and resetting the GPS units, the Outreach Specialist was able to assist with coordinating the disbursement and collection of supplies and equipment, coordinating with and delivery to the lab, and communicating with fleet management and vessels. This greatly reduced the time required by the genetics laboratory to process samples and thus facilitated more rapid genotyping of the fish.

As the project progressed, it became important to track individual "boat-days" of participation consistent with meeting project objectives. These included managing sampling effort throughout the season and across geographic areas, and communicating remaining eligibility to each fisherman.

A spreadsheet model of total fishery participation was updated daily. This model incorporated actual budget expenditures, information from individual fishermen regarding future participation, and estimations of weather and fishing factors. This allowed the management team to produce an estimation of the remaining "boat-days" that the budget would support. In the last weeks of the project, the remaining days of eligibility were calculated and communicated to each fisherman, and additional days of availability were offered to those with remaining eligibility.

Results

87 vessels were on the list with fishermen from the following counties;
Benton, Clackamas, Coos, Curry, Douglas, Garibaldi, Lane, Lincoln, Linn, Marion, Tillamook, and Yamhill
72 vessels participated in at least 1 opener (72 operators, 54 crew members)
707 days were fished
4,278 fish were sampled
$332,100 was distributed to vessels (operators/crew) for participation

Observations and Suggestions

At the beginning of the project, there was some skepticism about the project from within the fishing fleet. This seemed to be primarily focused on two areas. One was the possibility that information gathered from this type of study would be used 'against us' to unfairly limit fishing due to previously undiscovered impacts on critical stocks of salmon, or impacts on small populations which had previously been aggregated into a larger stock composite. The second area of concern was that the project would not fairly distribute the research dollars within the fleet, would favor certain sectors, or would discriminate against very small vessels.

As the project progressed, these concerns diminished and there appeared to be an increase in enthusiasm about the goals and probability of success of the project. (See end of season participant survey results in Appendix 5.) Some of this may have been due to the fact that fishermen were paid for their participation, but the types of questions and positive suggestions that project team members received over the course of the project seemed to indicate a real change in attitude. Comments ranged from 'anything would be better than status quo' to relatively informed discussions about the 'inevitability that better data is going to lead to improved access to healthy stocks of fish'.

The decision that, up until September 1, every Oregon resident permit holder who requested to participate would be offered a contract, helped to gain support for the project. The fact that even those fishermen who were late in contacting the OSC (after the published cutoff date and the July training session) were still eligible for at least 10 days of work, was perceived by fishermen and the fleet at large as fair.

Comments about sampling and reporting protocols focused primarily on either improving protocols or eliminating unnecessary activities. Early confusion about turning in samples, obtaining supplies, and turning in invoices, were significantly reduced as the project proceeded and more fishermen participated. Information on protocols was passed around by word of mouth and became fairly common knowledge in the fleet.

Future Planning

The fleet management team continues to meet with the overall CROOS Team to refine and plan expansion of the project into the future.

Topics which need to be addressed to support future research include:

1. Planning for fishery sampling outside of normal operating areas. This could include not only preparing for fishing permits and protocols for fishing in areas which are closed to fishing, but also for directing fishing in areas which would not normally be fished by participating vessels (non-volitional fishing). These options would probably require additional training and higher levels of daily compensation.
2. Logistical issues about reporting, sample collection, compensation, etc. Coordinating and fleet management issues may change if fisheries are managed on a continuous basis rather than on the basis of short, weekly openings as it was in 2006.
3. More of the at-sea data recording tasks will need to be done digitally. Disruptions of normal fishing routines will present more problems as catch rates improve, and manual data entry in the laboratory is costly and time consuming.
4. Integrating experience gained from the CROOS project into future, coast wide GSI based research programs. Coordination of fleet management over the entire West Coast will be a particularly important challenge. Contacts have been made with industry representatives from California, and CROOS fleet management representatives have agreed to meet with them to assist in their planning for future GSI projects. Fleet management comments and recommendations were incorporated into the Salmon Advisory Subpanel report to the Pacific Fishery Management Council in November on the Salmon Methodology Review of Future GSI-based management strategies.
5. Consideration of the unique logistical realities which will be encountered at each potential port of landing in the range of the project. Prompt transfer of samples and data to the laboratories, resupplying fishermen, and invoicing and compensation logistics are best accomplished by establishing an office or dropsite in each port staffed by a trained "liaison person". The model ultimately developed in Newport of a drop/distribution site at the Port of Newport Terminal staffed by a trained Port Outreach Specialist was far more efficient than earlier attempts to do these tasks at separate sites or by mail.
6. Communication protocols and daily check-in requirements will need to be clearly defined and explained at the training sessions. The roles of at-sea liaisons will need to be further defined. The use of a shore-based call-in line should be tested.

GENETICS

Introduction

Alternate freshwater drainages where salmon spawn can act as primary delineating forces resulting in isolated populations (stocks) that can have varying levels of genetic uniqueness depending on history and the fidelity of natal homing of the species in question. Among those salmon with high levels of natal philopatry, Chinook salmon display concordantly high levels of genetic structure. These unique genetic signatures can be used to estimate the most likely source population of individual fish (individual assignment) and to estimate the percentage that a particular stock contributes to a total sample of a mixed-stock fishery (mixed-stock analysis, MSA) if an adequate genetic baseline has been developed. The application of molecular genetic data to estimate stock-mixture proportions has made substantial contributions to Chinook management for over two decades (Milner et al. 1983, Teel et al. 1999, Shaklee et al. 1999, Banks 2005). Recent discovery and application of microsatellite molecular markers (Banks et al. 1999, Nelson and Beacham 1999, Williamson et al. 2002, Greig et al. 2003) and advancement of statistical methodologies (e.g. Rannala and Mountain 1997, Banks et al. 2000, Pella and Masuda 2001, Banks et al. 2003, Kalinowksi 2003) have enabled fine-scale detection of genetic differences among populations, increased the accuracy of estimates of mixture proportions, and permitted the assignment of individual fish to their most-likely natal source populations with high levels of confidence (Banks 2000, Beacham et al. 2002, Baudouin et al. 2004, Banks 2005, Banks et al. in prep, Seeb et al. in press).

The distribution of Chinook off the coast of Oregon has traditionally been estimated using coded wire tags (CWT) recovered from a subset of harvested fish sampled dockside by Oregon Department of Fish and Wildlife (ODFW) port-checkers. Coded wire tags are small wires with embedded individual numbers that are inserted into the snouts of some hatchery fish. In-season fisheries management has not been attempted with the current CWT program, probably because data from the small number of tags usually collected in a given fishery are difficult to interpret until all tag returns for the season have been compiled.

The CWT program has recently been under scrutiny because mark-selective fisheries make it more difficult and expensive to sample tags and samples no longer represent unmarked stocks. There are also long-standing concerns over whether the distribution and behavior of hatchery fish is representative of natural stocks, and statistical uncertainties related to sampling, the difficulty of detecting rare stocks, and the need to account for stocks that are unmarked (Hankin et al. 2005). Recommendations by the Expert Panel on CWTs conclude that genetic stock identification techniques could be used to augment the CWT program and assist in modeling stock abundance projections (Hankin et al. 2005).

Recent technological advances in GSI make this a viable option. The Pacific Salmon Commission funded the development of a microsatellite baseline database of Chinook salmon genotypes called GAPS (Genetic Analysis of Pacific Salmonids), that can be used to identify 44 separate reporting groups represented by 160 stocks from California through Alaska (Figure 1, Moran el al. 2005, Seeb et al. in press, Banks et al. in prep). Techniques are now available for rapid scoring, allow near "real time" assessment of the origin of individual fish with unprecedented degrees of accuracy and confidence. Further, because all fish "carry" genetic tags, mixture proportions (contribution rates of fish from many stocks mixed in a single sample, as would be collected from a mixed-stock ocean fishery) and most-likely source populations of both hatchery and wild Chinook stocks can be estimated.

Ecosystem processes and their affect on the distribution of specific fisheries stocks and their feeding behavior can be investigated by recording the specific location of catch for each fish along with location of fishing effort. Maps of oceanographic conditions can then be matched to these locations. Autonomous underwater vehicles, or gliders, are capable of measuring sea temperature at depth, dissolved oxygen content of water and salinity, and transmitting this information via satellite for "real time" provision of oceanic conditions. Likewise, weather permitting, sea surface temperature and chlorophyll maps are available from satellite imagery and surface currents are available from surface radar. The affordability of onboard handheld Global Positioning Systems (GPS) devices makes the economy of equipping a large fishing fleet to record high resolution special parameters of their fishing efforts feasible. By matching harvest location with genetic stock of origin data we can monitor stock composition by time and area, provide detailed information on the oceanic distribution of different stocks of fish, and explore how oceanic conditions affect fisheries behavior and distribution. Importantly, through long-term datasets we can explore how these factors vary in space and time, seasonally, through decadal oscillations, el Niño events and, potentially, global climate changes.

The Pacific Fisheries Management Council (PFMC) sets commercial troll and recreational fishing seasons based on a combination of factors including the projected abundance of fish expected to be encountered in a region and the expected stock mixture compositions by area. Current management practices are aimed at maximizing catch or fishing opportunity while achieving escapement or exploitation rate goals for all stocks in the fishery. As a result, seasons are frequently limited by weak stocks. If fisheries can be designed to avoid these weak stocks in favor of more abundant or healthier stocks, the fishing season can be extended. In 2005 and 2006 concerns over Klamath fall run was the most constraining factor limiting fisheries harvest between Cape Falcon South to the Mexico/US Border (Pacific Fishery Management Council 2006). A fishery resource disaster was declared in 2006 by the Secretary of Commerce and a complete closure of Chinook fishing from Cape Falcon, Oregon to Point Sur, California was only avoided in a collaborative effort by National Oceanic and Atmospheric Administration (NOAA), PFMC, state and tribal representatives to identify a scientific basis to allow a limited fishing season (Gutierrez 2006). Currently, the estimated contribution of Klamath stock to commercial troll and recreational fisheries is based on a complex model that uses, among other parameters, CWT data obtained from years prior. To date, detailed and specific information on timing of return and oceanic distribution of this and other stocks encountered off the Coast of Oregon and California are unknown. Genetic data can be used to identify the stock composition of a mixed stock fishery throughout the season, and to monitor when a particular stock moves in or out of an area being fished. This can be performed rapidly (24-48 hours), allowing for near "real time" monitoring of stocks being impacted by fisheries harvest. Near "real time" availability of such data could enable fisheries managers to apply in-season adjustments to fishing seasons, re-directing fishery efforts towards stocks of harvest intent.

The objective of this study was to test the feasibility of near "real time" genetic analysis coupled with developing fine-scale maps of fish encounter locations. We also developed a prototype system to disseminate this information to fisheries managers and scientists via the world wide web, to be available for "real time" management decisions and ecosystem-based research.

Methods

The feasibility of rapid (24-48 hour) genetic stock identification of individual Chinook salmon harvested by Fishermen during commercial troll fisheries conducted off the Coast of Oregon was tested by the Marine Fisheries Genetics Laboratory at Oregon State University. "Openers" (the time within a calendar week when fishing was permitted) lasted three or four days per week in June - August 2006 and had a retention limit of 75 fish per week (Figure 2; details on openers can be found at http://oregonsalmon.org/2006%20Troll%20Season%20Regs.pdf). Fishermen were instructed to sample up to the first 70 fish retained in openers. September and October openers generally lasted a full week and had a retention limit of 50 fish; every retained fish was required to be sampled by fishermen during these months.

Participants of Project CROOS were issued either a handheld GPS unit (Garmin GPS 60) or an electronic logbook to record track locations while they fished and to record each location where a fish was harvested (brought up on the boat) and sampled. Pre-printed envelopes with barcode labels on the outside and matching metal barcodes inside were provided to fishermen for data collection and tracking barcoded fish. To tag fish, participants removed the barcode from inside the envelope and strung it on a plastic zip tie threaded through a slit cut in the lower jaw of each salmon. Individual fish data were recorded on the matching numbered envelope (unless the participant had an electronic datalogger). Data records included: date and time of harvest, location (waypoint number from GPS), length of fish, depth of capture, whether a hatchery mark was present, if a stomach was saved for content analysis. Check-boxes were provided to indicate that scales and a tissue-sample had been collected. A subset of fishermen was provided temperature-and-depth dataloggers to record oceanographic conditions while fishing. These records will be used to assess whether these devices can detect ocean fronts and to determine how the variation in oceanic conditions influences feeding behavior, spatial distribution, and population specific oceanic distribution and aggregate patterns of Chinook salmon. In the laboratory, data were compiled in an Access database. ArcGIS spatial analysis software was used to analyze fishermen's track logs, fish encounter locations, and to assess spatial and temporal changes in fish encounters off the Oregon Coast.

Each time a participant returned to port after fishing, they were required to check in with the port liaison who, in turn, was responsible for downloading GPS track logs and fish encounter information and transferring this data, along with tissue and scale samples, to the genetics laboratory. The genetics laboratory matched each fish's barcode to the latitude and longitude where that fish was harvested, genotyped a subset of all the fish sampled that week, and used genetic data to estimate the mixture proportions of all stocks present and the individual stock of origin. Critical to rapid sample processing and mapping was the port liaison's ability to collect both fish samples and GPS coordinates from the fishermen, and to provide these data together to the genetics laboratory. After the genetic stock of origin was estimated, the sample envelopes were sent to ODFW for scale aging analysis.

The Marine Fisheries Genetics Laboratory at Oregon State University archived a total of 4,317 fish samples collected by fishermen participating in Project CROOS during the 2006 fishing season (Table 1). This project's initial objective was to identify the stock of origin for 2,000 fish, however it was necessary to process more than 2,000 fish for two reasons: 1) missing genotypic data or 2) low assignment probabilities (< 90%). Fish were required to have data for eight or more of the standardized GAPS 13 loci before they would be included in our genetic stock assignment dataset. Missing genotypic data results from a sample failing to amplify at a genetic marker. This can occur due to low quality DNA caused by tissue degradation (rotting), inefficient sample digestion in the laboratory, sample contamination, or an inefficient polymerase chain reaction. It is generally difficult to tease out which specific issue contributed to amplification failure. For example the majority of samples provided by fishermen were of excellent quality and taken with obvious care. From the total number of fish processed (3,097), 530 (17.11%) fish did not amplify at 8 or more loci and were subsequently removed from the dataset; the remaining 2,567 fish were used to estimate stock mixture proportions and for individual assignment to baseline populations.

Probability values of stock assignment for the 2,567 fish ranged from 28% - 100%; recent power analyses (Banks et al. in prep) indicate that fish with probability values < 90% are more likely to assign to an incorrect stock of origin. By the end of the season a total of 2,097 fish were assigned probabilities ≥ 90%, while 470 fish with sufficient genotypic data did not meet the 90% criterion (18.3% of the total dataset). Samples not processed in the laboratory (1,221) are in the OSU archive and can be genotyped at a later date.

Laboratory Analysis

Tissue samples were digested and DNA extracted using silica membrane-based kits (Qiagen® DNeasy™ kits) following manufacturer's protocols or by standard chelex methodology. Genomic DNA was arrayed into either 384- or 96- well plates for high throughput genotyping. The polymerase chain reaction (PCR) was used to amplify 13 microsatellite loci standardized by GAPS: *Ogo2, Ogo4* (Olsen et al. 1998), *Oki100* (unpublished; provided by Canada's Department Fisheries and Oceans), *OMM1080* (Rexroad et al. 2001), *Ots201b, Ots208b, Ots211, Ots212, Ots213* (Greig et al. 2003), *Ots3M, Ots9* (Banks et al. 1999), *OtsG474* (Williamson et al. 2002), and *Ssa408* (Cairney et al. 2000). PCR was performed in 5 ul reactions with 1X Promega buffer or 1x GoTaq® Promega buffer, 1.5 mM $MgCl_2$, 0.1667 - 0.5 uM primer concentration, with annealing temperatures ranging from 50 - 63 degrees C. Locus-specific details for PCR conditions and thermal cycling programs can be obtained by request from R. Bellinger. Forward primers were fluorescently labeled, and PCR products were visualized using an Applied Biosystems® model 3730xl genetic analyzer. GeneMapper software was used to assign standardized GAPS allele calls to allele peaks. Individual fish's unique genotypic profiles were tracked using the unique barcode number, transferred from GeneMapper to Microsoft excel spreadsheets, and archived in the final Microsoft Access "Project CROOS" database.

Genetic Stock Identification

Genetic stock estimates were performed using GAPS baseline v2, which contains 166 Chinook salmon populations from mid-California north to Alaska (Figure 1, Appendix 1). The GAPS baseline uses "reporting regions" for compositional analyses: reporting regions are groups of populations with similar genetic signatures, as previously identified by other allozyme and microsatellite studies, taking into account a combination of geographic features and management applications (Teel et al. 1999, Seeb et al. in press, Banks et al. in prep). Several rivers, such as the Klamath and Rogue, are genetically distinct enough to be considered their own reporting regions. We combined California Central Valley fall and spring runs into one reporting region because of known shortcomings in discriminating fall from spring runs in this drainage and because the relative contribution of these two runs, per se was not of direct importance to the focus of this study.

Genetic-based estimates of stock mixture proportions (mixed stock analysis, MSA) and individual assignment (IA) probabilities were calculated using the computer program Genetic Mixture Analysis (GMA; Kalinowski 2003). GMA uses Bayesian priors to calculate the probability that an individual fish came from a specific population in the baseline. The proportion that a stock contributes to a mixture can also be calculated by summing the number of individual fish assigned to reporting region (IA) and dividing this number by the total. Mixture proportions using IA data were calculated using Microsoft Excel. Compositional results from IA are nearly identical to MSA.

Accuracy of individual assignment rapidly declines with probabilities of less than 90% (Banks et al. in prep), therefore two alternatives to traditional MSA were tested. In the first approach we summed the number of fish with IA ≥ 90% by region, pooled assignments for fish with probabilities of less than 90% into an "uncertain" category, and then recalculated stock mixture proportions (hereafter referred to as the "rigorous dataset"). The second approach calculated mixture proportions only using fish with high IA probabilities (≥ 90%) (hereafter referred to as "conservative dataset").

Pooling individuals with IA < 90% into a separate category and including these in the denominator biases mixture proportions low because some of the fish removed from a reporting region may have been correctly assigned. This amount of bias is dependent on the proportion of fish that were correctly versus incorrectly assigned. The percent contribution of fish with IA < 90% to a reporting region's total allocation was calculated to evaluate the potential range of bias in the rigorous dataset.

The conservative dataset, limited to fish with high probabilities, would only be more accurate than traditional MSA if confidence limits were equal for all fish considered in the mixture and all fish with lower probabilities were incorrectly assigned. Since it is known that accuracy drops below 90% probability values, a dataset restricted to the most accurate data possible may provide a more reliable estimate of stock mixture proportions if bias factors are known and taken into account, however, bias may confound findings if specific stocks are more likely to be mis-classified than others. Increased accuracy is critical in applications such as considered here because precision of the "weak stock" estimate has overriding importance and this bias factor can be taken into account. Analyses using GAPS baseline v1 and stock mixture proportions calculated using only fish with IA ≥ 90% were used for genetic analysis presented at CROOS meetings and during the 2006 fishing season. After baseline v2 was released, however, we reanalyzed all data using all three treatments of data and present results here. GAPS v2 adds 56 population samples to the 110 population samples in GAPS v1. This should, in principle, reduce the number of mis-classified fish.

The effect of pooling or removing fish with low assignment probabilities was evaluated several different ways. First we verified that estimated stock mixture proportions from MSA were similar to those obtained from IA. The difference between results obtained from the IA conservative and IA rigorous datasets was calculated to determine which stocks were potentially affected the most by pooling or limiting data. A bias factor for the rigorous dataset was estimated by calculating the percent that, if assigned correctly, IA < 90% fish would have contributed to a region's estimated contribution in the mixture.

The region or groups of regions that were assigned the greatest percentage of fish with low probabilities (< 90%) might benefit the greatest from increased baseline coverage or by selection of specific genetic markers to increase genetic assignment power (Banks and Jacobson 2004). We assessed which regions fish were frequently assigned to with low probabilities (IA < 90%) by summing the number of fish with IA < 90% assigned to each region and dividing this number by the total (n = 470).

Power analyses indicate that increasing fishery sample sizes from 100 to 400 fish has a strong affect on the minimum stock component one might be able to estimate in the fishery sample; i.e., the smallest component estimates for fishery sample size of 100 is 0.04, but fishery sample sizes of 200 allow component estimates down to 0.02 (Banks et al, in prep). We estimated stock mixture proportions for weeks with sample sizes of IA ≥ 90% and n > 100. To increase our power and accuracy, we plan to genotype additional fish and attempt to bring the total sample size per week to over 200 fish. This will affect calculations for weeks of July 16-22 and October 22-28 and overall averages for the total dataset.

We evaluated the estimated stock contribution from the Klamath basin on a weekly basis, for weeks with sufficient sample sizes (n > 100 with IA ≥ 90%), and provided a comparison of all treatments of data (IA total, IA rigorous, and IA conservative). Weekly contributions from the Klamath, California Coast, and the Northern California/Southern Oregon Coast were compared on a week-by-week basis using MSA.

Variation in spatial and temporal stock composition and harvest rate per unit effort was calculated in a preliminary test of feasibility for fisheries management and applications. For simplicity purposes, we limited analyses to two weeks, September 17–23 and 24–30. Fishermen's track log records and fish harvest locations were mapped onto the ocean using ArcGIS spatial analysis software. Two areas were hand selected to maximize sample size for assessment of harvest rate per unit effort and to compare relative stock proportions. "Harvest rate" was defined as the location where one fish was landed and "unit effort" was measured as one record in a 5-minute interval recorded by the GPS unit for each fisherman in their track log. Fish harvested by participants not equipped with GPS units were removed from the comparison of harvest rate per unit effort; however, these fish were included in genetic estimates of stock mixture compositions. Three fishermen (different fishermen each week) were not equipped with GPS units and their fish were excluded from the harvest per unit effort calculation to normalize results.

Oregon Department of Fish and Wildlife port samplers at Newport and Garibaldi routinely sample fish for presence of CWTs. Since all fish marked with CWTs are from known populations, these provide a means to validate genetic stock identification methods and scale aging analysis. All fish sampled by ODFW that contained CWTs and were marked with Project CROOS barcodes were recorded and data were provided, with the ODFW snout ID number, to the OSU genetics laboratory. Validation of genetic stock assignments was conducted as a "blind test" as follows. The OSU Genetics Laboratory provided ODFW the genetics results prior to CWT data availability. After the CWT data were available, ODFW personnel matched snout identification numbers and barcodes to determine the true population, and compared these results to those obtained by genetic analyses. To assist in scale analysis conducted by the ODFW scale-aging laboratory, best estimates of river of origin and run-time were provided with the scales when they were given to ODFW.

Results

Feasibility of "real time" analysis and synthesis of findings

By September/October of this project, fish were successfully assigned individual genetic stock estimates and mapped by their harvest location in near "real time" (within 24-48 hours of laboratory receiving the sample). In contrast, during the first few months of the project, genetic analysis was delayed (conducted between 48-96 hours) because personnel in the genetics laboratory were attempting to conduct genetic analysis plus organize project logistics. By the end of the season protocols had been developed, minor laboratory issues had been resolved, and near "real time" analyses were achieved.

Stock identification and distribution

Population based mixed stock analysis
It has been well documented that population-based methods of stock assignments provide more reliable estimates of stock proportions than individual based methods, primarily because the sub-populations defined within a fishery sample provide more information than is contained within a genotype of a single individual. Results of mixed stock analysis (MSA) (Table 2, Figures 4, 5) indicated that the majority of fish were from California's Central Valley (59.08%). The Rogue River was estimated to contribute the second greatest proportion (7.61%), followed by the Mid Oregon Coast (7.11%) and the Klamath basin (6.58%). The California Coast and Northern California Coast/Southern Oregon Coast regions contributed 2.17% and 1.89%, respectively. The Upper Columbia River summer/fall run was estimated to contribute 3.03% of the total. Twenty other stocks contributed less than 2% each.

Individual assignment and alternate data treatment
The MSA analysis provides the best estimate for overall stock proportions, but does not produce estimates of stock for individual fish. Stock mixture proportions estimated from Individual Assignment (IA) with the conservative dataset (fish with IA $\geq$ 90%) indicated that the majority of fish were from California's Central Valley (70.53%). The Klamath Basin was estimated to contribute the second greatest proportion (6.77%), followed by the Rogue River (5.39%) and the Mid Oregon Coast (4.05%). The California Coast and Northern California Coast/Southern Oregon Coast regions contributed 2.29% and 2.10%, respectively. The Upper Columbia River summer/fall run was estimated to contribute 2.15% of the total. Twenty other stocks contributed less than 2% each. These proportions are similar to the mixture proportions for all stocks except those estimated for the California's Central Valley (CACV) fall and spring run. These two runs were grouped into a single reporting region so the criterion for accepting a CACV fish was essentially widened and more fish assigned to this group with high probability, inflating their stock proportion. Rigorous comparison of differences between the two analytical techniques will require confidence limits for each estimate.

The greatest proportion of fish with low probabilities (IA < 90%, n = 470) was assigned to the Mid Oregon Coast (20.00%), followed by the Rogue River (18.72%) and the Central Valley (10.21%; Table 3). The lower Columbia fall run and upper summer/fall run contributed 6.17% – 6.81% respectively, followed by the Klamath (5.11%) and the mid Oregon Coast (4.89%). Northern California/Southern Oregon Coast and California Coast were estimated to contribute

3.62% and 1.91%, respectively. The remaining 17 stocks contributed less than 5% to the IA < 90% dataset.

Distribution patterns over time
We collected sufficient sample sizes (n > 100) for weekly estimates of stock composition in seven weeks (Figure 3). The number of samples collected per weekly opener ranged from 0 – 1173 and sampling efforts were highly dependent on weather conditions. Sample sizes were sometimes limited by low catch rates. Weekly stock proportions from IA and MSA averaged over all weeks were similar: Central Valley fall and spring contributed the greatest percent (MSA weekly average 61.01 %; range 43.91% - 71.49%, Table 4). The Klamath ranged from 3.82% to 11.32% (weeks of 9 July 2006 and 17 September 2006, respectively) with an average over all weeks of 6.47%. The Rogue River spiked at 19.13% during October, up from 1.70% in the first week of August (average 7.26%). Stocks from the California Coast reporting region averaged 2.20% (range 0.67% - 5.38%), and the Northern California/Southern Oregon Coast contributed an estimated average of 2.25% (range 0.60% - 5.75%). Weekly trends for the Klamath, California Coast, and Northern California/Southern Oregon stocks were largely comparable (Figure 7). One of Project CROOS's objectives was to test our ability to provide genetic stock estimates for management and protection of fish from the Klamath basin. Of all treatments of data considered, the conservative dataset estimated the greatest contribution from the Klamath basin on a weekly basis (Figure 7) but the method that would be most useful for management remains to be determined.

Global position system technology was successfully implemented to record fishermen's track logs and harvest locations throughout the season (Figure 8). Oceanographic data were collected with temperature-at-depth dataloggers during the last portion of the season (September and October), and by the OSU COAS AUV glider. These results will be discussed separately in the Oceanographic section.

Preliminary analysis of distribution patterns over space
Catch per unit effort (CPUE) differed between Sections 1 and 2 during the week of 17–23 September (Figure 9). A total of 3,918 and 1,362 units of effort were exerted in Sections 1 and 2, yielding a harvest of 956 and 19 fish (0.239 and 0.041 fish/unit effort, respectively). The following week, fishermen exerted 1,541 and 6,781 units of effort to harvest 63 and 351 fish from Sections 1 and 2 (0.014 and 0.052 fish/unit effort, respectively), so it appears that CPUE in Section 1 dropped. Considerable work remains to be done before we can analyze the CPUE and distribution data with confidence.

Stock mixture composition (MSA) in Sections 1 and 2 followed previously identified trends, dominated by contributions from the California Central Valley (Figure 10; n = 468, 19 fish in Sections 1 and 2, respectively for week 1; n = 35 and 192, Sections 1 and 2, respectively for week 2). It is premature for us to attempt to compare contribution rates for other stocks.

Blind testing against CWT results
Port samplers removed a total of 56 snouts from fish thought to contain CWTs; of these, five were false-positives and did not contain a CWT. From 51 fish with CWTs, 31 were assigned with >90% stringency and each of these were correctly assigned to the CWT stock of origin using genetics. Eight fish did not meet the criteria of ≥ 90% IA, thus we did not consider these

for the empirical validation of genetic assignment, however data are reported for comparison purposes (Table 5). One fish was initially reported as having a genetic identity that did not match the true source population, however, the scale-derived age of the fish also did not match CWT data and further investigation revealed this tag number was read incorrectly. The majority (n = 5) fish with probabilities < 90% incorrectly assigned to their true source population, while three correctly assigned. Eleven fish failed to amplify at ≥ 8 loci and will be reanalyzed. Of the 31 CWT fish that could be assigned with ≥ 90%, all 31 fish (100%) were assigned correctly.

During this first CROOS season we culled a substantial portion (17%) of fish from the genotype dataset due to missing data. The first few months of the project we used Chelex to extract DNA because it is less expensive and faster than using prepared extraction kits. However, kits such as Qiagen, using silica-based columns, produce cleaner DNA, which has a better amplification efficiency. By the end of the project we had switched to Qiagen DNA kits and reduced the number of genotypes requiring removal from the dataset (3-10%).

Discussion

Project CROOS's approach of associating genetic stock identification of individual fish with at-sea data harvest locations and oceanic conditions provides high levels of resolution for stock behavior studies of Pacific salmonids. Combining genetic stock of origin data with other analytical techniques such as otolith microchemistry may enable us to elucidate vexing questions such as where fish go after they enter the ocean and whether they remain as aggregated stocks or mix freely in the ocean. This project demonstrates the feasibility of using molecular genetic technology and stock assignment techniques for stock identification of fish harvested off the Coast of Oregon. We provide proof in principle for generating near "real time" stock origin and distribution estimates for in-season management of fisheries. Internet technology, spatial analysis software (ArcGIS) and Arc IMS interface are the key to successfully distributing this information to fishermen, managers, scientists and consumers.

Genetic data holds great promise for fisheries management; however, statistical and analytical biases need to be evaluated to ensure the best data for fisheries management is provided. Stocks which are a low percentage of a mixed-stock fishery sample are problematic because power declines for smaller contributions (Reynolds and Templin 2004). Three other factors which also contribute to accuracy and bias of genetic estimates of mixture proportions are: 1) marker power, 2) genetic similarity of stocks, and 3) baseline coverage. Marker power for the GAPS baseline has been evaluated by Seeb et al. (in press) and Banks et al. (in prep); results indicate that MSA estimates are accurate within 1–5% of the true value more than 90% of the time. Genetic similarity of stocks can reduce the accuracy of mixture proportions and individual assignments because individuals from similar populations tend to mis-assign. The genetic relationship of stocks in the GAPS baseline has been evaluated to group closely related populations into reporting regions. In some cases, for management purposes, it is desirable to maintain separate reporting regions despite similarity of genetic signatures. Consequently, bias is introduced because measures of baseline accuracy decrease.

Genetic similarity of stocks can cause biased results because of potential mis-assignment. For example, if two rivers included in the baseline, "River A" and "River B" were known to be genetically similar and 10% of all River "B" fish consistently, but incorrectly, assign to River "A", a 10% bias correction factor could be applied. This might occur because stock from River A was moved to River B, thus clouding the genetic difference between the two populations. Chinook salmon stock transfers between basins have occurred for establishment and maintenance of hatchery breeding programs. Current Oregon legislation mandates that 35% of all hatchery brood stock must originate from the wild stock. However, the long established hatchery brood stock population may contain genetic heritage from any of several out-of-basin stock transfers. For example, the Rogue River, a southward migrating stock, has been transferred to the Coos and lower Columbia Rivers as an attempt to establish southward instead of northward migrating stocks. While populations from these three rivers are genetically distinct, fish with intermediate Coos or Columbia /Rogue genetic signatures may assign to both basins with low probabilities.

The third factor affecting accuracy and bias of genetic stock estimation can be attributed to inadequate baseline coverage. All individuals included in a mixed stock fishery sample must assign to a population in the baseline, regardless of whether its source population is represented in the baseline. Statistical methods to address this shortcoming are being developed by Pella and Masuda (2006, program *HWLER*), however this computer analysis method currently requires an excessive amount of computer time and is not publicly available. Since every fish must assign back to a baseline population, a fish from a population not in the baseline will assign to the stock that it is the most similar to. This can inflate the estimated contribution from such most similar baseline stocks.

To explore the relative contribution of fish that might not originate from a stock represented in the baseline we created the category "uncertain" for all fish with probabilities less than 90%. These fish might represent a different stock, or they might be fish at the perimeter of the "average" genotypic profile of a river. Given that the true stock of origin is only known for fish with CWTs, we assessed the contribution of fish with low probabilities by reporting region. The Mid Oregon Coast and Rogue River comprised the greatest component among this group of assignments with low probability. Either fish from genetically similar stocks are mis-assigning to these regions, or fish assigning to these regions are from other perhaps nearby areas. Empirical tests of these hypotheses can be provided by collecting known genetic samples and assessing their relative assignment probability values to calculate bias factors. Although CWT data for fish with IA < 90% were limited to eight fish, results indicate that excluding them from the dataset was appropriate. Five fish with IA < 90% were incorrectly assigned (62%, n = 8), demonstrating that including these fish in stock mixture compositions would have incorrect results. Alternatively, genetic markers can be selected to increase resolution for these regions.

Genetic stock of origin estimates for fish with high probabilities were 100% consistent with CWT data (n = 31). While our mixture proportions calculation is based only on fish with high probabilities and may bias slightly high for the Klamath, these results provide the most conservative (in terms of our confidence in the stock identifications) measure for stocks originating from those regions. If a "weak stock" has potential to constrain a fishery, then policy may find the most conservative dataset more desirable because all conservative dataset assignments including those to the "weak stock" have high certainty.

The Klamath-Siskiyou region has a complex biogeographical history and is the site of numerous "species breaks" (Soltis et al. 1997, Bury and Pearl 1999, Bellinger et al. 2005, Miller et al. 2006). Only the highest elevations in the Klamath-Siskiyou range were glaciated during the Pleistocene, so lower elevation rivers in this area provided refugia during the last ice age. Within the Klamath basin, Banks (1999) documented substantial heterogeneity among Klamath River Chinook stocks. Currently the Klamath basin is represented by three stocks in the GAPS baseline v2: Klamath fall, Trinity fall, and Trinity spring. Stocks divergent from what is currently included in the GAPS baseline from the Klamath basin and similar stocks from adjacent rivers have the potential to either mis-assign or assign with low probabilities back to the Klamath. The California Coast is represented by two stocks, the Eel and Russian Rivers, and the Northern California/ South Oregon Coast is represented only by the Chetco. There are several rivers with Chinook populations in Southern Oregon and Northern California that have the potential to mis-assign to the Klamath or California/Oregon Coast. Further characterization of stocks within and adjacent to the Klamath basin are recommended to assess potential mis-assignment to this region.

Accurate assessment of Klamath basin and California's coastal stocks would likely benefit from better genetic characterization of fish in these regions. Statistical methods to reduce bias and increase accuracy are funded by the Pacific Salmon Commission and NOAA to support work by S. Kalinowski (personal communication). With improved stock characterization data and statistical methods we hope to increase our accuracy of estimates of mixture proportions and justify likely error rates with greater accuracy.

Stock mixture composition of Chinook salmon encountered off the Coast of Oregon is expected to vary throughout the season, by stock and life history types (ocean and stream), and by migration timing of adults returning to breed (Nicholas and Hankin 1988). Our results demonstrate the potential to detect differential use of habitat by Chinook salmon over relatively short time intervals (one week).

Using studies of this type we have the potential to detect short-term fluctuations in the distributions of adult Chinook salmon. The weeks when the Klamath and Rogue contributions were the greatest, 11.32% and 19.13% respectively (mixture proportions calculated with IA) were notable because they represent spikes well above the average. This could be related to timing of migration of these stocks through specific regions. CWT data would not be capable of discriminating spikes in migratory timing and oceanic distribution such as detected using genetic analyses, primarily because they are not present in a sufficiently large number of fish and do not provide spatial or temporal resolution.

Project CROOS represents application of genetic information to estimate stock distribution and behavior of fish in the ocean. Fish harvest locations and genetic stock identification coupled with unit fishing effort provided by fishermen has allowed us to compile and analyze detailed data. As this dataset grows over time it will allow us to address a wide range of management and science questions and provide a foundation to measure seasonal, regional, decadal, and global climate change on the distribution of salmon stocks.

Acknowledgements

Sampling for Project CROOS began June 4 with the in-kind contribution of volunteer fishermen participating on the steering committee, however official funding was not granted by Oregon's Watershed Enhancement Board until June 23, 2006. Clearly the success of this project relies upon the continued advice, participation and contributions from fishermen participating on the steering committee and project. Four members of the steering committee (Scott Boley, Jeff Feldner, Bob Kemp and Paul Merz) helped develop at-sea protocols and logistics of training fishermen, providing them with sampling materials, and recovering the samples and transporting them to the lab. We are especially grateful for these contributions and to the Oregon Watershed Enhancement Board for funding this research as well as the Pacific Salmon Commission's Chinook Technical Committee for funding the standardization of the GAPS microsatellite baseline.

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Table 1. Total number of samples collected during 2006 CROOS fishing season, total number processed by the Genetics laboratory, and total number fish assigned to the GAPS baseline.

Samples	Number	Number subtracted from dataset	Reason
Total Collected	4318	1221	Archived in laboratory (can be genotyped with additional funding)
Total processed	3097	530	Failed to amplify at 8 or more loci
Total assigned to baseline	2567		

Table 2. Genetic estimates of mixture proportions for fisheries samples collected off the Coast of Oregon during Project CROOS (2006). Mixed Stock Analysis (MSA) using the total dataset (n = 2567) was compared to results from Individual Assignment (IA) and by varying how individuals with <90% IA were treated. The difference between IA (all fish) and IA rigorous dataset is provided as a bias factor. Difference between MSA and stringent results are provided for comparison. Sample sizes for all regions are split by IA ≥ 90% and IA < 90%.

	MSA (all fish)	IA (all fish)	Stringent dataset (IA < 90% grouped)	Conservative dataset (IA ≥ 90%, n = 2097)	Proportion fish IA < 90% to total dataset (bias factor)	Difference stringent from MSA dataset (as %)	Sample size by region (all data)	Sample size rigorous (IA ≥ 90)	Sample size IA < 90
Central Valley fa/sp	59.08%	59.49%	57.62%	70.53%	1.87%	-1.46%	1527	1479	48
Rogue R.	7.61%	7.83%	4.40%	5.39%	3.43%	-3.21%	201	113	88
Mid Oregon Coast	7.11%	6.97%	3.31%	4.05%	3.66%	-3.80%	179	85	94
Klamath R.	6.58%	6.47%	5.53%	6.77%	0.93%	-1.05%	166	142	24
U Columbia R. su/fa	3.03%	3.00%	1.75%	2.15%	1.25%	-1.28%	77	45	32
N CA / S OR Coast	2.36%	2.38%	1.71%	2.10%	0.66%	-0.65%	61	44	17
California Coast	2.17%	2.22%	1.87%	2.29%	0.35%	-0.30%	57	48	9
N Oregon Coast	1.89%	1.87%	0.97%	1.19%	0.90%	-0.92%	48	25	23
L Columbia R. fa	1.78%	1.87%	0.74%	0.91%	1.13%	-1.04%	48	19	29
S Puget Sound	1.57%	1.64%	0.82%	1.00%	0.82%	-0.75%	42	21	21
L Fraser R.	1.11%	1.17%	0.86%	1.05%	0.31%	-0.25%	30	22	8
Mid Col. R. tule	1.05%	1.01%	0.86%	1.05%	0.16%	-0.19%	26	22	4
Hood Canal	0.82%	0.78%	0.23%	0.29%	0.55%	-0.59%	20	6	14
Deschutes R. fa	0.75%	0.55%	0.19%	0.24%	0.35%	-0.56%	14	5	9
L Columbia R. sp	0.74%	0.58%	0.16%	0.19%	0.43%	-0.58%	15	4	11
N Puget Sound	0.58%	0.43%	0.04%	0.05%	0.39%	-0.54%	11	1	10
SnakeR. fa	0.46%	0.31%	0.08%	0.10%	0.23%	-0.38%	8	2	6
S Thompson R.	0.37%	0.39%	0.19%	0.24%	0.19%	-0.18%	10	5	5
Washington Coast	0.25%	0.27%	0.04%	0.05%	0.23%	-0.21%	7	1	6
SSE Alaska	0.17%	0.23%	0.04%	0.05%	0.19%	-0.13%	6	1	5
Mid Fraser R.	0.14%	0.12%	0.08%	0.10%	0.04%	-0.06%	3	2	1
Willamette R.	0.12%	0.12%	0.08%	0.10%	0.04%	-0.04%	3	2	1
U Fraser R.	0.09%	0.08%	0.08%	0.10%	0.00%	-0.01%	2	2	0
W Vancouver Is.	0.07%	0.08%	0.04%	0.05%	0.04%	-0.03%	2	1	1
E Vancouver Is.	0.05%	0.08%	0.00%	0.00%	0.08%	-0.05%	2	0	2
Central BC Coast	0.03%	0.04%	0.00%	0.00%	0.04%	-0.03%	1	0	1
N Thompson R.	0.03%	0.04%	0.00%	0.00%	0.04%	-0.03%	1	0	1
Unknown (IA < 90)			18.31%	n/a			n/a	470	
Total	100%	100%	100%	100%	18.31%	18.31%	2567	2567	470

BC = British Columbia, CA = California, Col. = Columbia, E = East, L = Lower, N = North, OR = Oregon, R = River, S = South, W = West,

Table 3. Total number of fish that did not assign to a region of origin with ≥ 90% probability and these fish expressed as a percentage of the total "unknown" dataset.

	n < 90% probabilities	n ≥ 90% probabilities	Total n	Proportion by region of IA < 90% fish to all < 90 %
Mid Oregon Coast	94	84	178	20.00%
Rogue R.	88	113	201	18.72%
Central Valley	48	1479	1527	10.21%
U Columbia R. su/fa	32	45	77	6.81%
L Columbia R. fa	29	19	48	6.17%
Klamath R.	24	142	166	5.11%
N Oregon Coast	23	25	48	4.89%
S Puget Sound	21	21	42	4.47%
N CA / S OR Coast	17	44	61	3.62%
Hood Canal	14	6	20	2.98%
L Columbia R. sp	11	4	15	2.34%
N Puget Sound	10	1	11	2.13%
California Coast	9	48	57	1.91%
Deschutes R.fa	9	5	14	1.91%
L Fraser R.	8	22	30	1.70%
Snake R. fa	6	2	8	1.28%
Washington Coast	6	1	7	1.28%
SSE Alaska	5	1	6	1.06%
S Thompson R.	5	6	11	1.06%
Mid Columbia R. tule	4	22	26	0.85%
E Vancouver Is.	2	0	2	0.43%
Central BC Coast	1	0	1	0.21%
Mid Frase rR.	1	2	3	0.21%
N Thompson R.	1	0	1	0.21%
Willamette R.	1	2	3	0.21%
W Vancouver Is.	1	1	2	0.21%
U Fraser R.	0	2	2	0 %
Total	470	2097	2567	100%

* hypothetical calculation based on all "incorrect" fish actually assigning correctly

Table 4. Weekly and average over all week genetic estimates of stock mixture proportions (MSA) in weeks with sample sizes over 100 fish IA ≥ 90% harvested during openers in July, August and September in 2006.

Reporting_Unit	July 9	July 16	July 30	Aug 1	Sept 17	Sept 24	Oct 22	Average
Central Valley fa/sp	58.88%	71.26%	66.08%	71.49%	50.46%	65.00%	43.91%	61.01%
Mid Oregon Coast	4.72%	5.39%	4.90%	4.68%	7.79%	12.14%	12.61%	7.46%
Rogue R.	4.49%	2.99%	2.45%	1.70%	15.03%	5.00%	19.13%	7.26%
Klamath R.	3.82%	4.19%	6.99%	4.26%	11.32%	4.29%	10.43%	6.47%
U Columbia R. su/fa	4.94%	2.99%	4.55%	2.98%	0.74%	0.71%	1.30%	2.60%
N CA / S OR Coast	1.12%	0.60%	1.40%	2.13%	5.75%	2.14%	2.61%	2.25%
California Coast	0.67%	1.20%	0.70%	2.13%	5.38%	1.43%	3.91%	2.20%
L Columbia R. fa	4.49%	2.40%	1.75%	2.55%	0.74%	0.71%	0.00%	1.81%
S Puget Sound	4.04%	1.20%	3.15%	1.28%	0.19%	0.71%	0.00%	1.51%
N Oregon Coast	0.22%	0.60%	0.70%	0.00%	0.93%	5.71%	2.17%	1.48%
Mid Columbia R. tule	1.57%	2.40%	1.05%	2.55%	0.00%	0.36%	0.00%	1.13%
L Fraser R.	2.47%	0.00%	2.10%	1.28%	0.19%	0.00%	1.74%	1.11%
Hood Canal	2.92%	1.20%	0.70%	0.43%	0.00%	0.00%	0.43%	0.81%
Deschutes R.fa	0.67%	1.20%	0.35%	1.28%	0.37%	0.36%	0.00%	0.60%
L Columbia R. sp	0.90%	0.60%	0.35%	0.43%	0.19%	0.36%	0.87%	0.53%
S ThompsonR.	1.12%	0.60%	0.70%	0.00%	0.00%	0.36%	0.00%	0.40%
N PugetSound	0.90%	0.60%	0.35%	0.43%	0.19%	0.00%	0.00%	0.35%
Snake R.fa	0.67%	0.60%	0.35%	0.00%	0.00%	0.00%	0.00%	0.23%
Washington Coast	0.22%	0.00%	0.00%	0.00%	0.37%	0.36%	0.43%	0.20%
SSE Alaska	0.22%	0.00%	0.00%	0.43%	0.19%	0.00%	0.43%	0.18%
W Vancouver Is.	0.00%	0.00%	0.70%	0.00%	0.00%	0.00%	0.00%	0.10%
U Fraser R.	0.22%	0.00%	0.00%	0.00%	0.00%	0.36%	0.00%	0.08%
E Vancouver Is.	0.22%	0.00%	0.35%	0.00%	0.00%	0.00%	0.00%	0.08%
Willamette R.	0.22%	0.00%	0.35%	0.00%	0.00%	0.00%	0.00%	0.08%
Mid Fraser R.	0.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%
N ThompsonR.	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.03%
Grand Total	445	167	286	235	539	280	230	

Table 5. Results from coded-wire tag (CWT) blind test: the Oregon State University Marine Fisheries Genetics Laboratory provided population assignments for individual fish to the Oregon Department of Fish and Wildlife prior to CWT data availability. ODFW assembled this comparison of known-origin fish to OSU's genetic assignment. 100% of fish (n = 31) with probabilities ≥90% were assigned correctly.

Barcode	Snout ID	Hatchery of Origin (CWT)	Stock of Origin (CWT)	Regional Genetic Assignment	Regional Probability	Accuracy of Genetic Assignment
6432	06J3385	MATTOLE SAL. GP. HAT	MATTOLE RIVER	California Coast	1	Correct
7748	06J3364	COLEMAN NFH	COLEMAN NFH	Central Valley fa	1	Correct
7730	06J3366	COLEMAN NFH	COLEMAN NFH	Central Valley fa	0.97	Correct
6424	06J3386	COLEMAN NFH	COLEMAN NFH	Central Valley fa	1	Correct
7465	06J3395	COLEMAN NFH	COLEMAN NFH	Central Valley fa	1	Correct
7704	06J3368	FEATHER R HATCHERY	FEATHER RIVER	Central Valley fa	0.93	Correct
8170	06J3379	FEATHER R HATCHERY	FEATHER RIVER	Central Valley fa	1	Correct
7469	06J3394	FEATHER R HATCHERY	FEATHER RIVER	Central Valley fa	0.97	Correct
910	06J6503	FEATHER R HATCHERY	FEATHER RIVER	Central Valley fa	0.99	Correct
7706	06J3367	FEATHER R HATCHERY	FEATHER RIVER	Central Valley fa/sp	1	Correct
4924	06J3378	FEATHER R HATCHERY	FEATHER RIVER	Central Valley sp	1	Correct
7487	06J3397	FEATHER R HATCHERY	FEATHER RIVER	Central Valley sp	0.97	Correct
9018	06J3381	COLEMAN NFH	COLEMAN NFH	Central Valley sp/fa	1	Correct
3341	06J3399	FEATHER R HATCHERY	FEATHER RIVER	Central Valley sp/fa	1	Correct
913	06J6513	FEATHER R HATCHERY	FEATHER RIVER	Central Valley sp/fa	1	Correct
4859	06J6510	COLEMAN NFH	COLEMAN NFH	Central Valley fa	1	Correct
3781	06J2497	FEATHER R HATCHERY	FEATHER RIVER	Central Valley fa/sp	1	Correct
6175	06J5416	FEATHER R HATCHERY	FEATHER RIVER	Central Valley fa/sp	1	Correct
6409	06J3387	IRON GATE HATCHERY	KLAMATH RIVER	Klamath River	1	Correct
9991805	06J3353	TRINITY R HATCHERY	TRINITY RIVER	Klamath River	1	Correct
6426	06J3357	TRINITY R HATCHERY	TRINITY RIVER	Klamath River	1	Correct
7471	06J3392	TRINITY R HATCHERY	TRINITY RIVER	Klamath River	0.99	Correct
7488	06J3396	TRINITY R HATCHERY	TRINITY RIVER	Klamath River	1	Correct
3331	06J6400	COWLITZ SALMON HATCH	COWLITZ R 26.0002	L Columbia fa	0.92	Correct
6357	06J3358	H-CHEHALIS R	S-HARRISON R	L Fraser R.	0.99	Correct
7454	06J3393	ELK R HATCHERY	ELK R (ELK R HT)	Mid Oregon Coast	0.99	Correct
904	06J6405	ELK R HATCHERY	ELK R (ELK R HT)	Mid Oregon Coast	1	Correct
921	06J6514	SIUSLAW NATURAL PRODUCTION TAG	SIUSLAW R	N Oregon Coast	0.96	Correct
848	06J2804	ELK R HATCHERY	CHETCO R	N California/ S Oregon Coast	0.99	Correct
4403	06J2816	COLE RIVERS HATCHERY	COLE RIVERS HATCHERY	Rogue	1	Correct
6246	06J6403	COLE RIVERS HATCHERY	COLE RIVERS HATCHERY	Rogue	0.99	Correct
9447	06J3391	N/A	N/A	Rogue	0.98	TAG READ WRONG
919	06J6512	FEATHER R HATCHERY	FEATHER RIVER	Central Valley fa	0.64	n/a (<90%); correct
7746	06J3365	ROCK CREEK	UMPQUA R (ROCK CR HT)	Mid Oregon Coast	0.8	n/a (<90%); correct
9015	06J3382	COLE RIVERS HATCHERY	COLE RIVERS HATCHERY	Rogue	0.63	n/a (<90%); correct

(Table 5, Cont.)

Barcode	SNOUT ID	HATCHERY of Origin (CWT)	STOCK OF ORIGIN (CWT)	REGIONAL GENETIC ASSIGNMENT	REGIONAL PROB-ABILITY	ACCURACY OF GENETIC ASSIGNM.
1516	06J3321	GROVERS CR HATCHERY	GROVERS CR 15.0299	Mid Oregon Coast	0.66	n/a (<90%); incorrect
3747	06J3359	COLE RIVERS HATCHERY	COOS R - PUBLIC	Mid Columbia tule	0.62	n/a (<90%); incorrect
3731	06J3363	TRINITY R HATCHERY	TRINITY RIVER	Rogue	0.48	n/a (<90%); incorrect
1031	06J2495	KALAMA FALLS HATCHRY	KALAMA R 27.0002	Mid Oregon Coast	0.42	n/a (<90%); incorrect
6232	06J6402	ELK RIVER	ELK R (ELK R HT)	N California/S Oregon Coast	0.81	n/a (<90%); incorrect
6152	06J5415	BANDON HATCHERY	COOS R - PUBLIC			amplification failure
1823	06J2806	CARLTON REARING POND	METHOW & OKANOGAN			amplification failure
3185	06J6401	COLEMAN NFH	COLEMAN NFH			amplification failure
7772	06J6500	COLEMAN NFH	COLEMAN NFH			amplification failure
9720	06J6508	COWLITZ SALMON HATCH	COWLITZ R 26.0002			amplification failure
1024	06J2496	ELK R HATCHERY	ELK R (ELK R HT)			amplification failure
1016	06J3348	FEATHER R HATCHERY	FEATHER RIVER			amplification failure
7703	06J3369	FEATHER R HATCHERY	FEATHER RIVER			amplification failure
9009	06J3380	FEATHER R HATCHERY	FEATHER RIVER			amplification failure
9717	06J6509	FEATHER R HATCHERY	FEATHER RIVER			amplification failure
9374	06J2814	TRINITY R HATCHERY	TRINITY RIVER			amplification failure
3197	06J3398	NO TAG				
4360	06J3388	NO TAG				
4373	06J3389	NO TAG				
9446	06j3390	NO TAG				
846	06J2805	NO TAG				

Figure 1. Reporting regions (numbers) and populations (letters) for GAPS baseline v1 (population latitudes/longitudes not available for v2) used for Project CROOS genetic stock identification (Key to numbers and populations listed in Appendix 1).

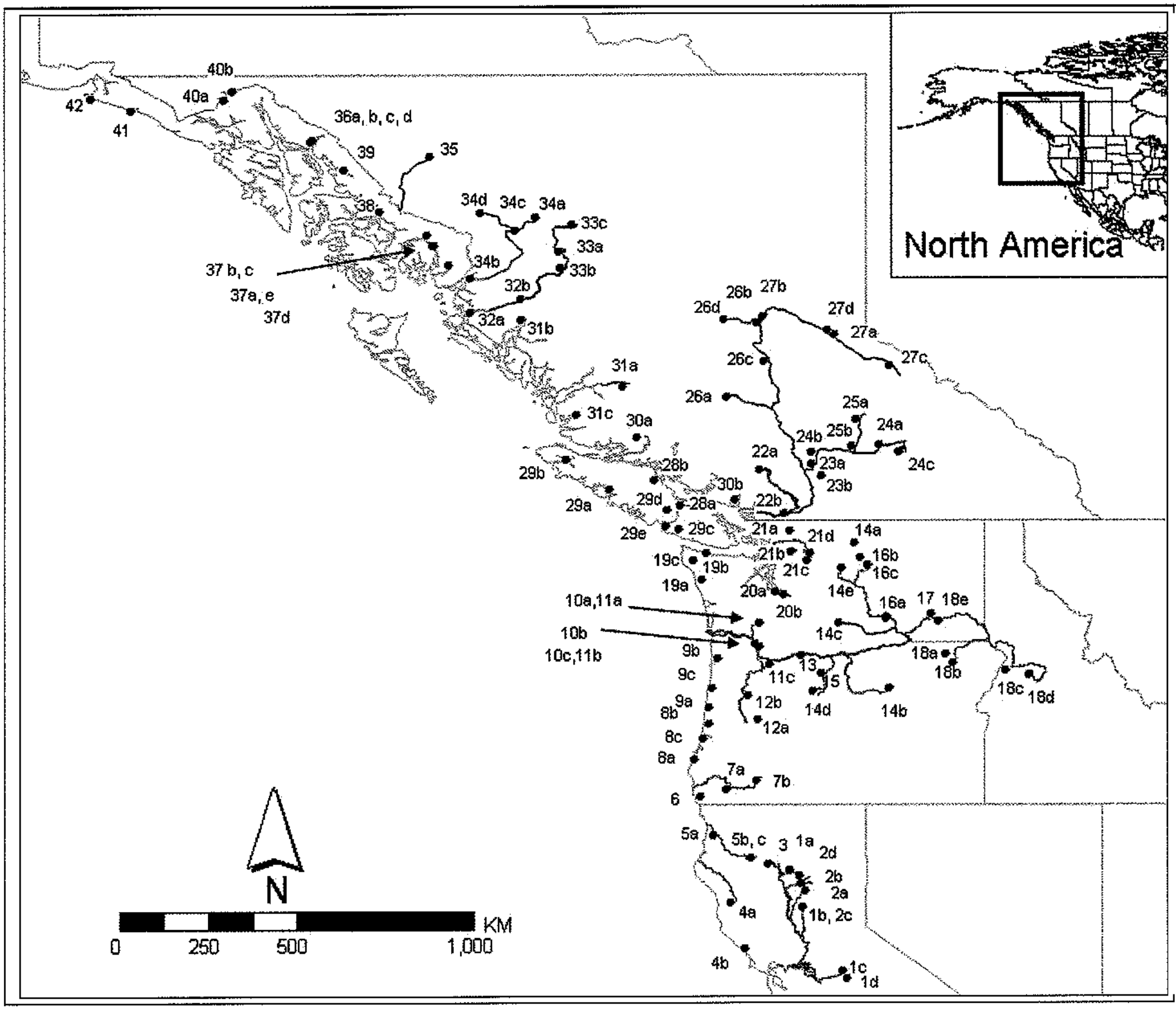


Figure 2. Fishing days open on weekly basis ("opener") and harvest limits for commercial fisheries conducted from Cape Falcon south to Humbug Mountain.

JUNE

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

Weekly harvest limit 75 fish

JULY

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Weekly harvest limit 75 fish

AUGUST

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Weekly harvest limit 75 fish

SEPTEMBER

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Weekly harvest limit 50 fish

OCTOBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

Weekly harvest limit 50 fish

Figure 3. Samples received, genotyped, analyzed for stock mixture analysis, and number with individual assignment probability ≥ 90%.

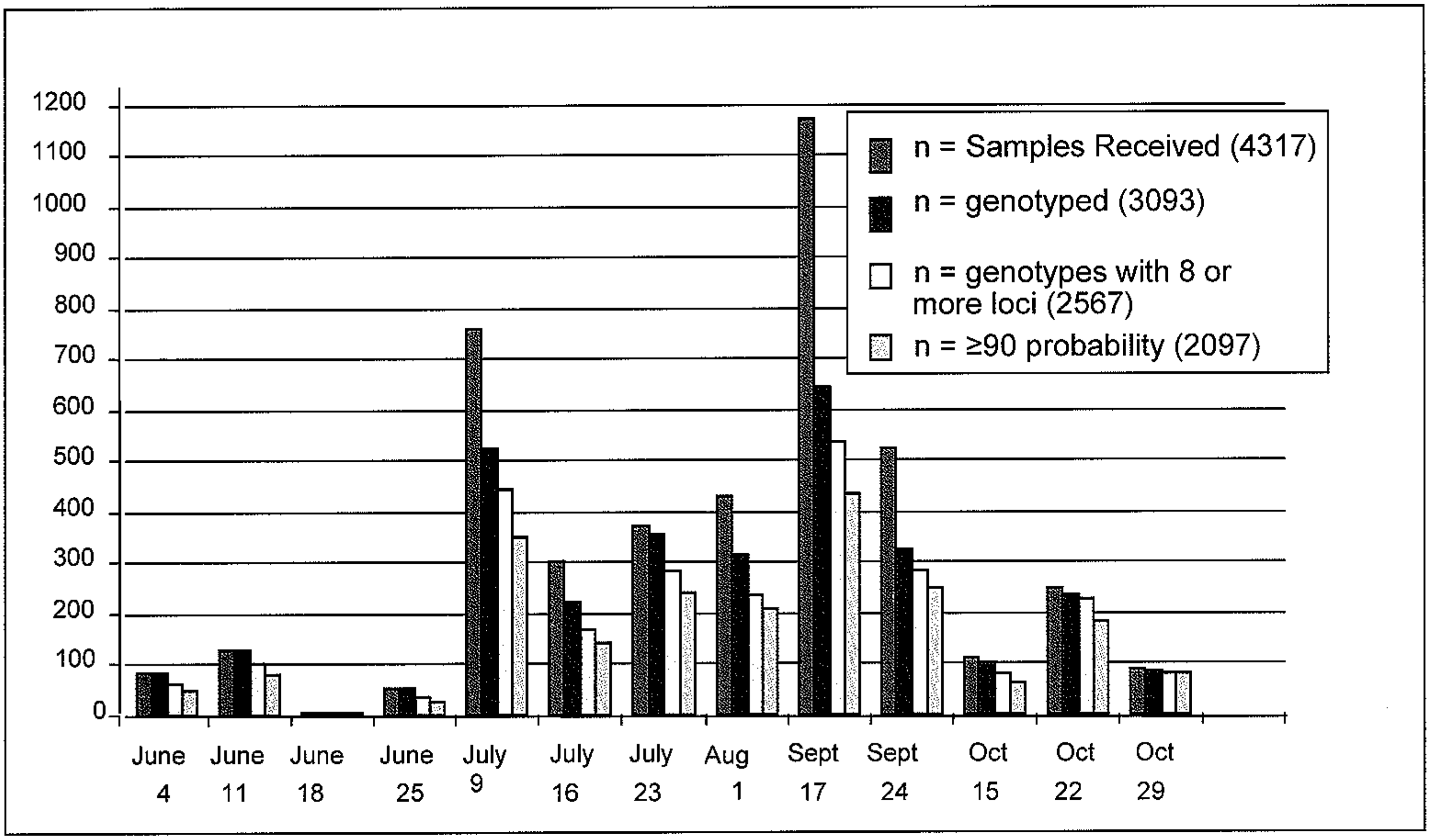


Figure 4. Genetic estimates of mixture proportions of Chinook harvested off the Coast of Oregon during the 2006 Project CROOS pilot study. Mixture proportions were calculated using estimates of mixture proportions calculated with GMA (Kalinowski 2003).

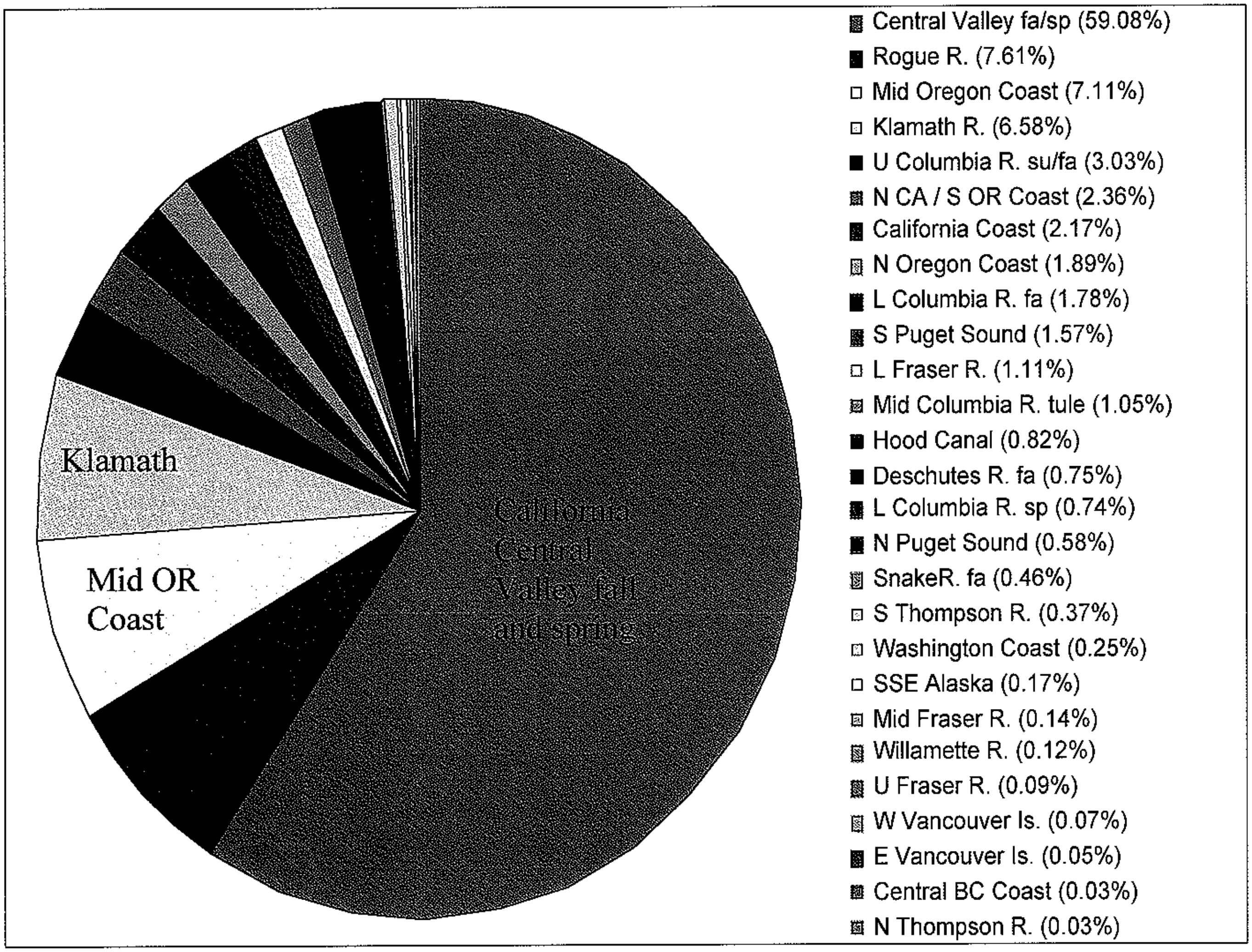


Figure 5. Comparison of four different treatments of genetic data to estimate stock mixture proportions. MSA and IA (all fish) include all fish in the dataset; stringent dataset groups fish with low probabilies (<90%) into "uncertain" category, and the conservative dataset only includes fish with IA ≥ 90% to calculate stock mixture proportions (see text for details).

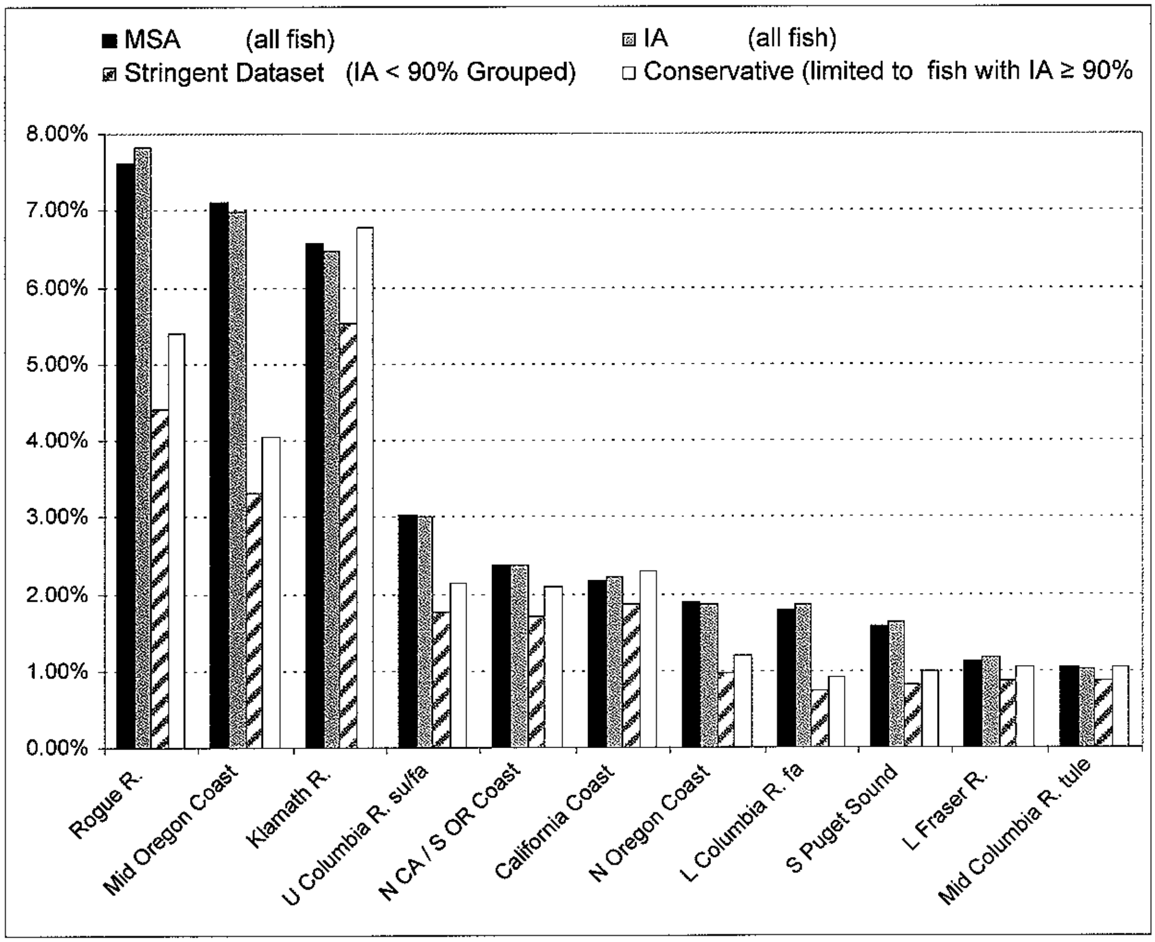


Figure 6. Genetic estimates of stock mixture proportions for Klamath River, California Coast, and Northern California/Southern Oregon stocks of Chinook salmon (weeks with n > 100 fish, MSA).

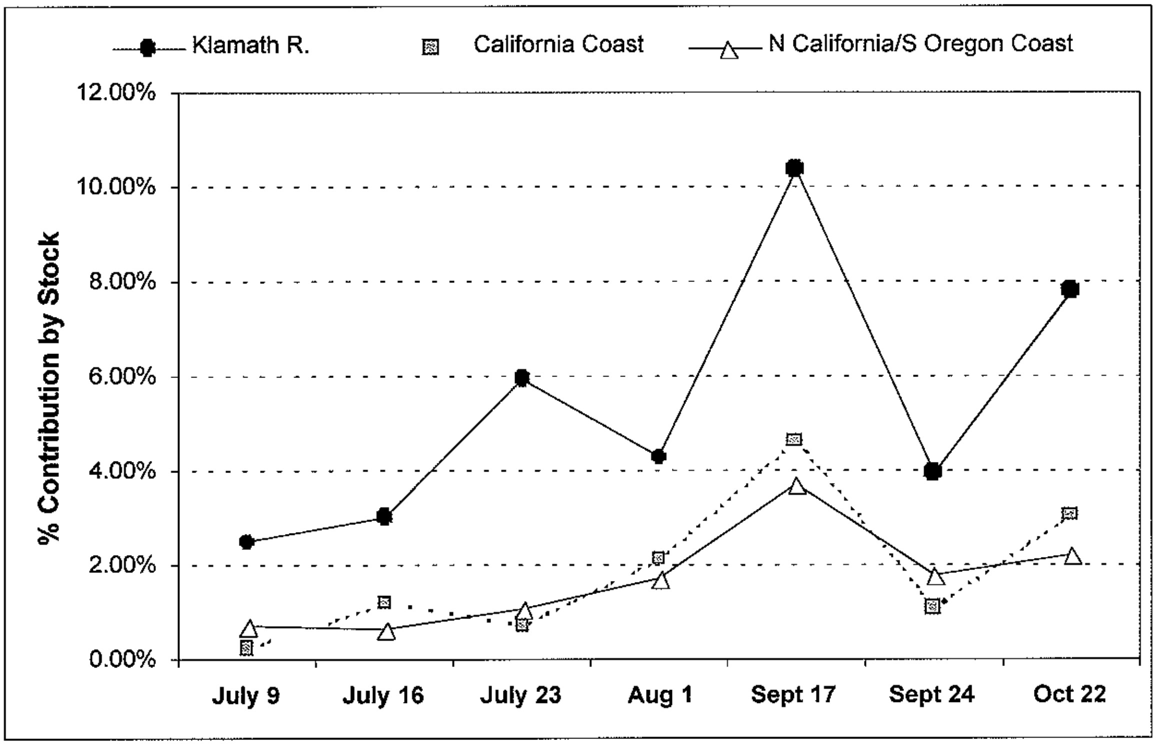


Figure 7. Contribution of Klamath fish as a percent of the total dataset for weeks with n > 100 and IA ≥90% probabilities. Three methods of stock mixture proportions are shown below for comparative purposes of accuracy and bias. The first (all) dataset is calculated using traditional MSA techniques; the second (stringent) dataset is calculated using individual assignment with fish having assignments < 90% pooled, and the third dataset (conservative) is calculated only using individual assignments for fish with ≥ 90% probabilities.

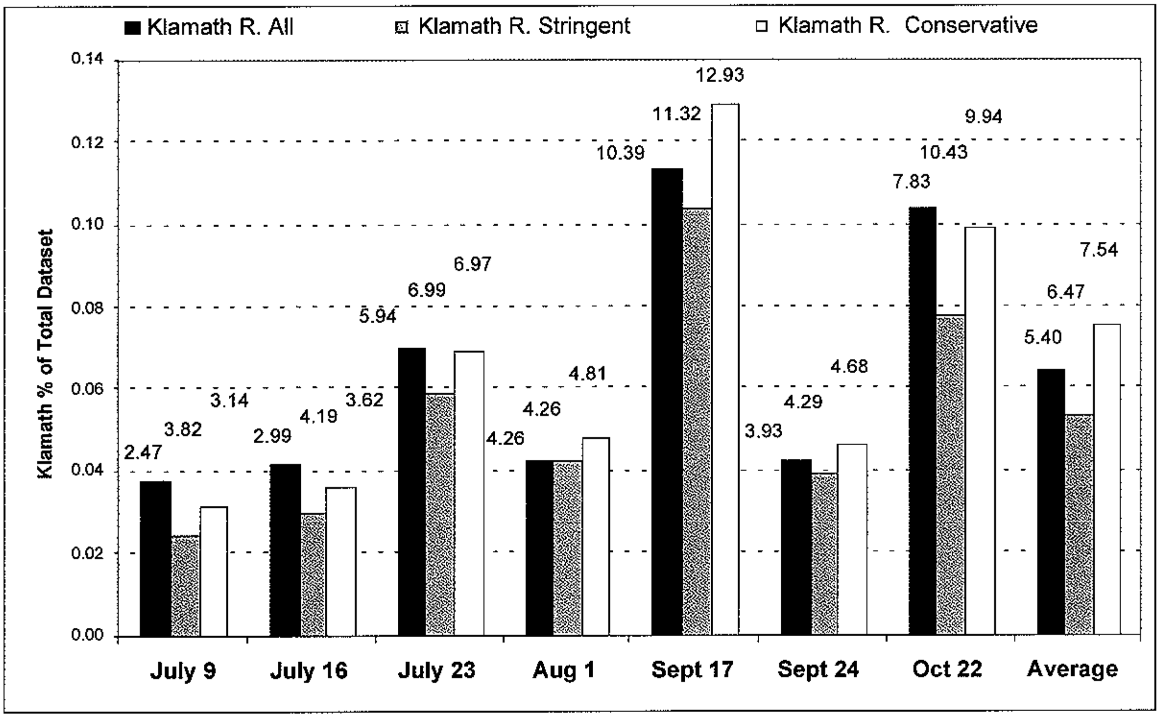


Figure 8. Time series for two weeks of data for fish harvested off the Coast of Oregon. Harvest during the week of September 17 - 23, 2006 (A) contributed the greatest number of samples harvested in week, with 1173 fish sampled and 645 genotyped. The following week (B), September 24-30, 2006 yielded 521 fish sampled; of which 280 were genotyped. Fish assigning to the Klamath basin are highlighted in red.

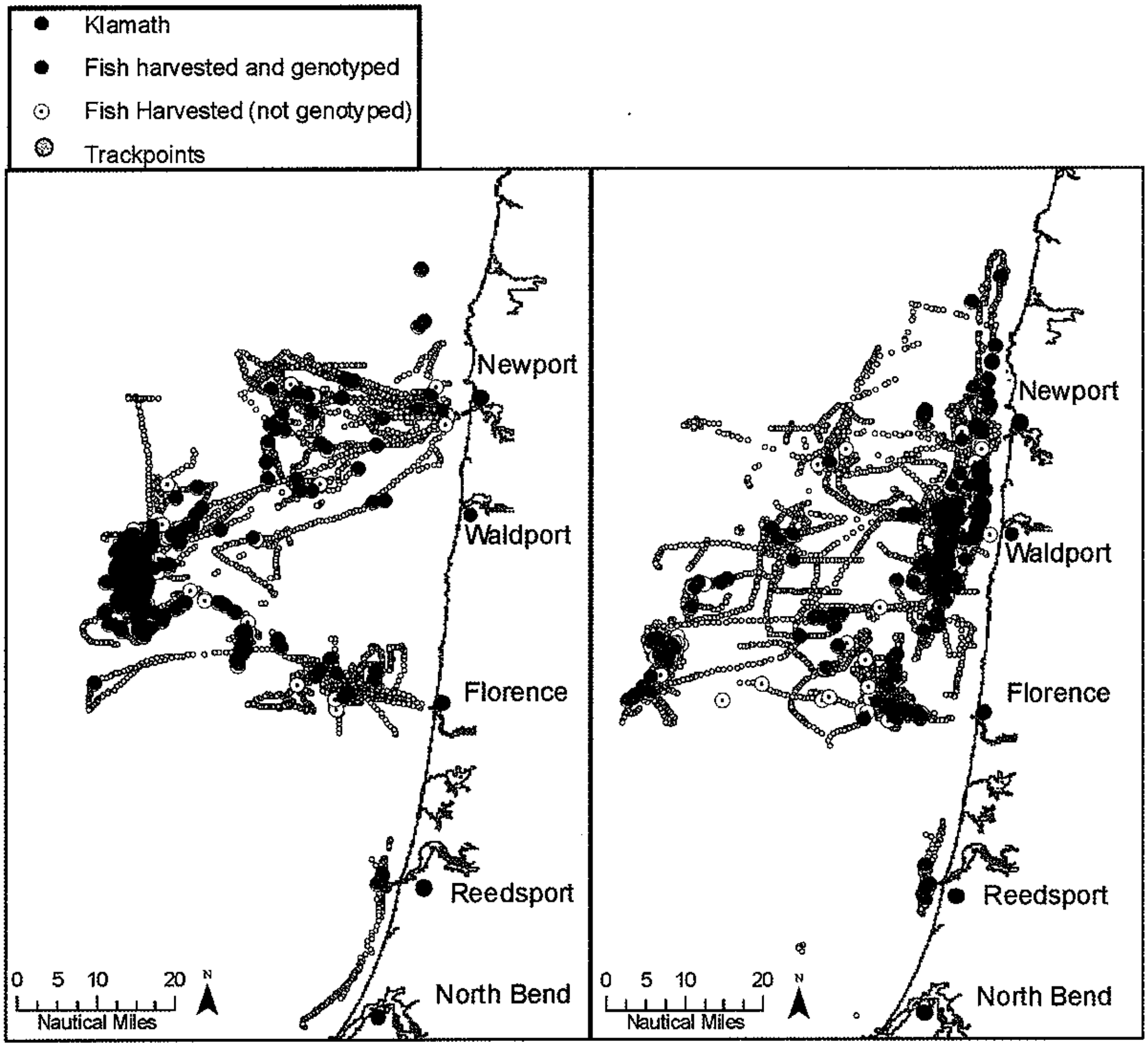


Figure 9. Genetic stock mixture analysis and fish harvested per unit effort in two sections of ocean fished during weeks of September 17-23 and 24-30th. Fish assigning to the Klamath basin are highlighted in red.

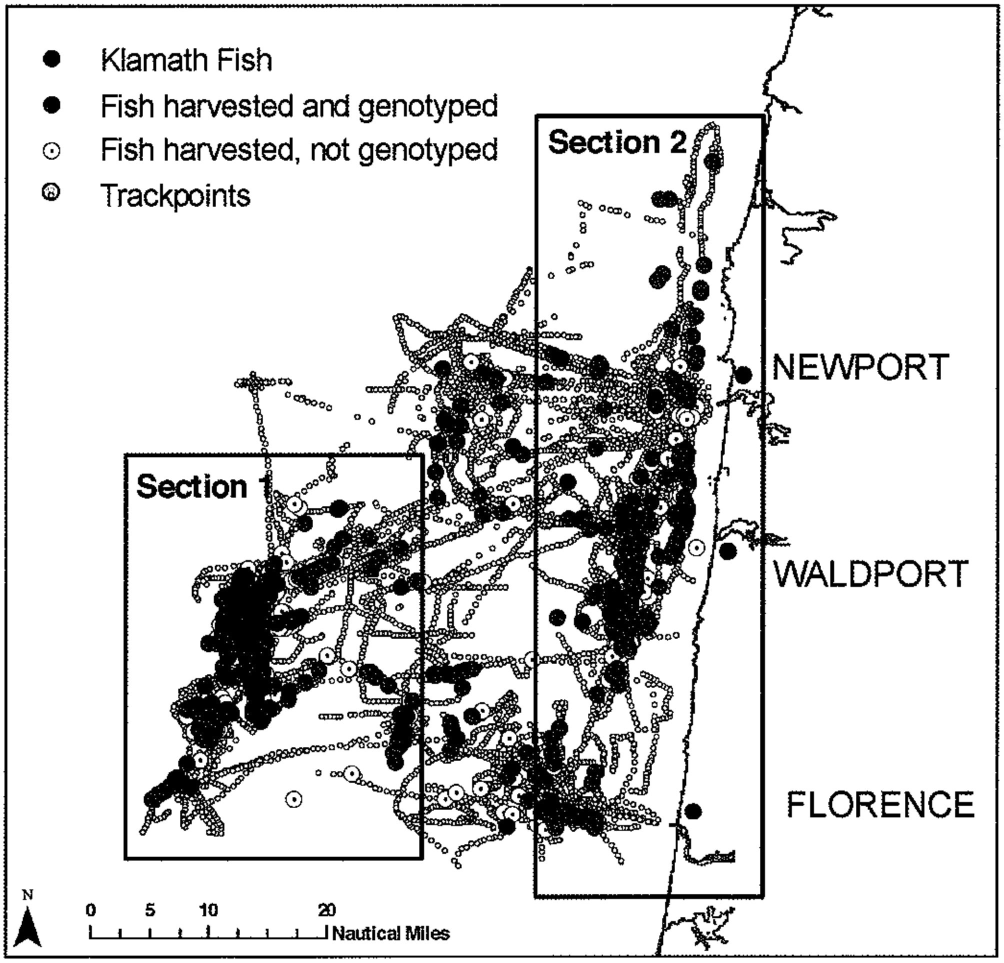
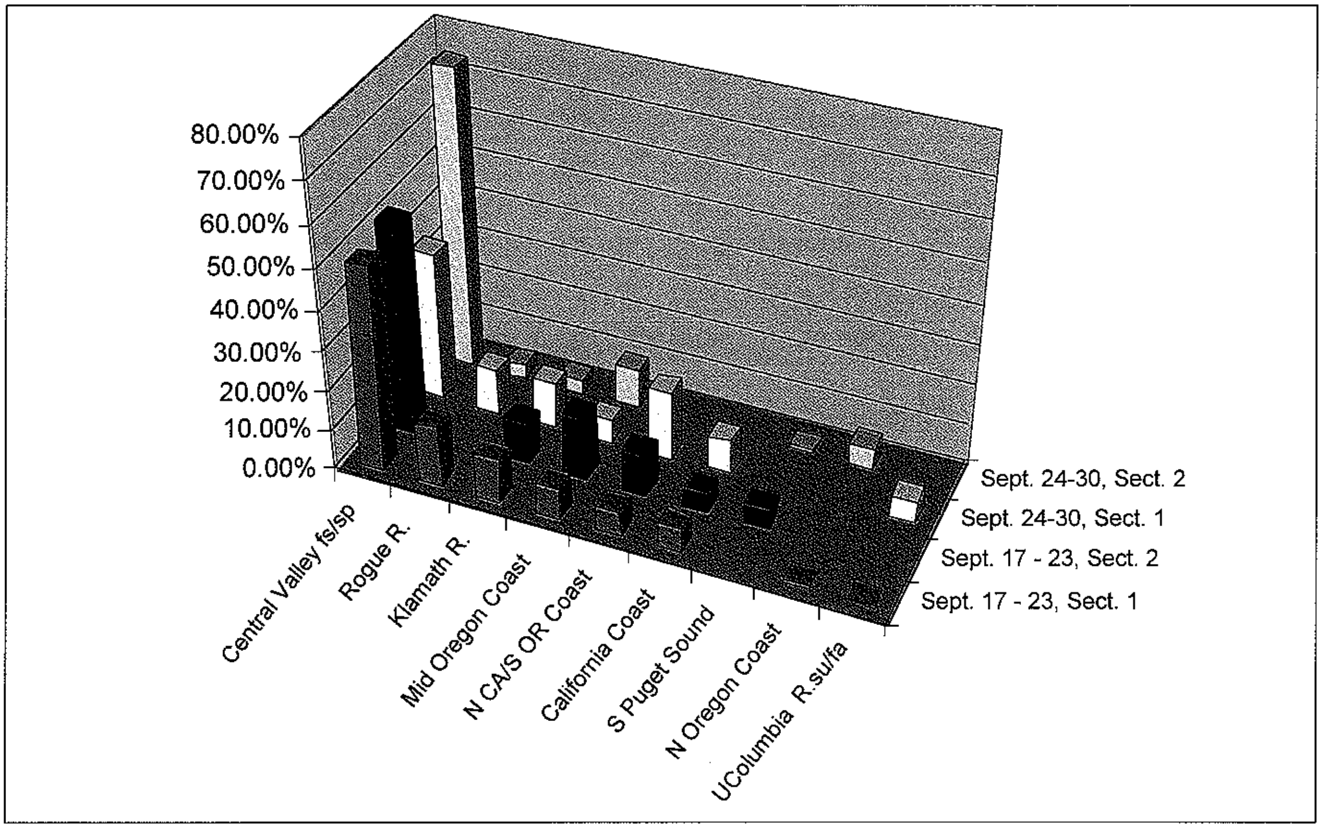


Figure 10. Genetic estimate of stock composition for regions that contributed at least 5% to the total mixture in Sections 1 and 2 (n = 469, 19 respectively) during September 17 – 23, 2006 and September 24-30th (Section 1, 2; n = 35, 192, respectively) detailed in Figure 9.



DATALOGGER DEVELOPMENT

Planning

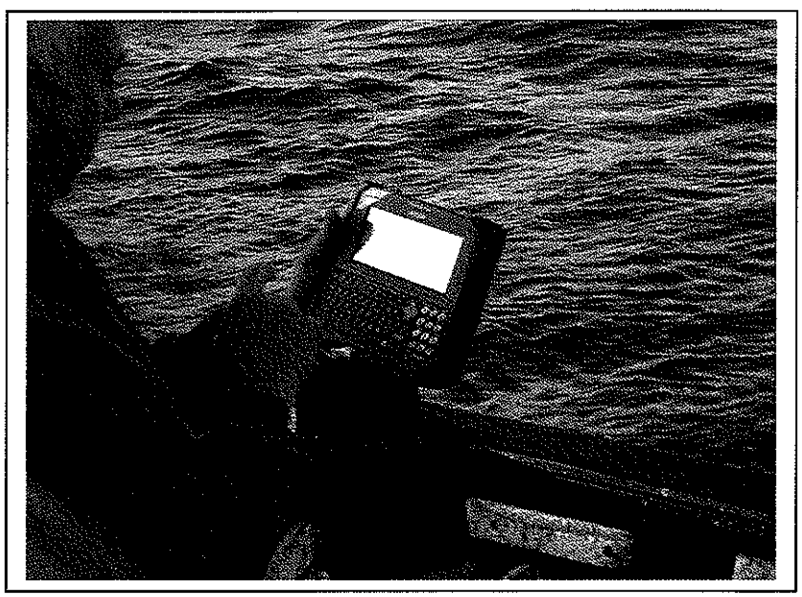
One of the original goals of the CROOS project was to investigate technologies that could facilitate incorporation of genetic, fishery, and oceanographic information collected into near "real time" management of future fisheries. To advance this objective, we tested the use of an electronic "datalogger" to record fishery information onboard the vessel and rapidly transmit the data to scientists and managers on shore.

Digital information from these records could also be used by potential seafood consumers. They could find, by looking up an online record of selected project information, the origin of a given fish, who caught it, and even information about its storage and handling history.

Various devices have been tested in other fisheries, including the Albacore tuna fishery. These devices are capable of electronically recording high resolution spatio-temporal information about the catch location of each fish, the fishing track of the vessel, depth of capture, oceanographic observations, mark or tagging information, fish storage information, and fisherman comments. The information can then be transmitted to either a storage device on the vessel (generally a laptop computer) or, with suitable onboard telecommunication equipment, to receiving stations on shore. The information can be used in electronic fishermen logbooks, as part of tracking and traceability systems, or to build "expert systems' for individual fishermen or fishery managers.

These devices must be rugged enough to function on the deck of the fishing vessel under sometimes extreme weather conditions, must tolerate exposure to salt water, and be capable of operating with wet or gloved hands. They must also be simple enough to be operated by users with limited technical expertise, and must be able to be downloaded, adjusted, and/or reset without the use of highly skilled technicians. To be incorporated into full-scale data collection regimes, they must be inexpensive enough so that many of them can be deployed over the full geographic range of the fishery being tested.

The devices chosen for this project were a functional combination of a DAP CE8640 handheld computer (the data entry device), a wheelhouse mounted laptop computer to store the data, a connected GPS unit, and the necessary auxiliary equipment needed to power and connect these devices.



A full description of these devices and the protocols for their operation is provided in Appendix 3.

Results and Observations

Up to four datalogger systems were installed on selected vessels at any given time during the course of the 2006 CROOS project. Software settings and protocols for their use were adjusted during the project as experience dictated. Some of these adjustments were complicated by the requirement that the majority of the software configuration for the datalogger devices had to be performed by factory technicians.

Once the equipment was installed and configured for each vessel, and fishermen became acquainted with its operation, the systems generally worked well over a wide range of environmental conditions. Operation of the equipment was reported to be compatible with the other requirements for project data collection, and was not particularly disruptive of the normal fishing routine. Most fishermen testing these units thought that the equipment was easier to use than "manual" sampling protocols (e.g. paper logs, writing on envelopes, etc.).

There were some difficulties in selecting vessels for datalogger use. Salmon fishing boats are generally smaller vessels with very limited space for additional equipment. They are generally set up for optimum efficiency in fishing operations, with limited options for placement of temporary electronics. They are uniquely different in their electrical and electronic configuration, and technical assistance was required for each installation. There was also some difficulty in finding fishermen who felt comfortable with learning a new technology for such a short project.

Due to the inexperience of some fishermen in hardware configuration protocols, there were several cases of equipment failure. The need to integrate the datalogger's software with the wheelhouse computer and the GPS signal inputs created some problems when the equipment was first turned on or was restarted. Sometimes this happened as a result of electrical supply interruptions, either as a result of temporary power interruptions, or, for example, due to normal shutdown of vessel electronics between fishing periods.

Although these problems could generally be solved at sea, in some instances, the equipment could not be successfully restarted, and the fishermen were required to manually log the data and use the handheld GPS devices.

Due to the demands of downloading the data (which was stored in Microsoft Access database format) and resetting the equipment for the next fishing trip, technical assistance was generally required after each fishing trip to transfer data to the laboratory. Although the equipment had the capability of downloading data directly from the vessel to the lab, the need for satellite communications equipment or cell phone modem software on each vessel and the appropriate training for their use prevented us from utilizing that option.

Because of these issues and the relatively high cost of the systems (approximately $5,700 per unit), it was generally concluded that a more rugged but less complex and costly system would be desirable for future projects that require this type of virtual "real time" information from large numbers of relatively small vessels. Research into identifying and developing such equipment will continue.

In general, the use of datalogging devices proved to be successful and deserves further testing and development. Additional refinement of equipment, software, and protocols will be needed for applying this technology to applications in large projects requiring numerous fishing vessels. But the potential for improvement in data collection was demonstrated and the long term benefits for cost effective and comprehensive "real time" data collection may be substantial.

SCALE ANALYSIS

Introduction

The Scale Project of the Oregon Department of Fish and Wildlife interprets circuli patterns on scales to determine age composition, hatchery or wild origin, life history, and growth information for salmonid and warmwater fish species. Data provided by this project are used for trend analyses, stock size forecasts, status assessment, identification of hatchery strays, and growth analyses. We analyze about 15,000 scale samples annually. By number, we analyze scales from more Chinook salmon than any other species. For the CROOS Project, we determined the total age of Chinook salmon that were sampled from the ocean troll fishery and had high probability of assignment to a genetic group. Our data will help with status assessment and, if continued in the future, may be used for stock abundance projections.

Methods

The scales that we analyzed were collected by commercial fishers at sea. We provided each collector with sampling instructions, including a diagram showing location of the key scale area (Nicholas and Van Dyke 1982), so that all scales were sampled by the same methods.

After scales were removed from the fish, they were placed in an envelope that was labeled with the bar code assigned to that fish. Sampling data were recorded on the envelope. After the genetic analysis was completed for each fish, we were given the scale samples from those fish that were assigned to a genetic group with greater than or equal to 0.90 probability of group membership. From each sample we mounted one to four of the best scales on gummed cards and made plastic impressions using a hydraulic heat press.

Fish age was determined by counting winter annuli. We identified annuli as bands of closely spaced or broken circuli (Figure 11). If the winter has been harsh, an annulus may also appear to have scarring which is caused by resorption of the scale. For salmon such as Chinook salmon that spawn in the fall, total age equals the count of annuli plus one to account for the winter spent in the gravel as an egg or sac fry. Catch year minus total age provides the brood year. An exception to this last equation is the late fall Chinook population that spawns in California's Central Valley. They are spawned January to March so are of a different brood year than the fish that are spawned in August through December. Since the scale pattern of the late fall Chinook looks the same as that of other Chinook, we aged them in the same manner. This means that catch year minus our assigned age does not provide their brood year although the assigned age still reflects an accurate total age had they escaped to spawn.

Two people read the collection and resolved disagreements during a joint, third reading. The first reading by both people was made without knowledge of field data, such as length, so that the reading was based only on information provided by the scale pattern and was not biased by conflicting field data. Field data were taken into consideration for the third reading.

We randomly mounted 31 "known age" samples from coded wire tagged fish within the collection that served as a test to our accuracy. The "known age" samples were aged in the same manner as the general collection except that if we disagreed on any of the 31, the tag code and know age was withheld from the field data that was available during our third, joint reading.

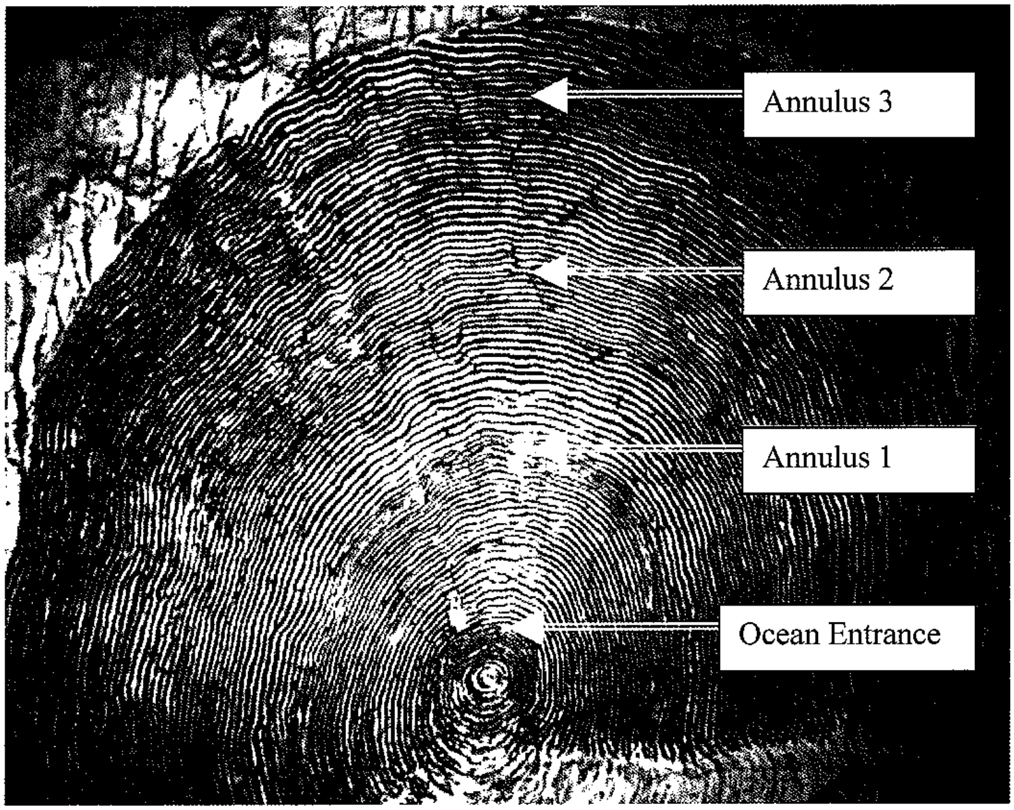


Figure 11. Scale of an age-4 Chinook salmon caught in the ocean off Oregon in 2006.

Results and Discussion

We mounted 2,094 scales samples and were able to determine the age of 2,045 fish. We were unable to read 49 scales because they had been regenerated after the original scale had been lost. Regenerated scales have no circuli or annuli in the regenerated portion. We included 31 samples from CWT fish in our analysis. Three samples were of late fall stock from Coleman National Fish Hatchery. These fish were spawned in January or February of 2003 so were calculated to be age-3 in the summer of 2006. We aged all three fish as age-4 since they carry the same scale pattern of Chinook salmon that were spawned from August to December in 2002. As stated in our methods section, this is an error that we cannot correct and these fish would have been age-4 upon return to their hatchery. The other 28 samples from CWT fish were correctly aged. A list of the CWT fish included in the scale collection is found in rows 1-31 of Table 5 in the Genetic Science section of this report.

The age composition for the entire collection was 0.1% age-2, 57.0% age-3, 38.5% age-4, 3.9% age-5, and 0.5% age-6. The age composition by month is given in Table 6. We saw a big change in the percentage of age-3 and age-4 fish between August and September with age-3 fish increasing and age-4 fish decreasing. The fishery was closed between August 4 and September 16. Had samples been available later in August and earlier in September, the age composition shift might have been less dramatic but the trend would probably still exist.

Table 6. Age composition Chinook salmon stocks caught in the ocean in the summer of 2006.

Month	Percentage of sample					Number of scales aged
	Age 2	Age 3	Age 4	Age 5	Age 6	
June	0.0	30.5	59.4	9.9	0.0	131
July	0.0	36.0	59.7	3.7	0.6	705
August	0.0	43.8	51.7	4.0	0.5	201
September	0.2	77.8	18.4	3.2	0.5	657
October	0.0	77.9	18.0	3.5	0.6	316

To further explore the shift in age composition between June through August samples and September and October samples we looked at the individual assignments to stock groups determined from the genetic analysis (Genetic Science section, this report). Genetic stock compositions for age-3, age-4, and age-5 Chinook salmon are given in Tables 7-9. The one age-2 fish in the sample was of Central Valley stock, while 8 of the 10 age-6 fish were from North or mid-Oregon coast stocks.

In catch of age-3 and age-4 fish, California's Central Valley (fall and spring runs combined) was the major genetic stock for the entire season. Some age-3 fish of Central Valley stock probably left the fishery area to spawn since we saw a small decrease in their contribution in the September fishery. Fisher (1994) estimated that the 3-year-old age class was predominant among Central Valley runs, being 77 and 57% for fall and late-fall runs, respectively. We theorize that Central Valley age-3 fish were still a major part of the fishery in September and October because smaller fish that would have matured at age-4 became large enough to enter the fishery. Information on the state of gonad maturation of smaller Chinook salmon (<75 cm) caught in September and October could determine if this is true.

On a monthly basis, the stock composition of age-4 fish showed a big decrease in Central Valley stock beginning in September. This coincides with the general decrease in age-4 fish in the catch for September and October and was probably the result of Central Valley stocks leaving the fishery area to return to California to spawn. In September, Rogue, Klamath and mid-Oregon coast stocks became more important contributors to the fishery and in October, Rogue stock fish made up almost a third of the catch of 4 year olds.

The stock composition of age-5 fish in our sample was more varied than other ages with major contributions of upper Columbia River summer/fall stocks in June, mid-Oregon coast stocks in September, and North Oregon coast stocks in October. Central Valley stocks were still major contributors in July and August. Age-5 fish are a major component of the spawning populations of North and mid-Oregon coastal fall Chinook salmon stocks (Nicholas and Hankin 1988, Borgerson and Bowden 2001) while they are a small component to Central Valley spawning populations (Myers et al 1998).

Table 7. Monthly estimates of genetic stock composition of age-3 Chinook salmon caught in the ocean troll fishery off Oregon in 2006. Greatest stock contributions each month are highlighted.

	Month, 2006						
Genetic Stocks	June	July	August	September	October	Season	N
Central Valley fa/sp	**66.67%**	**77.87%**	**83.72%**	**76.51%**	**73.98%**	**76.45%**	873
Klamath River	2.38%	1.98%	3.49%	**9.90%**	**7.72%**	**6.92%**	79
Rogue	2.38%	2.37%	1.16%	**4.85%**	**8.94%**	**4.82%**	55
S Puget Sound	**7.14%**	**8.70%**	3.49%	0.39%	0.41%	2.71%	31
California Coast	0.00%	0.40%	0.00%	3.88%	3.25%	2.54%	29
Mid Oregon Coast	2.38%	1.98%	1.16%	2.91%	2.03%	2.36%	27
L Fraser	7.14%	2.37%	2.33%	0.00%	1.63%	1.31%	15
Mid Columbia tule	**11.90%**	2.37%	3.49%	0.19%	0.00%	1.31%	15
N Cal. S Ore. Coast	0.00%	0.00%	0.00%	1.17%	0.81%	0.70%	8
L Columbia fall	0.00%	0.79%	0.00%	0.00%	0.41%	0.26%	3
L Columbia spring	0.00%	0.40%	0.00%	0.00%	0.41%	0.18%	2
N Oregon Coast	0.00%	0.00%	0.00%	0.19%	0.41%	0.18%	2
Deschutes River fall	0.00%	0.00%	1.16%	0.00%	0.00%	0.09%	1
SSE Alaska	0.00%	0.40%	0.00%	0.00%	0.00%	0.09%	1
U Columbia R su/fa	0.00%	0.40%	0.00%	0.00%	0.00%	0.09%	1
Monthly sample size	42	253	86	515	246	1142	1142

BC = British Columbia, CA = California, Col. = Columbia, E = East, L = Lower, N = North, OR = Oregon, R = River, S = South, U = Upper, W = West, fa/sp = fall/spring, su/fa = summer/fall

Table 8. Monthly estimates of genetic stock composition of age-4 Chinook salmon caught in the ocean troll fishery off Oregon in 2006. Greatest stock contributions each month are highlighted.

	Month, 2006						
Genetic Stocks	June	July	August	September	October	Season	N
Central Valley fa/sp	**77.78%**	**77.27%**	**74.26%**	**32.23%**	**19.30%**	**65.68%**	778
Klamath River	**4.94%**	**5.98%**	6.93%	**14.05%**	10.53%	**7.58%**	59
Rogue	3.70%	0.72%	0.99%	**18.18%**	**31.58%**	**6.04%**	47
Mid Oregon Coast	3.70%	**2.63%**	1.98%	**14.05%**	**14.04%**	5.27%	41
N Cal./S Ore. Coast	0.00%	0.96%	2.97%	9.09%	8.77%	2.96%	23
S Puget Sound	**4.94%**	3.59%	0.99%	0.00%	0.00%	2.57%	20
L Columbia fall	1.23%	2.39%	2.97%	1.65%	0.00%	2.06%	16
California Coast	1.23%	0.72%	**4.95%**	4.13%	1.75%	1.93%	15
N Oregon Coast	0.00%	0.00%	0.00%	4.13%	10.53%	1.41%	11
Mid Columbia tule	0.00%	1.20%	1.98%	0.00%	0.00%	0.90%	7
L Fraser	0.00%	1.44%	0.00%	0.00%	0.00%	0.77%	6
U Columbia R su-fa	0.00%	0.96%	0.99%	0.00%	0.00%	0.64%	5
L Columbia spring	2.47%	0.24%	0.00%	0.83%	0.00%	0.51%	4
L Thompson	0.00%	0.72%	0.00%	0.00%	0.00%	0.39%	3
Deschutes River fall	0.00%	0.24%	0.99%	0.00%	0.00%	0.26%	2
Mid Fraser	0.00%	0.24%	0.00%	0.00%	1.75%	0.26%	2
Snake R fall	0.00%	0.48%	0.00%	0.00%	0.00%	0.26%	2
U Fraser R	0.00%	0.24%	0.00%	0.83%	0.00%	0.26%	2
N Gulf Coast Alsek	0.00%	0.00%	0.00%	0.83%	0.00%	0.13%	1
Willamette R	0.00%	0.00%	0.00%	0.00%	1.75%	0.13%	1
Monthly sample size	81	418	101	121	57	778	778

Table 9. Monthly estimates of genetic stock composition of age-5 Chinook salmon caught in the ocean troll fishery off Oregon in 2006. Greatest stock contributions each month are highlighted.

	Month, 20006						Number
Genetic stocks	June	July	August	September	October	Season	of samples
Central Valley fa/sp	**21.43%**	**30.78%**	**75.00%**	4.76%	0.00%	**18.75%**	15
Mid Oregon Coast	**14.29%**	**11.54%**	12.50%	**38.10%**	9.09%	**18.75%**	15
N Oregon Coast	0.00%	0.00%	0.00%	**14.29%**	**81.82%**	**15.00%**	12
U Columbia R su-fa	**35.71%**	**15.38%**	0.00%	0.00%	0.00%	11.25%	9
N Cal. /S Ore. Coast	7.14%	3.85%	0.00%	**14.29%**	0.00%	6.25%	5
California Coast	0.00%	3.85%	0.00%	**14.29%**	0.00%	5.00%	4
L Columbia fall	0.00%	**11.54%**	0.00%	4.76%	0.00%	5.00%	4
Rogue	0.00%	3.85%	0.00%	4.76%	9.09%	3.75%	3
L Columbia spring	7.14%	0.00%	0.00%	4.76%	0.00%	2.50%	2
Mid Columbia tule	0.00%	3.85%	12.50%	0.00%	0.00%	2.50%	2
Snake R fall	**14.29%**	0.00%	0.00%	0.00%	0.00%	2.50%	2
Klamath River	0.00%	3.85%	0.00%	0.00%	0.00%	1.25%	1
L Fraser	0.00%	3.85%	0.00%	0.00%	0.00%	1.25%	1
L Thompson	0.00%	3.85%	0.00%	0.00%	0.00%	1.25%	1
S Puget Sound	0.00%	3.85%	0.00%	0.00%	0.00%	1.25%	1
Monthly sample size	14	26	8	21	11	80	80

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OTOLITH STRUCTURAL AND CHEMICAL ANALYSES OF CROOS CHINOOK SALMON

Background and Objectives

A portion of the CROOS funds contributed to an on-going effort to determine the feasibility of providing relevant information on the ocean ecology of Chinook salmon using otolith structural and chemical analyses. Here, we present the objectives and status of those efforts.

Otoliths are crystalline structures, comprised primarily of calcium carbonate, located in the inner ear of bony fishes, which function as balance organs. Otoliths grow by continuous deposition of calcium carbonate, which generates growth increments much like the annual rings on a tree. Therefore, an otolith provides a permanent chronological record. If fish reside in water masses with different chemical compositions and/or temperatures, those properties are reflected in the otolith composition. Certain elements, such as strontium and barium, and isotopes, which are forms of the same element that have different atomic masses, can tell different things about the life of a fish. Studies that examine a suite of elemental ratios, i.e., Ba/Ca, Sr/Ca, Mg/Ca, within otoliths can provide information on whether fish collected from different areas mixed together during past periods. This combination of elements within the otolith is often referred to as the otolith elemental signature. By examining the Sr/Ca ratio across the otolith growth axis, information on when an anadromous fish, such as Pacific salmon, entered the ocean can be determined. By measuring the oxygen isotope ratio in otoliths, we can learn about the temperature of the water the salmon lived in. The oxygen isotope analysis relies on the relatively well-established assumption that the oxygen isotopic ratios present in fish otoliths are in equilibrium with, or close to, seawater. The proportion of a heavier isotope, ^{18}O, incorporated into otoliths increases as water temperature decreases so that, all other things being equal, otolith carbonate precipitated at colder temperatures will be enriched with ^{18}O compared to otolith carbonate precipitated at warmer temperatures. All of these chemical analyses can be combined with microstructural analyses, i.e., counting of daily or annual increments within the otoliths, to provide information about discrete periods in the life of a fish.

Because otoliths grow continuously, spatially-explicit sampling methods can provide information from distinct periods in the life history. Laser Ablation-Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS) and micromilling techniques combined with Isotope Ratio Mass Spectrometry (IR-MS) allows for the determination of elemental and isotopic otolith composition at discrete regions on the otolith. Therefore, otolith chemical and structural analyses can be combined to provide novel information on individual life histories.

The otoliths of a subset of Chinook salmon collected during the CROOS project are being examined to determine:

1) If, and when, Chinook salmon from different stocks resided in waters with similar chemical characteristics. This will provide information on whether we can use otolith chemistry to learn more about stock-specific ocean migration and mixing in Chinook salmon.

2) The temperature history of individual Chinook salmon. Although we have information on the temperature of the water where fish were captured, we do not have information on the temperature history of individual fish. We will take a subset of individuals from 2 or 3 stocks and mill portions of the otolith for oxygen isotopic analysis. This will provide information about the past temperature history of individual fish.
3) If the ratio of $^{87}Sr/^{86}Sr$ in otoliths can be used to distinguish fall vs. spring Chinook. It is important to be able to determine the run time of a fish for ecological, conservation, and management reasons. Currently, genetic information cannot always readily separate fall vs. spring Chinook.

Methods

The otoliths were collected from a subset ($n = 420$) of the CROOS Chinook. This was accomplished through the cooperation of several CROOS fisherman and local fish buyers. Heads were frozen whole after fish were filleted for sale and frozen heads were then delivered to HMSC. All otolith pairs were extracted and a tissue sample from within the head region was placed in ethanol for genetic analysis. This second sample was collected in case there were problems with the field-collected fin clip, i.e., lost sample, DNA extraction problems, etc. This action proved very valuable as many of the secondary tissue samples were needed to verify the genetic identification of the fish used for otolith analysis. Genetic identification of the fish was finalized in early November 2006 and 280 fish were selected for otolith analysis based on stock composition. Otoliths were weighed, measured, cleaned, embedded in resin, sectioned, and polished. The form of calcium carbonate in otoliths is typically aragonite. Due to unknown reasons, aberrant otoliths comprised of vaterite, another structural form of calcium carbonate, occur frequently in fish from certain hatcheries. Vateritic otoliths do not form visible daily or annual check marks and incorporate elements differently that aragonite and are, therefore, useless for structural and chemical comparisons. A disproportionately high occurrence of vateritic otoliths was observed in Central Valley Chinook, i.e., 30%, which reduced the number of otoliths for analysis to 198 (Table 10).

Polished otolith sections were mounted onto glass slides, cleaned, and transported to OSU's WM Keck Collaboratory for Plasma Spectrometry, Corvallis, Oregon, for elemental analysis. Elemental data (^{25}Mg, ^{43}Ca, ^{55}Mn, ^{86}Sr, ^{88}Sr, ^{138}Ba, and ^{208}Pb) were collected along the otolith growth axis (Fig. 12). Time-resolved software allows elemental data from discrete periods in the life of the fish to be measured and compared. For example, Sr/Ca ratios are typically much higher in more saline ocean waters than freshwater rivers. Therefore, the period when a fish entered waters with elevated salinity can be identified by examining the strontium concentration across the otolith growth axis (Fig. 13). When combined with microstructural analysis, the elemental composition of the otolith during discrete periods of an individual's life can be determined.

Objective 1: Determine if, and when, Chinook salmon from different stocks resided in waters with similar chemical characteristics. This will provide information on whether we can use otolith chemistry to learn more about stock-specific ocean migration and mixing in Chinook salmon.

Elemental data were collected from 200 fish in early February 2007. Microstructural and statistical analyses are on-going. One potential concern was adequate identification of annuli, i.e., visible winter check marks on otoliths, to allow accurate identification of comparable years of ocean residence. Preliminary analyses indicate that visual identification of annuli is feasible in most all otoliths (Fig. 12). Age estimates generated through otolith microstructure will be directly compared with those generated by scale analysis, which was recently completed. Elemental concentrations within discrete years of ocean residence, i.e., 2006 vs. 2005 vs. 2004, will be compared among fish from different stocks.

Table 10. The stock, river of origin, and number of fish used in otolith structural and chemical analyses. The fa/sp and sp/fa fish from the Central Valley (*in italics*) will be further analyzed for $^{87}Sr/^{86}Sr$ to provide a determination of run-timing (See **Objective 3**).

Stock	River	n
Central_Valley_fa	Battle_Cr	32
Central_Valley_fa	Feather_H_fa	27
Central_Valley_fa	Butte_Cr_f	20
Central_Valley_fa	Stanislaus_R	10
South Puget Sound	Soos_Cr	18
Mid_Columbia_Tule	Spring_Cr_H	11
Rogue River	Applegate R	7
Rogue River	Cole Rivers H	4
Klamath River	Klamath	5
Klamath River	Trinity	8
Central_Valley_fa/sp	*Feather_H_fa*	*11*
Central_Valley_sp/fa	*Feather_H_sp*	*6*
Central_Valley_fa/sp	*Stanislaus_R*	*2*
Central_Valley_fa/sp	*Butte_Cr_f*	*3*
Central_Valley_fa/sp	*Battle_Cr*	*6*
Other stocks		30

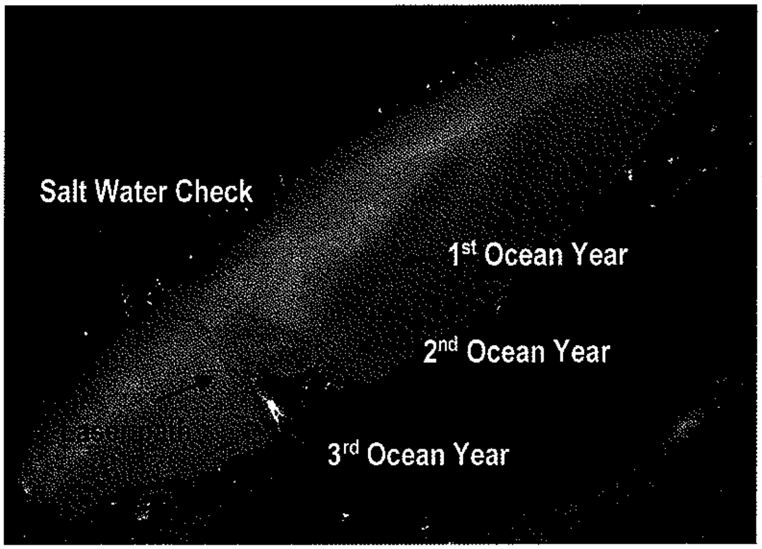


Fig. 1. Otolith from a 27 cm Mid-Columbia Tule Chinook collected on June 11, 2006. Laser path, time of entrance into higher salinity water, and three ocean years are identified. Time of entrance into salt water confirmed with Sr/Ca data.

(Figure 12)

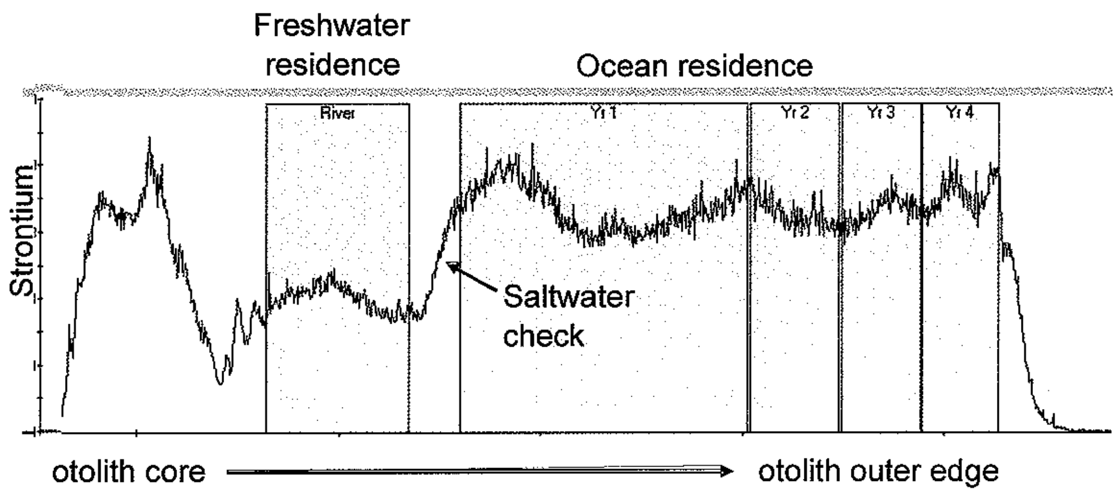


Fig. 13. Relative strontium concentrations across the laser path of fish pictured in Fig. 1. The period of freshwater residence, the salt water entry check, and years of ocean residence are identified.

Objective 2: Re-create temperature history of individual Chinook salmon.

Otolith carbonate for fish selected from 2 stocks will be sampled with a high precision micromill. The oxygen isotopic composition, i.e., $^{18}O/^{16}O$, from 8 to 10 time periods within each ocean year from 4 fish will be determined. The oxygen isotope analysis rely on the relatively well-established assumption that the oxygen isotopic ratios present in fish otoliths are in equilibrium with, or close to, seawater. The proportion of a heavier isotope, ^{18}O, incorporated into otoliths increases as water temperature decreases so that, all other things being equal, otolith carbonate precipitated at colder temperatures will be enriched with ^{18}O compared to otolith carbonate precipitated at warmer temperatures. This analysis will provide detailed information on temperature histories of individual fish and assess its feasibility for examining stock-specific variation in temperature preferences.

Objective 3: Determine if the ratio of $^{87}Sr/^{86}Sr$ can be used to distinguish fall vs. spring Chinook.

The genetic basis for differentiating between spring and fall Chinook is not fully established. In some regions, i.e., California's Central Valley, the inability to distinguish between spring and fall Chinook creates uncertainty and can pose management problems. We have been developing a method to distinguish maternal run-timing by examining strontium isotopic ratios in otoliths. The element strontium is well-mixed in the modern ocean and the ratio of two isotopes, i.e., $^{87}Sr/^{86}Sr$, is considered invariant (=0.7092). The $^{87}Sr/^{86}Sr$ ratio within a watershed, however, is dependent on local geology and weathering processes. The basaltic coastal watersheds in Oregon typically have lower $^{87}Sr/^{86}Sr$ ratios than seawater. For example, the Feather River in California has an average $^{87}Sr/^{86}Sr$ ratio = 0.706150 ± 0.00003.

The composition of a salmon's otolith core is influenced by its mother's body composition. Thus the otolith cores of offspring of spring Chinook, which have resided in freshwater for months prior to spawning, should have lower $^{87}Sr/^{86}Sr$ ratios than the otolith cores of fall-run offspring. This premise has been supported with juvenile spring and fall Chinook collected from hatcheries on the Rogue, Umpqua, and Trask Rivers. In all three watersheds, juveniles were correctly identified as spring or fall, based on the $^{87}Sr/^{86}Sr$ ratio in the core of their otolith, >90% of the time.

The $^{87}Sr/^{86}Sr$ ratios in the otoliths of a subset of the Central Valley Chinook that have been classified as spring or fall run but with low assignment probabilities, i.e., <60%, will be measured at the OSU WM Keck Collaboratory in late March or early April.

Additional Information: Determination of the size-at-ocean entrance for Chinook collected in the Oregon fishery.

The importance of early ocean survival is increasingly recognized as a key determinant of cohort size. The individual size and time a juvenile Chinook enters the ocean can be a determinant of overall survival. The majority of coastal Chinook in California and Oregon migrate to the ocean in their first year of life, i.e., as subyearlings. A small percentage of individuals from some basins, i.e., Rogue and Umpqua, display a yearling life history. Currently, estimates of size at ocean entrance are available for about 20% of Oregon's coastal Chinook. The hypothesis that there is a size or time for optimal survival has been postulated. If supported, there are implications for both hatchery management, i.e., release strategies, as well as habitat restoration and management implications.

Size-at-ocean entrance will be determined for all Chinook used in Objective 1. Preliminary estimates of individual size-at-ocean entrance, using linear regressions from Titus et al. 2004, were determined based on otolith microstructure and Sr/Ca transects along the otolith growth axis (Table 11). Based on discussions with hatchery operators, back-calculated estimates are reasonable given the size and timing of fish release with the exception of the Feather River Hatchery. This is somewhat surprising as the linear relationships used for back-calculation were generated based on Central Valley hatchery Chinook. The bulk of the Feather River hatchery production fish are released in May through June at sizes >100 mm. There are some experimental releases of smaller, coded wire tagged (CWT) fish from February to May. These preliminary data indicate that the fish released earlier may comprise a disproportionate percentage of the catch. We emphasize the preliminary nature of these results and additional analyses are on-going.

Table 11. Estimated size-at-estuary/ocean entrance based on back-calculated length determined with otolith microstructure and Sr/Ca transects. Mean, standard deviation (SD), range, and percentage classified as sub-yearling and yearling are included.

Basin	River	Mean	SD (mm)	Range	% Subyearling	% Yearling
Central Valley	Feather River Hatchery	77.63	23.1	37-99	100	
Klamath	Klamath River	77.59	24.1	45-96	100	
Mid Columbia	Spring Ck Hatchery	78.23	7.4	66-89	100	
Rogue River	Applegate River	91.48	42.7	39-151	80	20
So. Puget Sound	Soos Ck Hatchery	112.83	51.9	73-198	67	33

OCEANOGRAPHIC DATA COLLECTION

Summer 2006 CROOS-Glider Collaboration

Project CROOS partners recognized that it would be critical to collect oceanographic data in conjunction with fisheries and genetic stock information. The early strategy was to employ a subset of industry vessels and collect an array of oceanographic data using both simple and sophisticated oceanographic equipment. However, it became quickly apparent that this would require the vessels to stop their fishing operations to employ oceanographic instruments (e.g., CTD's). Although project vessels collected sea surface temperature, and some collected temperature at depth of fishing (via portable temperature recorders attached to the cannon ball), it was not practical for vessels to collect other types of oceanographic information (visibility, salinity, chlorophyll, etc.). Scientists from the College of Oceanic and Atmospheric Sciences, at no cost to the project, volunteered to help us test the feasibility of collecting oceanographic information near or below the CROOS project vessels using autonomous underwater robotic gliders. The following section describes the results of this pilot effort.

Beginning in April 2006, the OSU Glider Lab has more-or-less continuously maintained an autonomous glider, sampling a cross-shelf transect along the Newport Hydroline (44 39.1 N) off central Oregon to study wind-driven flow-topography interactions and the impacts on processes such as the formation of hypoxia in coastal waters. The Newport Hydroline is a 45 mile-long, cross-shelf array of hydrographic stations, mainly temperature and salinity observations, running from the 20 m isobath to the deep ocean, and has one of the best historical records in the northwest US. In September 2006, we coordinated the operation of two autonomous gliders with concurrent CROOS sampling from commercial fishing boats in Oregon's coastal ocean.

Autonomous underwater vehicle (AUV) gliders are robots capable of travel through and making observations in the ocean. The gliders do not have a propeller; instead they "fly" through the water by changing their buoyancy, using their wings to convert vertical motion into forward motion. At the surface the glider takes water in through the ballast pump. This makes the glider heavy relative to the surrounding water. The glider sinks, and some of this vertical motion is converted to forward motion by the wings. At the bottom, the glider expels the water in the ballast pump, becomes lighter than the surrounding water, and rises, reversing the process. In this fashion, the glider goes up and down, flying a saw-tooth pattern through the coastal ocean. This mode of propulsion is slow (1/2 – 1 knot), but the trade off is an especially long endurance (3-4 weeks). The glider comes to the surface at pre-programmed, six-hour intervals, and determines its location by GPS and communicates back to our lab via Iridium satellite phone, downloading data and uploading new instructions. The benefits of autonomous sampling are well known - the cost relative to comparable ship-time is miniscule, and sampling is not constrained by weather; the other benefits come by maintaining a continuous presence in the ocean - just by being there your chances of observing intermittent, unpredictable (possibly important) processes are increased.

In September 2006, we conducted a coordinated sampling plan with two gliders and the commercial fishing observations. One glider (Bob) continuously sampled the Newport Hydroline, a cross-shelf section off Newport, Oregon (Figure 14). The second glider (Jane) conducted a sampling pattern over sites selected to match the efforts of the commercial fishing observations. Jane started inshore, transited to the first site near Stonewall Bank, spent six days sampling there, then transited to the second site further south, spent four days sampling there, then transited back up to the offshore end of the Newport Hydroline, and finally sampled a transect onshore, where Jane was recovered.

Physical conditions in the coastal ocean during September 2006, as revealed by the glider observations, are the result of one of the strongest upwelling seasons in several years. The glider observations of temperature and salinity (Figure 15) were exceedingly cool and salty relative to historical averages.

This pilot project was a success and showed that autonomous underwater gliders could be used in conjunction with fisheries research conducted by commercial fishing vessels to record oceanographic data. Project CROOS partners believe this data will be important for both short and long term understanding of salmon migrations, feeding behavior, and other spatial/temporal characteristics of salmon stocks.

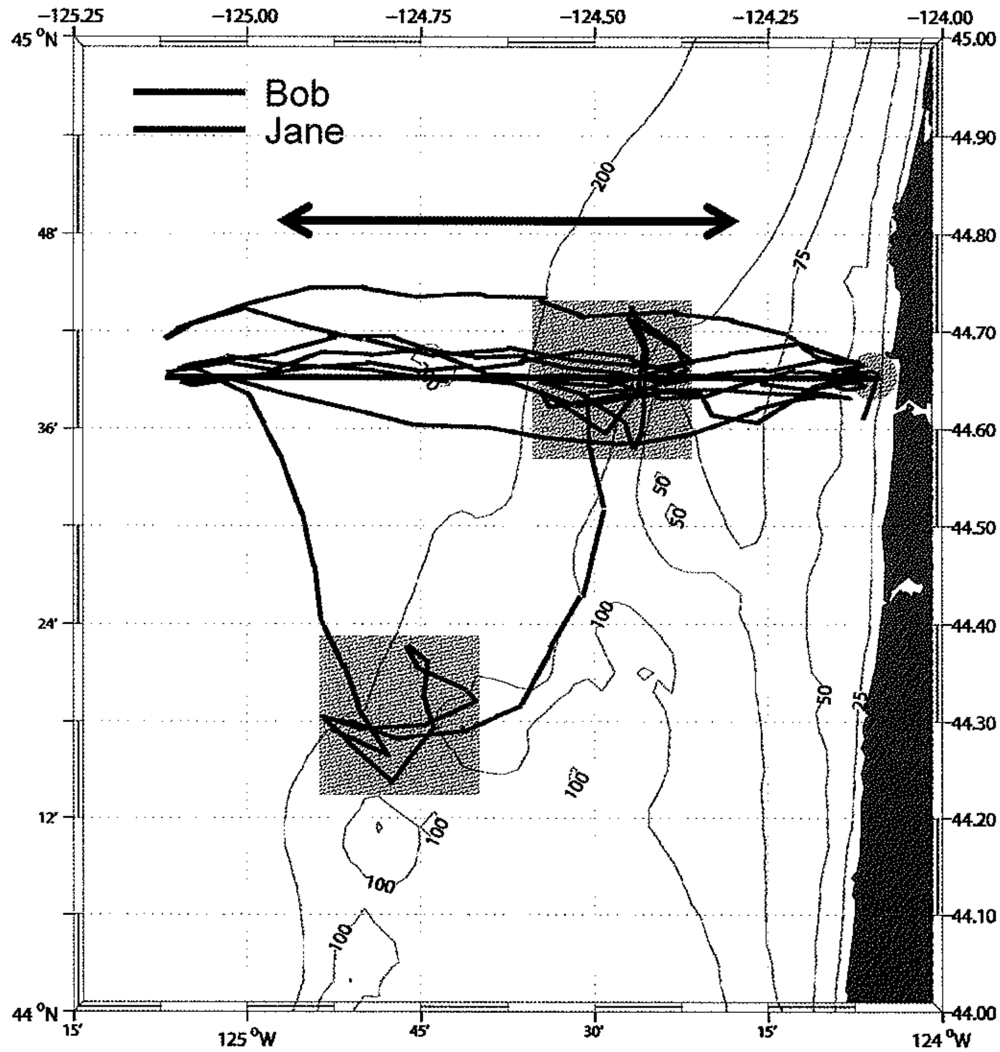

Bob
Jane
−125.25
−125.00
−124.75
−124.50
−124.25
−124.00
45 °N
48'
36'
24'
12'
44 °N
45.00
44.90
44.80
44.70
44.60
44.50
44.40
44.30
44.20
44.10
44.00
15'
125 °W
45'
30'
15'
124 °W
200
75
50
25
100

Figure 14

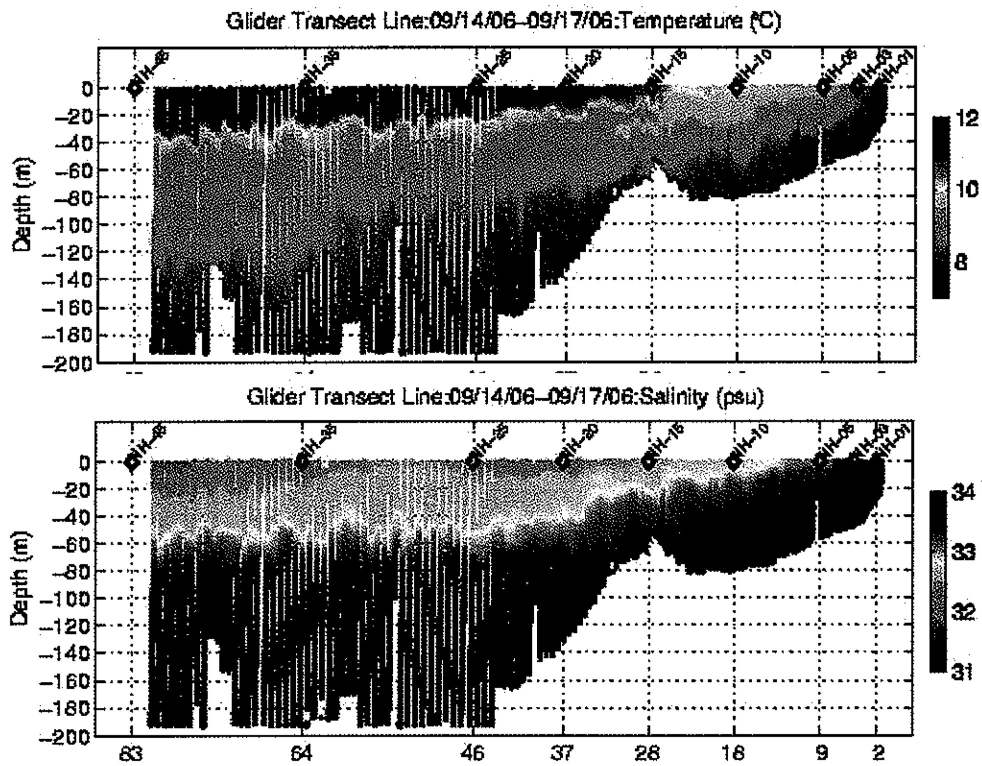


Figure 15: Glider observations of temperature and salinity form Sep 14-17 2006 along the Newport Hydroline. Temperatures were exceeding cool and salinities were very high compared to historical averages, reflecting the intense upwelling in 2006.

WEBSITE DEVELOPMENT

Planning

In planning for the CROOS project, it was envisioned that a website would be developed that could be used to:

1. Describe the project and report general project information to educators and the public
2. Compile data gathered from the project for analysis by affiliated researchers
3. Report the results of the genetic analysis of the sampled fish, their distribution, and other significant oceanographic information in "real time" to management entities
4. Report results and significant oceanographic data to the contributing fishers
5. Disseminate information about origin and catch history of individual fish to support marketing strategies

It was understood that varying levels of access would need to be designed into the site in order that confidentiality concerns were addressed. For example, the level of access to the raw data which makes up the basis for the website would be more restricted for individual fishermen and the general public than it would be for researchers and managers attempting to analyze the data. Participating fishermen would be able to access a higher level of information about their own data than they would about the cumulative data from the entire project. Potential consumers would be able to enter an ID number (associated with a bar code) and find information about the catch history of individual fish; however they would not be able to access many types of cumulative project information.

To visualize how such a website could be incorporated into a future, GSI based management application, a schematic diagram of how one such website would work for a hypothetical, real-time fisheries management regime is shown on Figure 20.

ProjectCROOS.com Website Development

The CROOS team hired Beartooth Creative Group which developed the original – *ProjectCROOS.com* website. The website is currently hosed on a server on an off campus server and describes the purpose and history of the CROOS project.

The site explains:
The need for the project at this time, including a description of the current problem with weak stocks of Klamath River salmon.

1. A description of the funding for the project
2. Identification of the project collaborators
3. An explanation of the science behind the project
4. The contribution of the fishermen to the project
5. A brief economic picture of the losses to the salmon fishery in 2006 due to weak stock management constraints

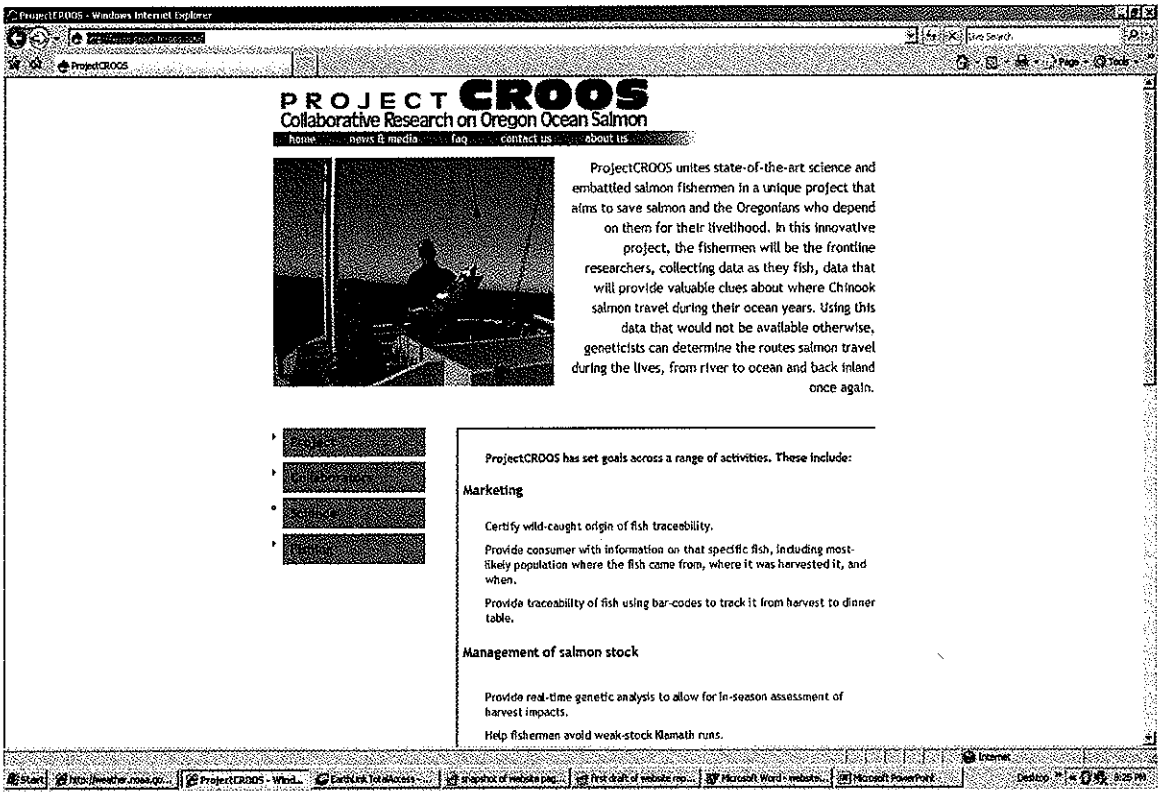


Figure 16 ProjectCROOS.com Home

At this stage of development, the ProjectCROOS.com website does not allow access to any data or results from the analysis of the 2006 data. When technical and confidentiality issues are fully addressed, the site will offer varying levels of access to those pages.

A more detailed explanation of the website is presented in the Appendix 6, _Project CROOS Website and GIS Development Proposal._

GIS based science website development

A separate website was developed to incorporate the interactive GIS facets of project information. This "beta" phase of the website was developed by Chris Romsos at OSU in the College of Oceanic and Atmospheric Sciences laboratory. This site, which is now restricted by user login and password, uses currently available interactive GIS web mapping software (ESRI's ArcIMS and Arc GIS) to display the full range of data collected in the project and allow for manipulation and interpretation. When access protocols are determined and technical issues fully developed, these pages will be accessed through the ProjectCROOS.com website.

This website actually consists of three linked websites, each dealing with separate areas of project focus.

The science and fisher sites are "viewers" or more simply, just websites. No specific software, license, or download is required by the end user other than a connection to the internet and a modern web-browser. The sites are coded primarily in HTML though some javascript is used for web configuration, initialization, and to build a Table of Contents. Each viewer contains a main map window, a set of navigation and query tools, a layer index or table of contents, and a results pane. Users interact with the site by toggling among various data layers and performing layer queries. In this way users may easily explore information from the project and from the fishing grounds by actively looking for relationships and trends, or by querying (selecting) subsets of a data layer. Query results are presented in tabular format.

The science site allows access to all of the data compiled in the project database. It allows researchers to view layers of information in a mapping format for each week of the duration of the project. Catch location of each sampled fish, including latitude/longitude as well as depth of capture, time of capture, water temperature, capture vessel, the length of the fish, its age, and the presence of any applied markings (fin clips, etc.) can be correlated to the probability that it "assigns" to a specific river of origin. The entire vessel track of each participating vessel (during the time it has gear in the water) can be displayed. Other geographical, bathymetric, oceanographic, and meteorological data can also be layered on the display.

At present, to protect the confidentiality of the participating fishermen, all information linking a datapoint to a specific vessel or fisherman has been removed from access by all reviewers, except that each fisherman may fully access his own data on a separate page (actually a separate, linked site). The science site can only be accessed with a unique login and password.

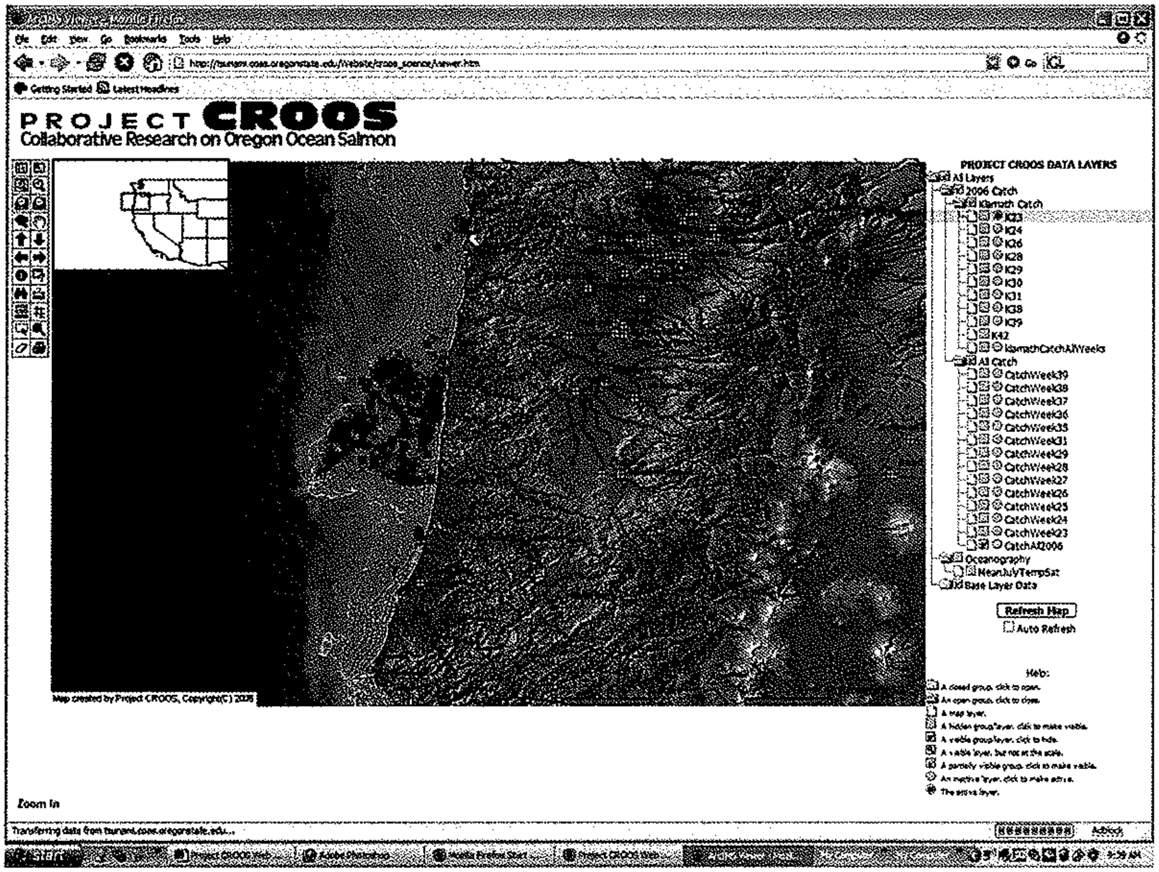


Figure 17. This Science web mapping site loads after the user is authenticated. Navigation and query tools are located in the upper left corner, the white space at the bottom of the view is reserved for query output, and the table of contents is located on the right. The main map window is manipulated by selecting a tool and performing either a click or drag inside the window.

The fishermen site also requires a unique login for each fisherman. It only presents the specific catch data that pertains to the catch information of that particular fisherman. Non-confidential data, such as oceanographic and bathymetric information, is identical with that on the scientist site.

The consumer site is in an early stage of development and is written with different software and has a different look than the science and fishermen sites. It will allow a consumer to perform a website "lookup" to find catch and stock origination information about a specific fish by entering the unique code number attached to that fish.

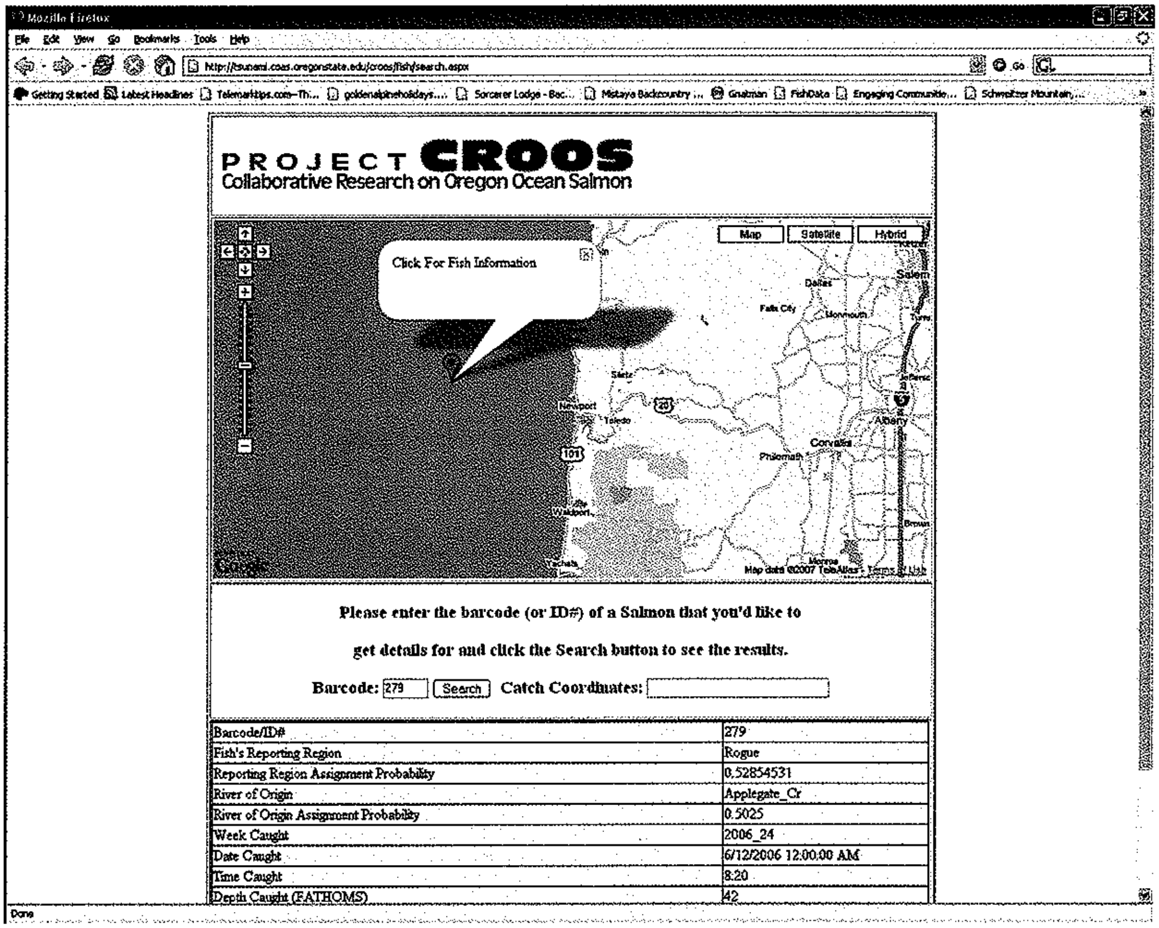


Figure 18. This is an example of the Project CROOS consumer webpage. The consumer enters a barcode from a fish that they purchased in the market and the website "looks up" that barcode in the database. Results are returned to the map and to a table.

Interactive Web Mapping Software

ESRI's ArcIMS (Internet Mapping Server) software was chosen to illustrate the geographic information generated through this project. ArcIMS is a mapservice, a type of server that generates maps in the form of an image. The server processes requests from a client (in this case, the CROOS science websites) and generates new map images based upon each request. ArcIMS integrates well with other ESRI GIS software and allows relatively easy creation and management of geographic representations of the tabular data records that constitute the database. It is also an extensible product that can grow, supporting customizations on the client side that could include building more sophisticated analytical capacity into the system.

Database Protocols and Maintenance

All data collected and generated through the efforts of project CROOS is currently stored in a Microsoft Access database. Data types include: Vessel Navigation, Salmon Catch Records, Sample Records, Genetic Stock Assignment Results, and Ocean Temperature data. Data from separate tables is indexed by a combination of Vessel (fisher's name) and Sample ID. An example of the nascent data model is shown in figure 19.

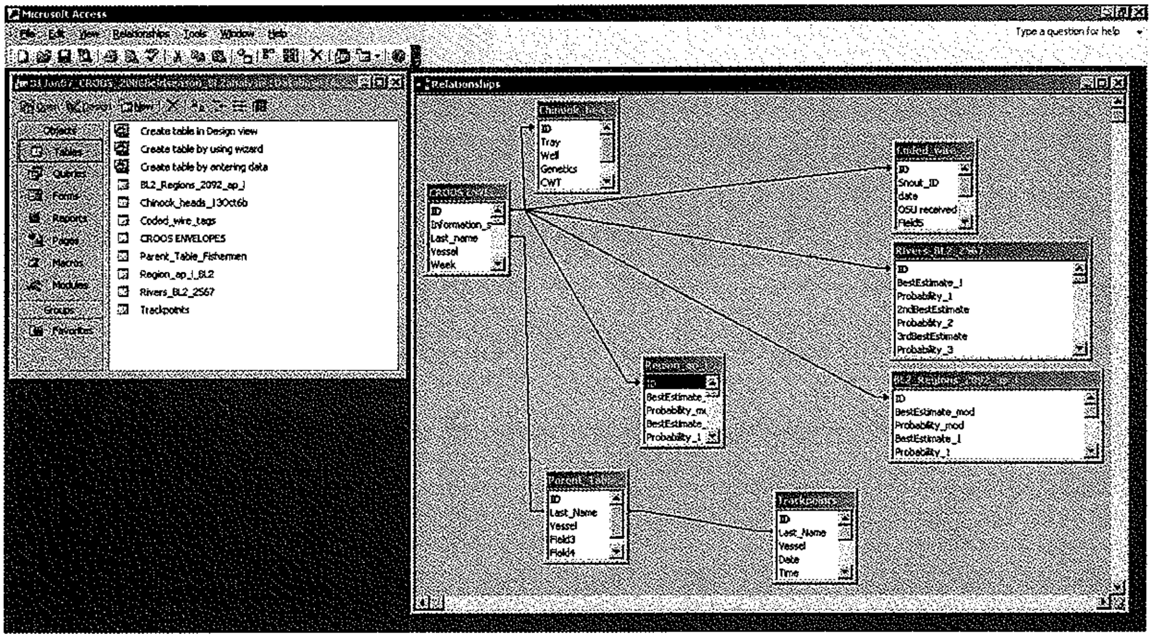


Figure 19. Diagram of the Project CROOS relational data model. Vessel navigation (trackpoints) is indexed using the last name of the fisher in a parent table; all other data is indexed by a unique sample ID.

Observations and Suggestions for Future

Accurate and rapid entry of data from the logs and electronic devices used in the sampling protocols and its correlation with the genetic information analyzed in the laboratory is vital to the success of not only the website, but the entire CROOS project. This is a complex and challenging task, particularly in a pilot stage project such as this.

As information from the participating fishermen arrives at the lab, it must be checked for obvious errors or omissions, and then entered into a format which will be compatible with that required by the website. This involves manual entry of the data from paper log sheets and digital entry of data from electronic dataloggers, temperature recording devices, and GPS units into a database where it can be correlated with the results of the genetic analysis for each fish. This process can involve several steps, and may require conversion of data from text, spreadsheet, and/or ACCESS database format to the eventual SQL database format required by the GIS software.

Utilization of the handheld GPS units to record vessel tracking and fish capture waypoints greatly simplified the database entry process, as manual transcription of each vessel's tracking logs was very time and effort intensive, but was not directly useful in transferring the information to the website.

Migrating newly entered data into an existing master ArcIMS database has proven to be challenging, and solving this shortcoming is critical to the website's success. A specialized web-programmer would need to write programming code to automatically update the database tables and maintain the integrity of the links. Accomplishing this was beyond the expertise of project participants, although the problem was temporarily circumvented by developing a master database table with the fields pertinent to immediate needs. This, however, is not a permanent solution as it does not deal with the necessity of maintaining the integrity of relationships wherein one datapoint links to other types of data (one-to-many relationships).

Optimization and standardization of these protocols will become even more important if results are to be uploaded to the website directly from different port liaisons in various ports and from several different laboratories. Such a capability would be desired in future projects, particularly if they involved other states and NMFS laboratories. A system to standardize the error checking and data filtering prior to uploading will have to be established, since some field errors will always be part of such a large research project.

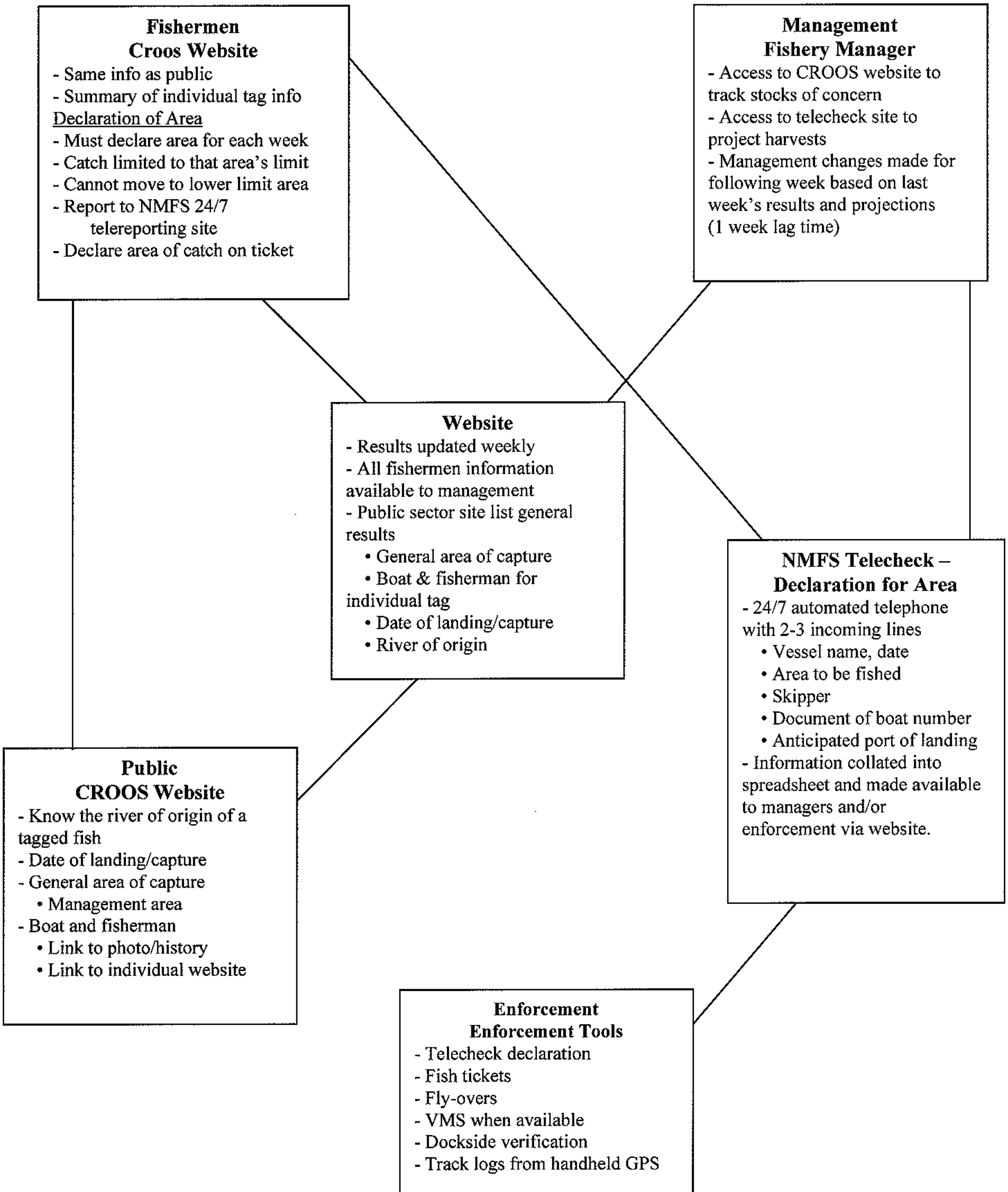
In future projects, spatio-temporal patterns of distribution or oceanographic/meteorological linkages to fish movements could be assessed directly using ArdIMS or MatLab software.

Since some sort of a central project website of this type would likely be expected in future GSI-based projects, further development of the present website should be explored. Plans are under way to use several analytical techniques, such as focus group sessions and surveys, to help define the best website design and functionality for presenting the results of those projects to scientists, fishery managers, the fishery itself, the seafood market, and the general public.

Figure 20

Collaborative Research on Oregon Ocean Salmon

How Things Work



MANAGEMENT

The long-term goal of this project is to increase the information available to managers on the temporal and spatial distribution of specific West coast salmon stocks. If this work indicates that substantial variation in temporal and spatial distribution exists, week to week management measures may be employed that allow commercial fishermen access to relatively abundant stocks of salmon while protecting weak stocks. The first step in applying GSI technologies to fisheries management is to explore and map the distributions of stocks in Council-managed fisheries. An Exempted Fishing Permit has been developed that will allow us to begin mapping stock distributions in ocean fisheries in 2007 in times and areas outside of the open areas and seasons. In addition, this proposal will allow us to test the feasibility of new techniques that could allow rapid-turnaround quota management in limited areas and times in the future. However, the biggest gains will ultimately come from an improved understanding of stock-specific marine distributions and migration pathways in relation to submarine topography and oceanic conditions. In the long term this constitutes a step toward ecosystem-based management for salmon.

The CROOS project is designed specifically to help improve fishery management. The short-term problem addressed is the need to reduce fishery impacts on Klamath fall Chinook while maintaining some access to other, more abundant stocks. In the longer term, GSI data could provide a superior add-on or alternative to the coded wire tag (CWT) data that have been the basis for management since the 1970s.

The primary objective is to improve information on spatio-temporal distribution of West coast Chinook salmon for use in salmon management. To achieve this we collected time and location-specific genetic samples, along with scales, otoliths, stomachs, and oceanographic data. The data of short-term interest to management is stock identification and specific catch locations. We demonstrated that we can map the precise locations of catch by stock. Data are currently being analyzed for differences in distribution among stocks that might be useful for directed harvest on non-Klamath stocks. From the data we collected in 2006 we hope to develop analytical techniques. Fisheries were not extensive enough to expect to see major distributional differences. Future years of data collection with a greater spatial extent will be needed to achieve this objective. We are working with fishermen in California to coordinate sampling from the two states. Washington has also expressed interest in sampling fisheries North of Cape Falcon.

The longer-term purpose of these collections is to begin developing a database of stock distributions for comparison with the historical CWT database. Over time we expect to develop a database similar to the CWT contribution rate database but with fewer assumptions (e.g.; fewer hatchery indicator stocks representing natural production) and much higher resolution in space and time. Coast wide, about 5 percent of Chinook and coho salmon have CWTs. With 20% of the catch sampled there is substantial statistical sampling and expansion error in catch composition estimates. Rare or untagged stocks are difficult or impossible to detect. With GSI data we can identify a high percentage of fish to stock of origin and map catch location precisely and in near real time. This enables us to identify stocks that are not CWT'd, and gives us a better likelihood of observing stocks that contribute at a rate of 1% or less to fisheries. This can be used to improve the base-year data used in fishery harvest models, thereby improving the preseason modeling of fishery impacts and perhaps allowing finer-scale shaping of fisheries.

In addition to the sampling component of Project CROOS we have expertise in the fishery management process. We plan to help develop the statistics and the modeling techniques that will be required to implement GSI data into fisheries management. As we develop these models we will also be looking to expand the scope of modeling to include links to economic models. In this way we will be able to project the impacts of fishery regulations on fishing communities along the coast and evaluate policies and incentives to help target healthy stocks while minimizing catch of weak stocks. This may result in fishing seasons that improve overall economic benefits while distributing economic impacts more equitably than is currently possible.

In addition to improving the stock contribution rate data we will be able to examine migration routes, evaluate "hot spots" and see how long they persist, relate fish distributions to ocean conditions, and generally expand the range of information available to fishery managers. Compilation of such a database will require several years. We anticipate providing preliminary results to fisheries managers after three years of sampling, with continuing improvement in the information in future years.

Work in 2007 will be designed to (1) extend the development of techniques and methodologies based on 2006 experience, (2) provide relief to fishermen via payment for participating in sampling programs, and (3) start to answer questions relative to distribution of Chinook stocks that may prove useful for management. It is too early to actively apply GSI technologies to fishery management on the West coast, although a simulation of a potential in-season weak stock quota management application may be conducted based on data collected during this study. Project CROOS is specifically designed to help meet the needs of management. Regional fisheries are managed by the National Marine Fisheries Service (NMFS) and the Pacific Fishery Management Council (PFMC).

NMFS has a Strategic Plan for Fisheries Research. In this plan Section I.A. treats "Biological research concerning the abundance and life history parameters of fish stocks." From that section:

> *Understanding aspects of the life history of fish stocks will be of increasing importance in the management of the Nation's living marine resources. Describing migratory and distribution patterns, habitat use, age, growth, mortality, age structure, sex ratios, and reproductive biology will be essential information for scientists and managers to optimize sustainability and yield of these resources...*

There is an increasing need to identify and characterize discrete stocks. This will allow scientists and managers to correctly structure stock assessments and design stock specific management measures for groundfish complexes, salmon species, coastal migratory and oceanic migratory species and reef fish. Stock identification involves many techniques, including mark-recapture, otolith shape analysis, parasite distributions, and biochemical genetic methods.

The improved understanding of ocean distributions that will result from conducting studies like this over a period of years will help us characterize discrete stocks and design stock-specific management measures. This is also directly related to Goal 1 of the Strategic Plan:

GOAL 1: Provide scientifically sound information and data to support fishery conservation and management. (Ongoing)

Objective 1.3: Determine and reduce the level of uncertainty associated with stock assessments through improved data collection and advanced analytical techniques. (FSP Strategy 1.2.1)

Objective 1.6: Collaborate with the Councils and other management authorities to develop fishery management regimes that will effectively control exploitation. (FSP Strategy 1.1.4)

The PFMC assesses its research and data needs every two years. The draft 2006-2008 Research and Data Needs for the Pacific Fishery Management Council (Council) identifies as its highest priority the development of GSI for fisheries management applications. The report states:

Advances in genetic stock identification, otolith marking, and other techniques may make it feasible to use a variety of stock identification technologies to assess fishery impacts and migration patterns: The increasing necessity for weak-stock management puts a premium on the ability to identify naturally reproducing stocks and stocks that contribute to fisheries at low rates. The CWT marking system is not suitable for these needs. The Council should encourage efforts to apply these techniques to management.

Substantial progress has been made on this item in the past 6 years. A coast wide microsatellite database for Chinook has been developed. A similar database for coho salmon is under development, but needs resources to coordinate efforts for the entire coast. GSI techniques have improved so that samples can potentially be analyzed within 24-48 hours of arrival at the laboratory. GSI is actively being used in Canada to manage coho salmon fisheries off the West coast of Vancouver Island. Studies are under way to evaluate the potential usefulness of real time GSI samples in Chinook management, particularly in relationship to Klamath fall Chinook. There are proposals to develop operational alternatives to time-area *management using these techniques, in combination with existing CWT marking, mass marking, otolith microchemistry, and other emerging stock identification techniques. These studies are now the highest priority for salmon management.*

The report also identifies emerging issues related to this priority. From the report:

> Emerging issues are related to the high priority recently assigned to the implementation of GSI technologies in weak-stock fishery management. Research tasks and products necessary for this to be successful are:
>
> 1. Identification of the error structure of GSI samples taken from operating fisheries.
>
> 2. Development and application of technologies to collect high-resolution at-sea genetic data and associated information (time, location, and depth of capture, ocean conditions, scales, etc.)
>
> 3. Identification of stock distribution patterns useful for fisheries management and appropriate management strategies to take advantage of these distribution patterns.
>
> 4. Development of pre-season and in-season management models to implement these management strategies and integrate them with PFMC management.

The studies proposed here will work toward resolving these issues. The second and third items will be addressed directly. Work on the first item will also be progressing during the course of this study. The fourth item, development of new management models, is a future project that depends on results of the proposed study and similar sustained efforts over the next few years.

SUMMARY: KEY FINDINGS AND RECOMMENDATIONS

CROOS was an ambitious undertaking given the relative short window of time for conducting the project (nine months) and the diverse set of objectives. CROOS project managers attempted to combine basic and applied interdisciplinary science, genetic and oceanographic research, industry and scientist collaboration, and data technology and website development -- while also providing financial assistance to a large portion of the fleet. This required a high degree of adaptive learning and a fundamental commitment to day-to-day communication and coordination. CROOS project accomplishments were due in large part to the cooperation and hard work of a large and diverse team including fishermen, scientists, managers, and educators from both the private and public sectors. Although readers of this report can make their own judgments regarding project success, the CROOS group is proud of its accomplishments and believes that the project builds a strong foundation for future work. Together with other salmon GSI work being conducted along the West Coast, these projects herald a new era for ocean salmon science, management, and marketing.

This project primarily focused on developing protocols, providing "proof" of concepts for science and management, and laying the groundwork for future GSI-based salmon research and management. What should not be overlooked are the core principles guiding this work:

- Authentic collaborative research between industry and scientists based on mutual learning and respect
- Integrated fishing and research activities benefiting fishermen, scientists, and resource managers
- Integrated research and project management using digital technologies
- Creating and managing "real time" data for diverse audiences and uses including fishery science, fishery business management, resource management, seafood marketing, and education.

Project Results and Findings

- Financial Assistance to the Fleet The project provided financial assistance to about 20% of the fleet that participated in the Oregon salmon troll fishery in 2006. More than seventy contracts were signed and 72 vessels participated in at least 1 opener (72 operators, 54 crew members) conducting 707 "sampling days". Sampled fish totaled 4,270 and represented 17% of all salmon harvested by the commercial fleet off the Oregon coast south of Cape Falcon in 2006. A total of $332,100 was distributed to operators and crew. A post-season fleet survey indicated that fishermen and crew were supportive of the project and satisfied with project management and financial remuneration.

- Protocols, Fleet Management, Project Coordination Project managers developed detailed protocols for biological sampling, data collection and management, fleet training, and project coordination. Fleet coordination required considerable staff time and will be a crucial component of any future work. These protocols will be invaluable for future GSI-based salmon research and management along the West Coast.

- Dataloggers Digital datalogging devices for fishing vessels proved to be successful. Most fishermen testing these units believed the equipment was easier to use than "manual" sampling protocols. The devices deserve further testing and development for cost-effective and comprehensive "real time" data collection.

- Genetic Stock Identification (GSI) From mid June to late October 2006, over 4,200 tissue samples were delivered to the genetics laboratory along with digital or paper logs with time/harvest location, troll tracks, fish length, harvest depth, water temperature, etc. The paper log data was then manually entered into the computer at the laboratory. Approximately 3,100 samples were processed and 2,567 fish were used to estimate stock mixture proportions and for individual assignment to baseline populations. Probability values of stock assignment for the 2,567 fish ranged from 28% - 100%. By the end of the season a total of 2,097 fish were assigned probabilities ≥ 90% to a specific hatchery or reporting region (river basin or coastal region). Samples not processed in the laboratory (1,221) were stored in the OSU archive and can be genotyped at a later date.

- Analysis of Stock Mixture Proportions Analysis of stock mixture proportions indicate that the majority of fish were from California's Central Valley (59.08%) The Rogue River was estimated to contribute the second greatest proportion (7.61%), followed by the Mid Oregon Coast (7.11%) and the Klamath basin (6.58%). The California Coast and Northern California Coast/Southern Oregon Coast regions contributed 2.17% and 1.89%, respectively. The Upper Columbia River summer/fall run was estimated to contribute 3.03% of the total. Twenty other stocks contributed less than 2% each.

- Stock Proportions Across Time Over time Central Valley fall and spring Chinook contributed the greatest percent (weekly average 61.01%; range 43.91% - 71.49%). The Klamath ranged from 3.82% to 11.32% with an average of 6.47%. The Rogue River spiked at 19.13% during October, up from 1.70% in the first week of August (average 7.26%). Stocks from the California Coast reporting region averaged 2.20% (range 0.67% - 5.38%), and the Northern California/Southern Oregon Coast contributed an estimated average of 2.25% (range 0.60% - 5.75%).

- 100% Assignment of Coded Wire Tag (CWT) Fish Thirty-one of the 2,097 fish that met the 90% probability criteria contained coded wire tags. All 31 CWT fish assigned to the correct hatchery of origin.

- Near "Real Time" Analysis During the "learning phase" of this project (June-August), real-time genetic analysis was delayed (conducted between 48 - 96 hours) due to inadequate personnel resources and other logistical problems. By September/October of this project, fish, in near "real time" (within 24-48 hours of laboratory receiving the sample) were successfully assigned to individual genetic stock estimates and mapped at their harvest location. Preliminary cost estimates to conduct near "real time" analysis and enter all associated data into a data base range from $40-$50 per sample.

- Monitoring Wild Salmon Stocks in Near "Real Time" This project demonstrated that stock composition of wild, as well as hatchery salmon stocks captured in commercial fisheries, could be evaluated in near "real time" using GSI analysis. This work provides new opportunities to link freshwater and marine salmon ecosystem research on all life stages of wild salmon.

- Geographic Information Systems (GIS) Maps GIS-based maps were developed that include information on each harvested fish. Maps were designed to provide virtual "real time" information to managers, scientists and other audiences. Using pull down menus, data can be explored and "remapped" based on stock identification, water temperature, harvest dates, areas, depth at capture, and other biological or environmental information. Maps will be accessible at www.ProjectCROOS.com by mid-late April 2007.

- Website Development "Real time" analysis based on GSI information requires a sophisticated website. The CROOS Project has designed a working "prototype" capable of describing the project and reporting information to multiple audiences using a variety of tools, maps and statistical analysis. The working website will be accessible to various audiences via specialized portals by mid-late April 2007 at www.ProjectCROOS.com.

- Scale Analysis and Age of Capture The age composition for the entire set of samples (about 2,000 fish) was 0.1% age-2, 57.0% age-3, 38.5% age-4, 3.9% age-5, and 0.5% age-6. There was a large change in the percentage of age-3 and age-4 fish between August and September with age-3 fish increasing and age-4 fish decreasing.

- Otolith Analysis The otoliths of a subset of Chinook salmon collected during the CROOS project are being examined to determine 1) if, and when, Chinook salmon from different stocks resided in waters with similar chemical characteristics, 2) the temperature history of individual Chinook salmon, 3) if the ratio of $^{87}Sr/^{86}Sr$ in otoliths can be used to distinguish fall vs. spring Chinook, and 4) size-at-ocean entrance for Chinook salmon. This work is expected to be completed by late April 2007.

- Oceanographic Data Collection by Autonomous Vessels In September, a successful pilot test was conducted by scientists from OSU's College of Oceanic and Atmospheric Sciences which showed that autonomous underwater gliders could be used in conjunction with research conducted by commercial fishing vessels. Results indicated that physical conditions in the coastal ocean, as revealed by glider observations, are the result of one of the strongest upwelling seasons in several years and that temperature and salinity were exceedingly cool and salty relative to historical averages.

- Development of an Experimental Fishing Permit (EFP) The success of project CROOS helped to motivate a two-day workshop (September 2006 Portland, Oregon, PFMC Headquarters) with over 40 West Coast participants from NMFS, PSMFC, ODFW, California Fish & Game and industry to discuss development of an experimental fishing permit and plans for a three year West Coast GSI project based on CROOS protocols. In order to provide for sampling in otherwise closed areas and times, PFMC discussed and determined that, if needed, an EFP could be issued on an emergency basis.

Recommendations

- Adjusting and Improving Project Protocols A wide range of protocols need improvement or adjustment in response to fishery sampling outside of normal operating areas, a continuous season versus short weekly openings, improved catch rates, and coordination of fleet management over the entire West Coast. CROOS project members can work with other West Coast states, industries, and agencies to help design and implement protocols.

- Improving the GAPS Database Continued improvement of the GAPS database (Genetic Analysis of Pacific Salmonids) is critical if GSI is to play a key role in salmon management. For example, there are several rivers with Chinook populations in Southern Oregon and Northern California that have potential to assign incorrectly to the Klamath or California/Oregon Coast. Further characterization of stocks within and adjacent to the Klamath basin are recommended to assess potential inaccurate assignment to this region. Funding to sample Lobster Creek, Hunter, Pistol, and Winchuck Rivers has been sought, but to date has not been awarded.

- Expanding GSI Data Collection and Analysis Coast Wide Implementing GSI to improve weak stock management will require expanded data collection along the West Coast. Expanded data should be used to identify error structure of GSI samples, identify stock distribution patterns useful for fisheries management, determine if, or whether, there are behavioral differences between hatchery and wild stocks, analyze inshore versus offshore hypotheses regarding differential stock migration patterns, and develop/apply technologies to collect and analyze high-resolution genetic data with other information (time, location, and depth of capture, ocean conditions, scales, etc.).

- Collecting and Integrating Oceanographic Information Oceanographic data will be critical for both short and long-term understanding of migration, feeding behavior, and other spatial/temporal characteristics of salmon stocks. Most oceanography data cannot be cost effectively collected by fishing vessels without major disruption of fishing operations. We recommend projects that combine vessel-based data collection with autonomous underwater gliders to record nine types of oceanographic data (temperature, chlorophyll, salinity, oxygen, etc.). The data should be shared in near "real time" between scientists and fishermen. Together with other biological information, the data should be analyzed to develop predictive models of salmon behavior.

- Improving the Design of Vessel Dataloggers The CROOS project showed that existing commercial digital dataloggers are inadequate given the needs for a tough, waterproof, relatively inexpensive, portable and reprogrammable logger that can be easily used on small fishing vessels by skipper and crew. A national workshop should be conducted to examine common needs across fisheries. Partnerships with private manufactures should be evaluated.

- Designing a Multiuse "Real time" Website The prototype GIS-based website constructed during the CROOS pilot project should be fully designed, developed, and tested to ensure it is secure, protects privacy of data providers, produces reliable information, and can accommodate multiple users. Focus groups and market research should be conducted to determine the "real time" needs of different audiences including scientists, managers, fishermen, seafood markets, and the public.

- Using Barcodes, Traceability, and the Website to Improve Salmon Marketing Test markets should be conducted using CROOS project technologies and data that 1) "link" individual harvest information with producer and consumer, 2) enhance market development, and 3) minimize fraud. Markets can provide near "real time" information on river basin of origin, fishing vessel, time-location of capture, and other quality, safety and sustainability data. Research should be conducted to determine the design of digital information systems that meet the needs of fishermen, wholesalers, retailers, food service, and consumers.

- Developing and Testing GSI-based Salmon Management Models Management models should be developed that incorporate GSI information. Management simulations should be conducted with salmon managers in "real time" to evaluate new in-season management approaches (closing areas, redirecting the fleet, revising harvest limits, etc.). Bioeconomic models should evaluate GSI information and potential incentives for improving management of the salmon fishery that increases industry, community, and regional benefits.

Conclusion

Project CROOS is an effort to implement state-of-the-art genetic information for estimating stock distribution and behavior of fish in the ocean. It is founded on principles that stress collaborative teamwork and integrative "real time" science and management. Although this project may herald new approaches for salmon science, management, and marketing, it is also a "precursor" to applied ecosystem-based fishery management that links behavior of a "top predator" (*Homo sapiens*) with fish migration, life histories, and environmental conditions in freshwater, estuarine, and marine habitats. But Project CROOS also provides a foundation for a database that can be used to understand weekly, seasonal, decadal, and longer-term oceanic and environmental change and their impacts on fishery stocks. It is our hope that this type of collaborative and integrated project will be used to improve fishery management, protect weak stocks, and increase benefits to people and communities that utilize valuable fishery resources.

Appendix 1

Appendix 1. Chinook salmon populations analyzed in this study and included in baseline Version 1.1. Run time, hatchery (H) or wild (W) origin, life stage, collection data, and analysis laboratory are given. Region numbers and letters match the baseline map for GAPS baseline v1.

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
1	Central Valley fall	Battle Creek (a)	Fa	W	Adult	2002, 2003	SWFSC
		Feather Hatchery fall (b)	Fa	H	Adult	2003	SWFSC
		Stanislaus River (c)	Fa	W	Adult	2002	SWFSC
		Tuolumne River (d)	Fa	W	Adult	2002	SWFSC
2	Central Valley spring	Butte Creek (a)	Sp	W	Adult	2002, 2003	SWFSC
		Deer Creek spring (b)	Sp	W	Adult	2002	SWFSC
		Feather Hatchery spring (c)	Sp	H	Adult	2003	SWFSC
		Mill Creek spring (d)	Sp	W	Adult	2002, 2003	SWFSC

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
3	Central Valley winter	Sacramento River winter	Wi	W/H	Adult	1992, 1993, 1994, 1995, 1997, 1998, 2001, 2003, 2004	SWFSC
4	California Coast	Eel River (a)	Fa	W	Adult	2000, 2001	SWFSC
		Russian River (b)	Fa	W	Juvenile	2001	SWFSC
5	Klamath River	Klamath River fall (a)	Fa	W	Adult	2004	SWFSC
		Trinity Hatchery fall (b)	Fa	H	Adult	1992	SWFSC
		Trinity Hatchery spring (c)	Sp	H	Adult	1992	SWFSC
6	N California/S Oregon Coast	Chetco	Fa	W	Adult	2004	OSU
7	Rogue River	Applegate (a)	Fa	W	Adult	2004	OSU

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Cole Rivers Hatchery (b)	Sp	H	Adult	2004	OSU
8	Mid Oregon Coast	Coquille (a)	Fa	W	Adult	2000	OSU
		Siuslaw (b)	Fa	W	Adult	2001	OSU
		Umpqua (c)	Sp	W	Adult	2004	OSU
9	North Oregon Coast	Alsea (a)	Fa	W	Adult	2004	OSU
		Nehalem (b)	Fa	W	Adult	2000, 2002-1, 2002-2	OSU
		Siletz (c)	Fa	W	Adult	2000	OSU
10	Lower Columbia R. spring	Cowlitz H. spring (a)	Sp	H		2004	CRITFC
		Kalama H. spring (b)	Sp	H		2004	CRITFC
		Lewis H. spring (c)	Sp	H		2004	CRITFC
11	Lower Columbia R. fall	Cowlitz H. fall (a)	Fa	H		2004	CRITFC

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Lewis fall (b)	Fa	W	Adult	2003	WDFW
		Sandy (c)	Fa	W	Adult	2002, 2004	OSU
12	Willamette River	McKenzie (a)	Sp	H	Adult	2002, 2004	OSU
		North Santiam (b)	Sp	H	Adult	2002, 2004-1, 2004-2	OSU
13	Mid Columbia R. tule fall	Spring Creek	Fa	H		2001, 2002	CRITFC
14	Mid and Upper Columbia R. spring	Carson H. (a)	Sp	H		2001, 2004	CRITFC
		John Day (b)	Sp	W	Juvenile, Adult	2000-1, 2000-2, 2000-3, 2000-4, 2000-5, 2000-6, 2004	OSU

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Upper Yakima (c)	Sp	H	Adult, Mixed	1998, 2003	WDFW
		Warm Springs Hatchery (d)	Sp	H		2002, 2003	CRITFC
		Wenatchee spring (e)	Sp	W	Adult	1993, 1998, 2000	WDFW
15	Deschutes River fall	Lower Deschutes R.	Fa	W		1999-1, 1999-2, 2001, 2002	CRITFC
16	Upper Columbia R. summer/fall	Hanford Reach CR (a)	Su/Fa	W		1999, 2000-1, 2000-2, 2000-3,2001-1, 2001-2, 2001-3	CRITFC
		Methow R. summer (b)	Su/Fa	W		1992, 1993, 1994	CRITFC

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Wells Dam (c)	Su/Fa	H		1993-1, 1993-2	CRITFC
17	Snake River fall	Lyons Ferry	Fa	W	Adult	2002-1, 2002-2, 2003-1, 2003-2	WDFW
18	Snake River spring/summer	Imnaha R. (a)	Sp/Su	W		1998, 2002, 2003	CRITFC
		Minam R. (b)	Sp/Su	W		1994, 2002, 2003	CRITFC
		Rapid River H. (c)	Sp/Su	H		1997, 1999, 2002	CRITFC
		Sesech R. (d)	Sp/Su	W		2001, 2002, 2003	CRITFC
		Tucannon (e)	Sp/Su	H	Adult	2003-1, 2003-2, 2003-2	WDFW

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
19	Washington Coast	Queets (a)	Fa	W	Adult	1996, 1997	WDFW
		Quillayute/ Bogachiel (b)	Fa	W	Adult	1995-1, 1995-2, 1995-3, 1996-1, 1996-2	WDFW
		Sol Duc (c)	Sp	H	Adult	2003	WDFW
20	South Puget Sound	Soos Creek (a)	Fa	H	Adult	1998-1, 1998-2, 2004	WDFW
		White River (b)	Sp	H	adult	1998-1, 1998-2, 2002	WDFW
21	North Puget Sound	NF Nooksack (a)	Sp	H/W	adult	1999	WDFW
		NF Stilliguamish (b)	Su	H/W	adult	1996, 2001-1, 2001-2	WDFW
		Skagit summer (c)	Su	W	adult	1994, 1995	WDFW

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Suiattle (Skagit) (d)	Sp	W	adult	1989, 1998, 1999	WDFW
22	Lower Fraser River	Birkenhead River (a)	Sp	H	Adult	1996, 1997, 1999, 2001, 2002, 2003	SWFSC
		WChilliwack (b)	Fa	H	Adult	1998, 1999	DFO
23	Lower Thompson River	Nicola (a)	Sp	H		1998, 1999	OSU
		Spius River (b)	Sp	H	Adult	1996, 1997, 1998	SWFSC
24	South Thompson River	Lower Adams (a)	Fa	H	Adult	1996	DFO
		Lower Thompson (b)	Fa	W	Adult	2001	DFO
		Middle Shuswap (c)	Fa	H	Adult	1997	DFO

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
25	North Thompson River	Clearwater (a)	Fa	W	Adult	1997	DFO
		Louis River (b)	Fa	W	Adult	2001	DFO
26	Mid Fraser River	Chilko (a)	Fa	W	Adult	1995, 1996, 1999, 2002	DFO
		Nechako (b)	Fa	W	Adult	1996	DFO
		Quesnel (c)	Fa	W	Adult	1996	DFO
		Stuart (d)	Fa	W	Adult	1996	DFO
27	Upper Fraser River	Morkill River (a)	Fa	W	Adult	2001	DFO
		Salmon River (Fraser) (b)	Sp	W	Adult	1997	SWFSC
		Swift (c)	Fa	W	Adult	1996	DFO
		Torpy River (d)	Fa	W	Adult	2001	DFO
28	East Vancouver Island	Big Qualicum (a)	Fa	H	Adult	1996	DFO
		Quinsam (b)	Fa	H	Adult	1996, 1998	DFO

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
29	West Vancouver Island	Conuma (a)	Fa	H	Adult	1997, 1998	DFO
		Marble at NVI (b)	Fa	H	Adult	1996, 1999, 2000	DFO
		Nitinat (c)	Fa	H	Adult	1996	DFO
		Robertson (d)	Fa	H	Adult	1996, 2003	DFO
		Sarita (e)	Fa	H	Adult	1997, 2001	DFO
30	S BC Mainland	Klinaklini (a)	Fa	W	Adult	1997	DFO
		Porteau Cove (b)	Fa	H	Adult	2003	DFO
31	Central BC Coast	Atnarko (a)	Fa	H	Adult	1996	DFO
		Kitimat (b)	Fa	H	Adult	1997	DFO
		Wannock (c)	Fa	H	Adult	1996	DFO
32	Lower Skeena River	Ecstall (a)	Fa	W	Adult	2000, 2001, 2002	DFO

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Lower Kalum (b)	Fa	W	Adult	2001	DFO
33	Upper Skeena River	Babine (a)	Fa	H	Adult	1996	DFO
		Bulkley (b)	Fa	W	Adult	1999	DFO
		Sustut (c)	Fa	W	Adult	2001	DFO
34	Nass River	Damdochax (a)	Fa	W	Adult	1996	DFO
		Kincolith (b)	Fa	W	Adult	1996	DFO
		Kwinageese (c)	Fa	W	Adult	1996	DFO
		Owegee (d)	Fa	W	Adult	1996	DFO
35	Upper Stikine River	Little Tahltan River	Sp	W	Adult	1989, 1990	OSU
36	Taku River	Kowatua Creek (Taku; a)		W	Adult	1989, 1990	ADFG
		Nakina River (Taku; b)		W	Adult	1989, 1990	ADFG
		Tatsatua Creek (Taku; c)			Adult	1989, 1990	ADFG
		Upper Nahlin River (Taku; d)		W	Adult	1989, 1990, 2004	ADFG

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
37	Southern Southeast Alaska	Chikamin River (West Behm Canal; a)		W	Adult	1990, 1993	ADFG
		Clear Creek (Unuk; b)		W	Adult	1989, 2003, 2004	ADFG
		Cripple Creek (Unuk; c)		W	Adult	1988, 2003	ADFG
		Keta River (Boca de Quadra; d)		W	Adult	1989, 2003	ADFG
		King Creek (West Behm Canal; e)		W	Adult	2003	ADFG
38	Southeast Alaska Stikine R.	Andrews Creek (Stikine)		W	Adult	1989, 2004	ADFG
39	N. Southeast Alaska	King Salmon River		W	Adult	1989, 1990, 1993	ADFG

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
40	Chilkat River	Big Boulder Creek (a)		W	Adult	1992, 1995, 2004	ADFG
		Tahini River (b)		W	Adult	1992, 2004	ADFG
41	Alsek River	Klukshu River		W	Adult	1989, 1990	ADFG
42	Situk River	Situk River		W	Adult	1988, 1990, 1991, 1992	ADFG

[1] Run time abbreviations: spring (Sp), summer (Su), fall (Fa), and winter (Wi)

[2]Laboratory abbreviations: OSU, Oregon State University; SWFSC, Southwest Fisheries Science Center – National Marine Fisheries Service; DFO, Department of Fisheries and Oceans Canada; CRITFC, Columbia River Inter-Tribal Fish Commission; ADFG, Alaska Department of Fish & Game; WDFW, Washington Department of Fish & Wildlife.

Appendix 2

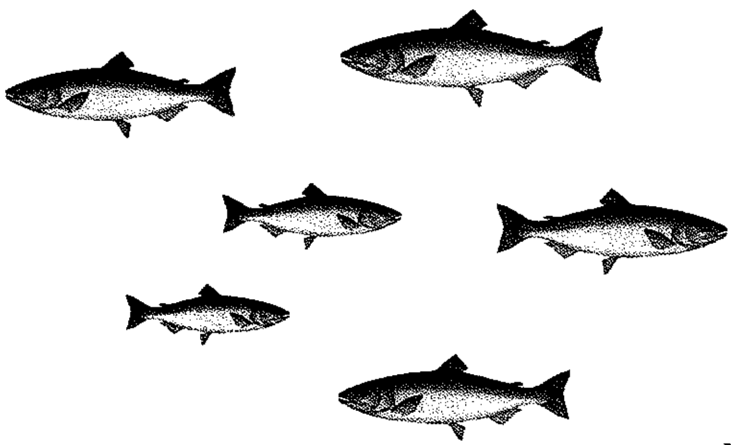
Cooperative Research on Oregon Ocean Salmon-OWEB Approved Budget

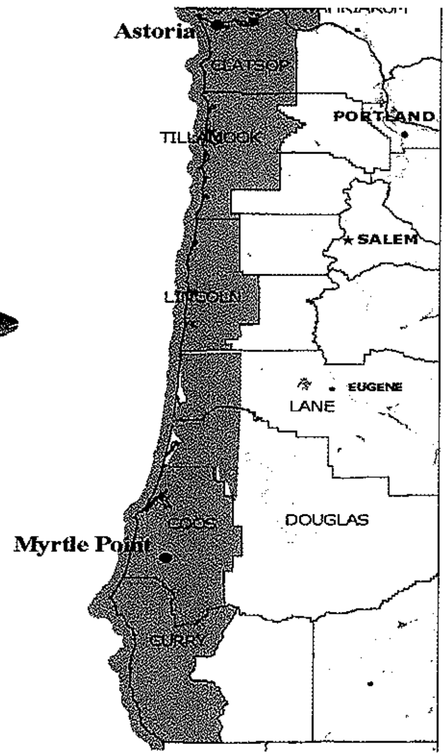
OSU SALARIES						
		Monthly	**OPE**			
Position, Name		**Salary**	**%**	**FTE**	**MM**	**Totals**
Professor (Gil Sylvia)		$ 8,703	39.4%	1.00	1	
Assistant Prof (Jessica Miller)		$ 5,250	41.9%	1.00	1	
Assistant Prof (Michael Banks)		$ 5,665	45.0%	1.00	1	
Professor (Michael Morrissey)		$ 7,942	40.5%	1.00	0.5	
Professor (David Sampson)		$ 6,445	42.8%	1.00	0.5	
Assistant Professor (Michael Thompson)		$ 4,168	43.5%	1.00	3	
Dr. Peter Lawson		$ 7,202	29.0%	1.00	1	
Faculty Research Associate (Renee Bellinger)		$ 3,250	0.59	1	7	$ 22,750
Faculty Research Associate (Renee Bellinger)		$ 3,250	0.59	0.25	5	$ 4,063
Res. Asst:(Summer salaries for tech staff - genetics)		$ 2,000	0.1	1	3	$ 6,000
Res. Asst:(Summer salaries for tech staff - otolith chemistry)		$ 2,000	0.1	1	3	$ 6,000
TOTAL OSU SALARIES & WAGES						$ 38,813
OSU FRINGE BENEFITS						$ 17,020
EXPENDABLE SUPPLIES & EQUIPMENT - under $5,000 per unit						$ 37,000
TRAVEL						
Travel OSU						$ 5,000
Travel Salmon Commission						$ 5,000
OTHER RESEARCH COSTS (Coordination, management, vessels, etc.)						
	No.					
Programming for data logging						$ 10,000
Port Coordinators	4	2,000/July-Aug, 1,000 Sept&Oct			3000	$ 12,000
GIS Consultant						$ 20,000
Fleet management	1					$ 20,000
ODFW scale aging (Lisa Borgerson)	2000				4	$ 8,000
			Boat Charge	No. boats	No. trips	
Boat Charter for fish sampling			1200			$ 318,000
Incentive boat charter for exploration			400			$ 32,000
Otolith sampling	500					$ 500
Boat electronic data loggers	4				6000	$ 24,000
CTDs for oceanographic data	1				8500	$ 8,500
Stowaway tidbit for temp det. at point of capture	100				110	$ 10,558
ADMINISTRATIVE COSTS						$ 20,000
GRAND TOTAL						**$ 586,391**
SALMON COMMISSION PORTION						$ 458,558
OSU PORTION						$ 127,833

Cooperative Research on Oregon Ocean Salmon-OWEB Budget				
Contract Services	Approved Budget	Amended Amounts	Amended Contract	Actual Expenditures
Agricultural Research Foundation (ARF)				
Total OSU Salaries & Wages	$ 38,813.00			
OSU Fringe Benefits	$ 17,020.00			
Travel OSU	$ 5,000.00			
Expendable Supplies & Equipment	$ 37,000.00			
Programming for data logging	$ 10,000.00			
GIS Consultant	$ 20,000.00			
Total to ARF	$ 127,833.00		$ 127,833.00	$ 155,233.00
Fleet management	$ 20,000.00		$ 20,000.00	$ 18,000.00
Port Coordinators	$ 12,000.00	$ (3,000.00)	$ 9,000.00	$ 9,000.00
ODFW scale aging (Lisa Borgerson)	$ 8,000.00		$ 8,000.00	$ 8,000.00
Boat Charter for fish sampling	$ 318,000.00	$ 39,000.00	$ 357,000.00	$ 332,100.00
Incentive boat charter for exploration	$ 32,000.00	$ (32,000.00)	$ -	$ -
Otolith sampling	$ 500.00		$ 500.00	$ -
Total Contract Services	**$ 518,333.00**	**$ 4,000.00**	**$ 522,333.00**	**$ 522,333.00**
Travel Salmon Commission	**$ 5,000.00**		**$ 5,000.00**	**$ 5,000.00**
Supplies & Materials	**$ 10,558.00**		**$ 10,558.00**	**$ 10,558.00**
Equipment	**$ 32,500.00**	**$ (4,000.00)**	**$ 28,500.00**	**$ 28,500.00**
Administrative Costs	**$ 20,000.00**		**$ 20,000.00**	**$ 20,000.00**
GRAND TOTAL	**$ 586,391.00**		**$ 586,391.00**	**$ 586,391.00**

Appendix 3

Collaborative Research on Oregon Ocean Salmon
(CROOS)





2006 CROOS Salmon Season Pilot Study
3 November 2006
draft

CROOS Partners:

Oregon Salmon Commission
Coastal Oregon Marine Experiment Station
Oregon Sea Grant
OSU Seafood Lab
Oregon State University

Funding provided by the Oregon Watershed Enhancement Board (OWEB)

Authors: Renee Bellinger, Michael Thompson, Jeff Feldner, Scott Boley, Paul Merz, Bob Kemp, Nancy Fitzpatrick, Michael Banks, Gil Sylvia, Pete Lawson, David Sampson, Michael Morrissey, Eric Shindler, Jessica Miller, Laurie Weitkamp

General Procedure

At Sea:

- Each participant will, using a zip-tie, attach a metal bar-code tag to each head of the first 70 fish (50 during September and October) harvested during an opener
- Collect 8-10 scales and one tissue sample from every tagged fish
- Record fishing location by turning on GPS unit when lines are in water and turning it off when lines are pulled up
- Press "waypoint" every time a fish is brought aboard to record the harvest location of the fish
- Write vessel name, date, time, depth of capture, fork length of fish, whether the fish has a hatchery marking, if a stomach was taken, and the waypoint number on the envelope provided for each fish tagged
- Attach an underwater temperature & depth reader (VEMCO Minilogger) on the deepest line near the deepest cannonball
- Keep a paper-logbook to record sea surface temperature in intervals at a minimum of 1 hour if a VEMCO Minilogger was not issued

Within 24 hours return from sea:

- Take samples, GPS and Miniloggers to port liaison for downloading of data and sample check-in
- Electronic logbooks will be collected at the end of each opener by logbook coordinator
- A subset of participants (volunteers) will be requested to take five to 10 stomachs from Chinook on the last day of fishing. Bags for collection will be provided.
- Port liaison will provide participants with more batteries, envelopes, datasheets, or zip-ties as necessary

GPS Units

- Fresh batteries every day so you don't stop taking a track mid-point
- When using GPS, keep it outside where it can get satellite reception (typically there is no reception in the wheelhouse)

Turn GPS **ON** when you gear is in water

Turn GPS **OFF** when gear is not in water

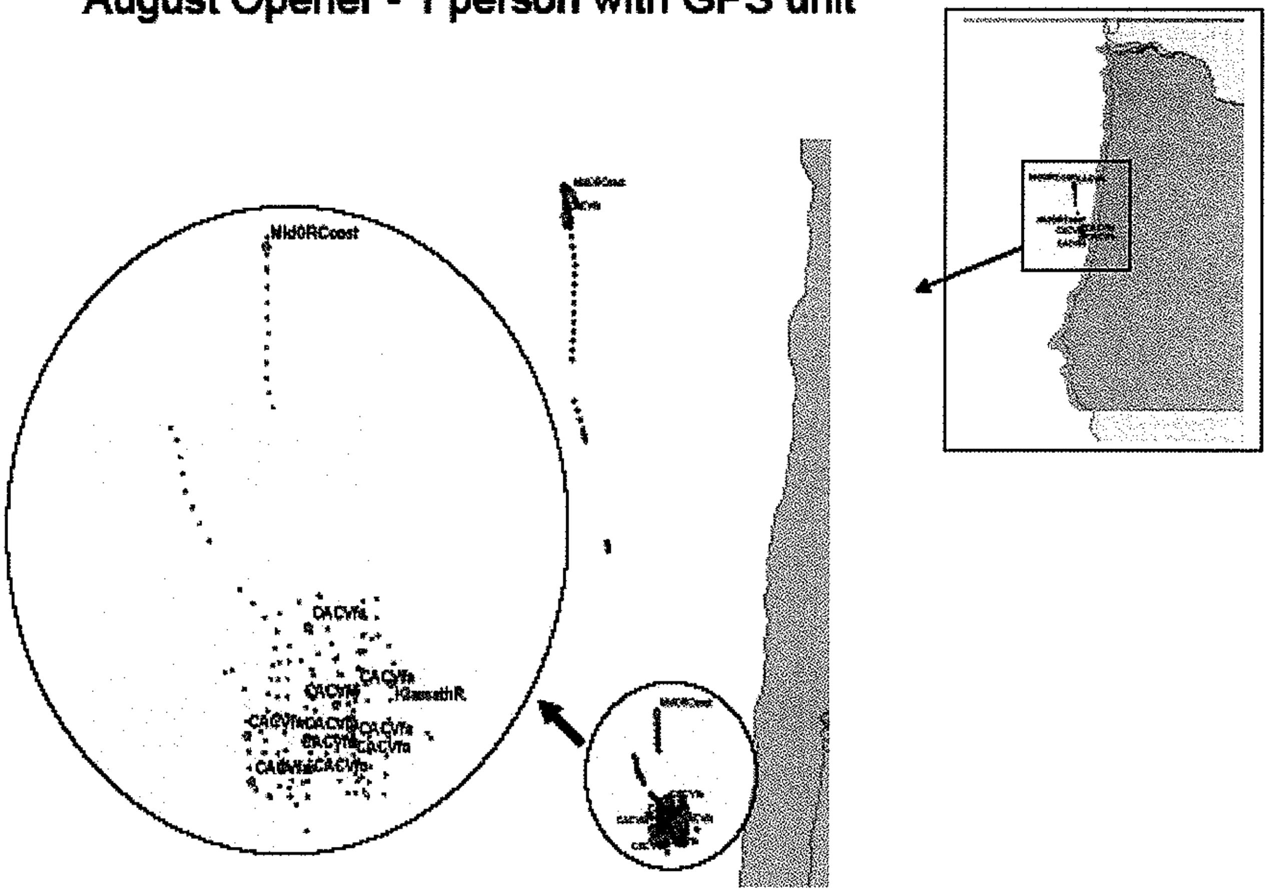
1. When you have landed a fish, press "MARK" button to record waypoint
2. Read the waypoint number recorded on the screen and note time/date
3. Hit " Enter" button to record the waypoint on the GPS unit
4. Write the waypoint number and corresponding time on the collection envelope

The GPS unit will automatically save your track as you fish. You won't see anything indicating that it is recording, but as long as the GPS is on, it is recording in 5 minute intervals.

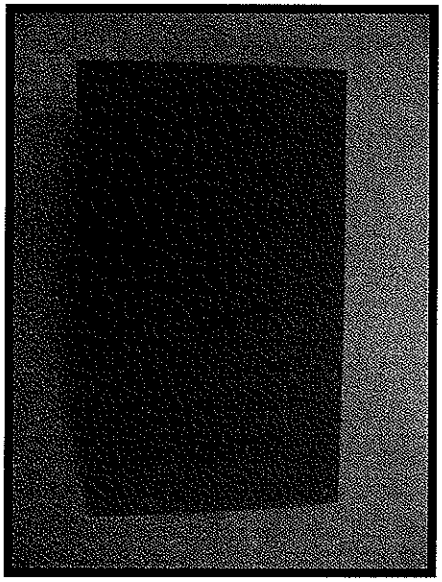
Jennifer Wimpress (Newport), Carla Hedgepeth (Winchester Bay) and Paul Merz (Coos Bay) are the contacts for downloading data from GPS units. The GPS contact person will download data from your GPS onto a computer and send to us. You can also download the data and email it if you prefer. If you have a computer and want software to view your track log, contact Jeff Feldner, who will arrange to have software sent to your home.

GPS Data will be used to locate where VEMCO minilogger data was taken, and to record where fish are NOT being harvested as well as where they are being harvested. We can match your fishing efforts to oceanographic conditions (currents, chlorophyll-a, sea surface temperature). This information may be useful to determine what triggers feeding of fish, different schooling behaviors, etc.

Example Data for one Fisherman
August Opener - 1 person with GPS unit

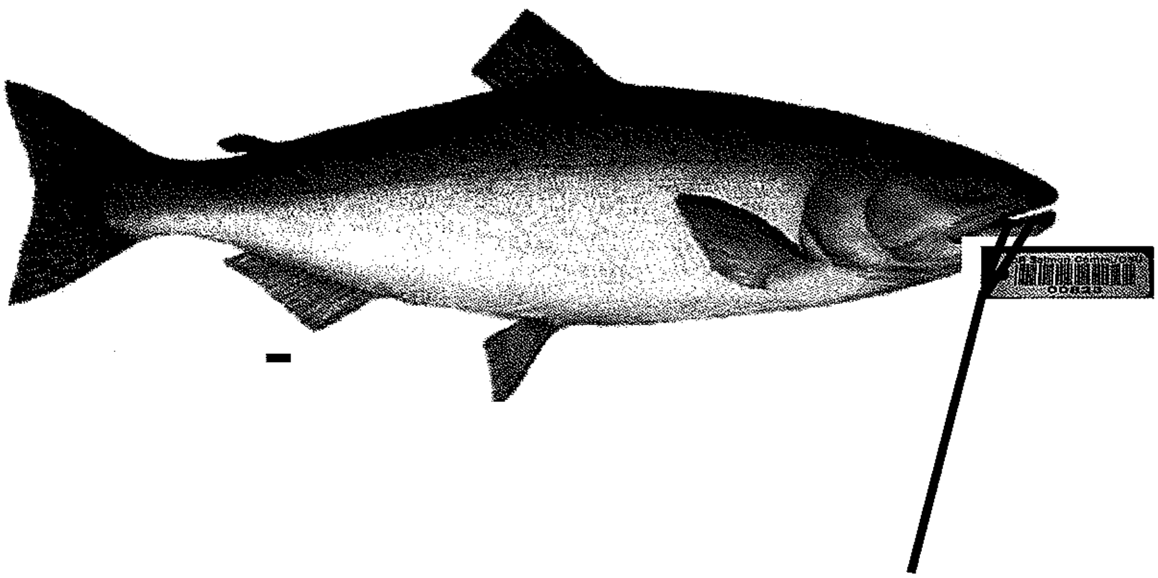


GENERAL PROCEDURE FOR EACH CHINOOK SALMON HARVESTED
(Up to FIRST 50)



1) When a fish is landed, press the Mark button to record a waypoint
2) Check this waypoint number and time, and press the enter button to record the number on your GPS
3) Select the envelope that you will use for that fish
4) Write the waypoint number on this collection envelope
5) Write the time of the waypoint number on the envelope
6) Record depth of capture on envelope
7) Write your Vessel name on envelope
8) Write the date on envelope
9) Measure Fork length and write on envelope
10) Check for hatchery markings and use the envelope to indicate if you do or do not see any markings
11) Remove metal tag from envelope
12) Use a zip-tie to attach the metal tag to head (see procedure next page)
13) Remove 8 - 10 scales (see Scale Sampling Procedure)
14) Take genetic sample (see Genetic Sampling Procedure; be sure to take scales first)

Placing Metal Bar Code Tag on Fish



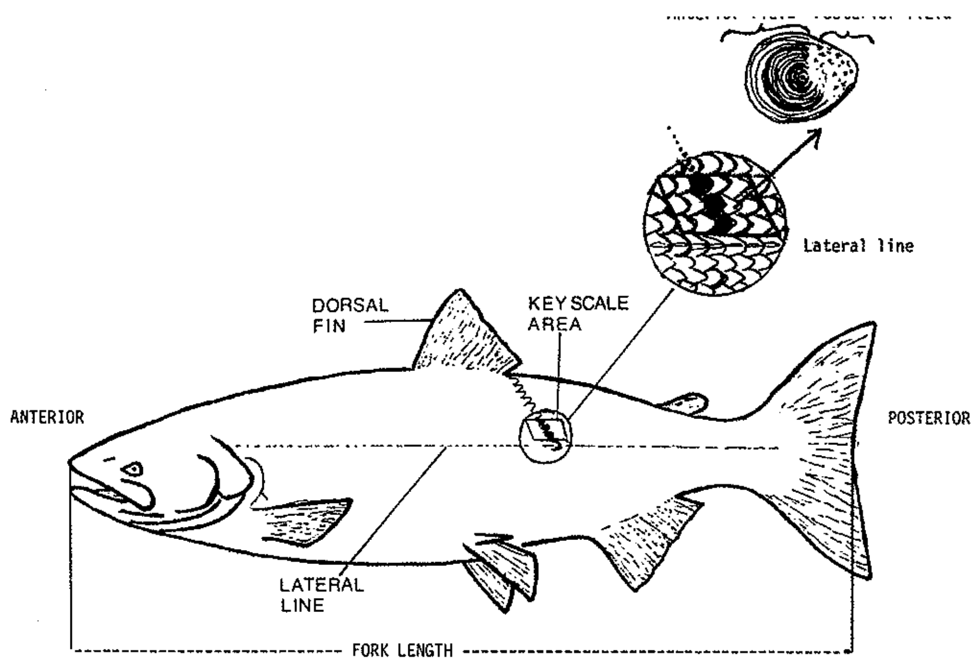
Scale Sampling Procedure
2006 Test Fishery, Ocean Chinook Salmon

1. Locate key area by following the diagonal row of scales down and back from the posterior insertion of the dorsal fin to the first 3 scales above, but not including the lateral line. One to two scales in front of (anterior) and behind (posterior) these three scales are within the key area.

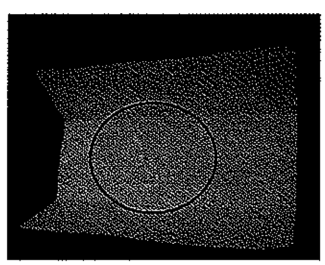
2. Scrape the key area with a knife to remove any slime. With forceps, pluck **8-10** scales from this area and place them neatly between the paper insert in the envelope. Be very careful that the scales come from the key area. Fold paper one time.

3. If scales are absent from the key area on one side of the fish, sample from the key area on the other side of the fish. **If fish has visible damage or scaring in key scale area use other side of fish for scale collection.** If both sides are damaged or scared do not take scale samples and make note on envelope in area provided (or see #4).

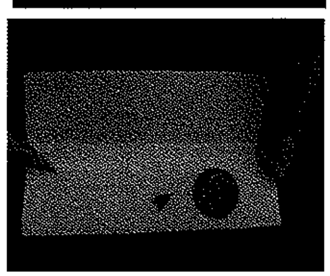
4. If scales are absent from key areas on both sides of fish, scales may be taken from under the dorsal fin but only from 1-4 scale rows above or below the lateral line. "Non-key" must be recorded on the envelope on the comments line.



TAKE 8 - 10 SCALES FIRST
Place in middle of paper

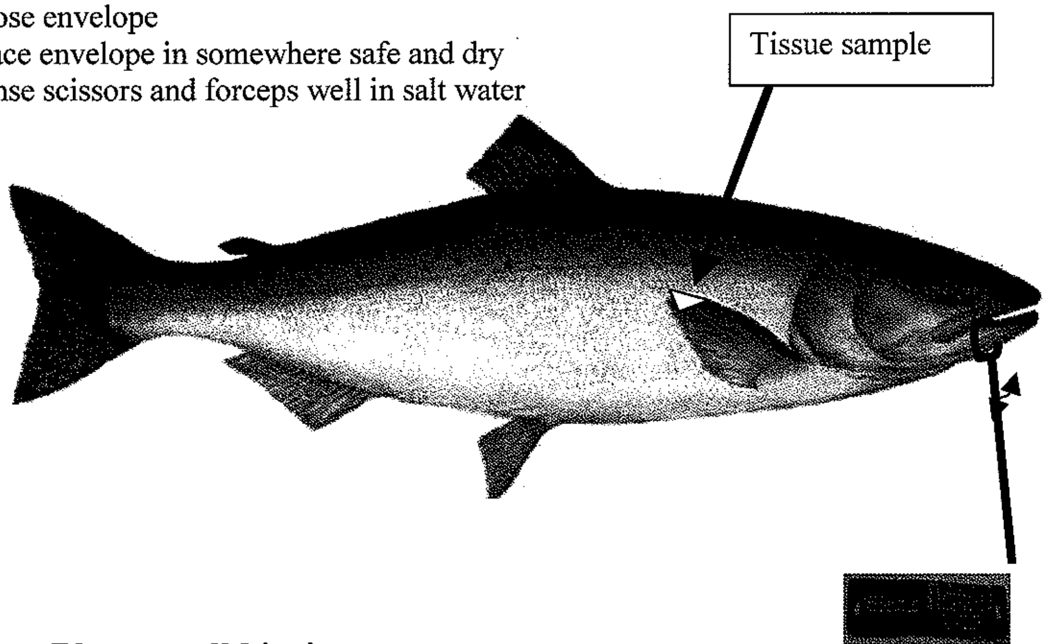


Fold paper once over scales
DNA tissue sample will go on next fold (pictured to right)

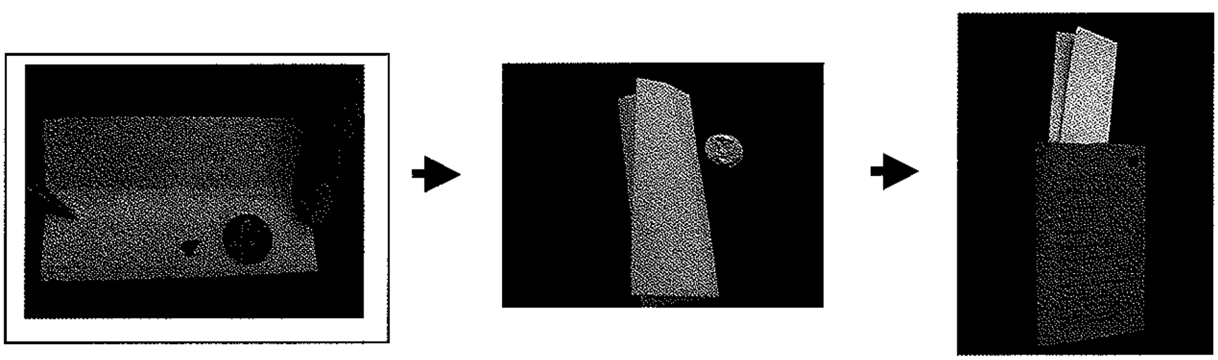


Genetic Sampling Protocol

1) Use ONLY **CLEAN** scissors and forceps
2) Remove small portion from pectoral fin (not larger than a dime)
3) Place fin snip flat on paper
4) Place flat on paper
5) Fold paper over
6) Slide paper in envelope
7) Close envelope
8) Place envelope in somewhere safe and dry
9) Rinse scissors and forceps well in salt water



Place small bit tissue on paper



Filling out Envelope Data:

We use date and time to match capture location to GPS data (or double-check if you write down waypoint information) and to record depth of capture, fork length, markings, and what biological samples have been taken (scales, DNA tissue sample, and stomach).

There are three different versions of envelopes because we have been modifying them as we proceed. This is the newest version.

Vessel Name__________________ Date __________________________ Time _________am ________ pm Depth of capture __________ fthms Fork Length _________inches (to _) No Mark ____ Ad Clip ____ Vent Clip____ Dye mark ____ Scale___ DNA___ Stomach____ GPS Waypoint ______________________________ notes:_________________________ Place any pit-tags in envelope **USE CLEAN SCISSORS/FORCEPS**	**WRITE YOUR VESSEL NAME** **Date** - day, month, year **Time** - Write time in appropriate slot, AM or PM **Fork Length** - from snout to fork in tail, in inches to the closest 1/2 " **Depth of capture** – in fathoms **Hatchery markings** – check box for no markings, adipose fin, right vent, left vent, or dye-markings Check box to indicate if scale, DNA, and/or stomach sample has been taken **Waypoint number** **Additional notes (white salmon, etc)** If you find a pit-tag, place in envelope. **** **USE CLEAN SCISSORS** ****

Paper Logbook

Paper logs will be used to plot sea surface temperature with GPS data. Please use the following format to record data in Paper Logbook:

	Vessel Name			
	Collector Name			
	Date			
	GPS Unit			
	Time (record every hour at minimum in 24-hour format)	**Sea Surface Temperature**	**Bycatch with last haul?**	**Bar Code # (optional) or other notes**
Example →	0615 (start)	50.2		Lines in
	0657	49.6	Coho, 2 shakers	

Stomach Collection Protocol – only three boats per opener:

- Collect stomachs from at least 5 (stop at five if stomachs are full) up to 10 fish during your last day of fishing.
- Use a new bag for every stomach. Fill out one Data Record for each stomach and place inside plastic bag
- Place the complete stomach and intestines in the plastic bag
- If fish or other stomach contents fall of out the stomach while removing it, place the contents in the plastic bag with the actual stomach
- Once collected, keep the stomachs on ice
- If freezer space is available, place stomachs bags in the freezer as soon as you arrive in port. Otherwise, keep on ice until they can be collected from you.
- When in port, please contact Laurie Weitcamp for pickup at 541-867-0504 (w)

Data Record for Stomachs

Vessel Name
Date
Time
ID (bar code number)
Notes:

VEMCO Temperature Depth Minilogger instructions

Vemco miniloggers automatically record temperature and depth in 5 second intervals. The data is stored in the minilogger until it is downloaded onto a computer. We use the GPS data to match where temperature/depth data was taken.

Placement of Minilogger

Place within 1 meter of cannonball on the deepest line.

Care of Minilogger when not in water

Batteries of loggers run down when they are exposed to extreme temperatures. Please don't place tidbit by a window where sun might shine on it for extended periods of time, especially if it is sitting in your vehicle.

Downloading data from VEMCO Miniloggers

- Only Vessels with computer logbook (download daily) or Port Coordinators

1. Run "minilog" software (double click on shortcut icon on desktop)
2. Dry Minlogger so it does not get the docking station wet
3. Place Minilogger on docking station so the serial number on the back of the Minilog is facing up.
4. Rotate the Minilog in the docking station interface until the silver temperature sensor drops into the guide hole in the interface. The serial number on the Minilog should be in the same orientation as the text on the top of the interface.
5. Click the *Load data from Minilog* button with the red arrow, shown here on the right. The software will communicate with the Minilog and begin to download the data from the Minilog's memory.
6. Wait while the data is downloading from the Minilog. A bar in the bottom left corner of the *Downloading data* window shows the progress of the download.
7. Select the YES button when prompted if you want to view the graph of the data
8. Remove the Minilog from the computer interface.

This next section is background information on the science in this project. The section after includes instructions on using Electronic logbooks while at sea.

CROOS collection of salmon heads for otolith collection
– for information only

- Heads will be collected by processors/buyers from a subset (at least 500) of the 2000 fish used for genetic analysis. This is why all fish need tags on their heads. Also, any fish with coded-wire tags detected by ODFW will have tags removed and returned to OSU.
- Collection of heads from buyers will be coordinated by Jeff Feldner and Jessica Miller.
- Once heads have been acquired, a tissue sample will be collected and stored in ethanol when otoliths are removed. Otoliths will be cleaned, dried, and stored with tissue sample and individual ID tag.

Contact:

Jessica Miller
Coastal Oregon Marine Experiment Station
Hatfield Marine Science Center
Oregon State University
2030 SE Marine Science Drive
Newport, Oregon 97365
541-867-0381 (office) 503-939-9812 (mobile)
Jessica.Miller@oregonstate

CROOS Otolith Collection

The otoliths of a sub-set of the Chinook salmon used for stock identification will be collected for chemical analyses. Briefly, otoliths are crystalline structures, comprised primarily of calcium carbonate, located in the inner ear and function as balance organs. Otoliths begin to grow during the egg stage and grow continuously throughout the life of a fish. Daily and annual rings, similar to a tree ring, are deposited in salmon. As an otolith grows, certain elements, such as magnesium, barium, and strontium, are incorporated into the crystal structure in relation to the amount of those elements in the water. Some variation occurs with water temperature as well. Therefore, an otolith can be used as a natural tag to provide information on past periods in the life of a fish. If fish reside in water masses with different chemical compositions and/or temperatures, those properties will be reflected in otolith composition. We will examine otoliths of fish from three to five selected stocks identified with genetic analyses and examine the chemical composition of the otoliths throughout the life history. This will allow us to examine fish of known origin and capture location and examine aspects of their past migration history. We can then compare aspects of the migration histories of fish from different stocks, as inferred from chemical composition, of the otolith rings. This will provide a first look at whether fish of similar age and origin appear to be following similar migration pathways and/or residing in similar water masses while in the ocean.

Project CROOS Electronic Data Collection System

Introduction, Installation and Operating Instructions

INTRODUCTION

The electronic fish data collection system is comprised of four main components which are listed below under System Components. This system was designed to provide accurate data collection at sea through the use of computers by utilizing touch screen technology for data entry. It replaces the need to record information manually on the specimen collection envelopes and allows for rapid data entry into the Project CROOS Chinook Salmon database.

The following sections will show you the systems components and how to install and operate the system on your vessel.

SYSTEM COMPONENTS

The Electronic Data Collection System is made up of the following four main components:

Laptop Computer

GPS Receiver

Handheld Computer

Docking Station for handheld

Each system includes:

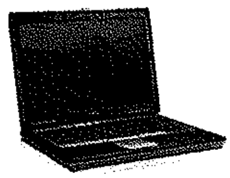
- Dell laptop computer
- DAP CE8640 Handheld computer
- DAP CBCE840 Handheld computer docking station
- GARMIN 17 HVS GPS receiver
- AC or DC power cord for laptop computer
- AC or DC power cord for handheld computer
- AC Power bar with surge protection

Make sure that all system components are present before beginning the installation. Before installation it is important to identify what you will need in order to supply power to the three pieces of equipment. Each unit can be powered by AC or DC through the use of various adapters. The standard power option is

110 AC utilizing standard AC plugs. Each unit will be supplied with a 5 slot power bar with a built in surge protector so only one AC outlet is required on the vessel. If your vessel does not have an AC inverter then DC power options are available. The standard DC power options are through the use of cigarette lighter plugs. If necessary a female DC adapter can be hardwired into the vessel that has multiple outlets to power all three components. Please identify which power options are appropriate for your vessel prior to system installation and they will be provided to you.

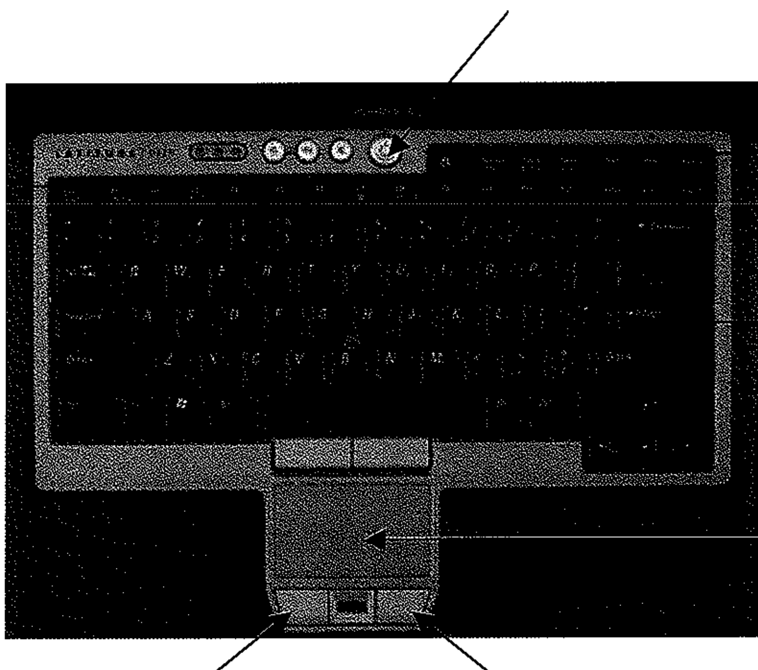
The following is a break down of the individual components and some basic information on how to operate then and where the various connections need to be made for installation.

Laptop Computer:



Dell Laptop Computer   **AC/DC Power Cord**

This section will give basic details about the laptop computer and what you will need to know to in order to start and operate the system. The laptop comes with its own AC or DC power cord that will need to be connected prior to use. You will also need to attach the GPS receiver to the computer before you start the system (see System Installation below). Once all the components are properly connected you are ready to turn on the laptop and get the system ready by following these instructions. Below is a picture of the laptop with important features highlighted:



To turn ... the **power button**. To op... will need to use the **Mouse** or **Touch Pad** to move the mouse pointer. To move the pointer touch the pad with your finger and move it around the pad until the pointer is in the desired location. To activate a program you will need to use the left or right **Mouse Buttons**. To activate a program using the **left mouse button** place the pointer over the screen icon and click the left mouse button quickly twice. You can also click on the left mouse button once, which will highlight the icon, and then press the **Enter key**. To open a program using the

right mouse button move the pointer on top of the screen icon and press the right mouse button once. This will pull up a drop down menu. Move the pointer over **Open** and **press** the **right mouse button** again or hit **Enter**.

If you are not able to supply power to the computer at all times you will need to turn off the computer when power is not available. Each laptop comes equipped with an internal battery; however it will only supply power for several hours. If power is terminated without properly shutting down the computer some data may be lost. To prevent this, **shut down** the computer by **pressing** the **Power button**. You can also shut down the computer by moving the mouse pointer over to the **Start** icon on the lower left hand corner of the screen and pressing the left mouse button. This will pull up a menu, move the pointer over shut down and click again. Make sure it says shut down in the box and then **press OK**.

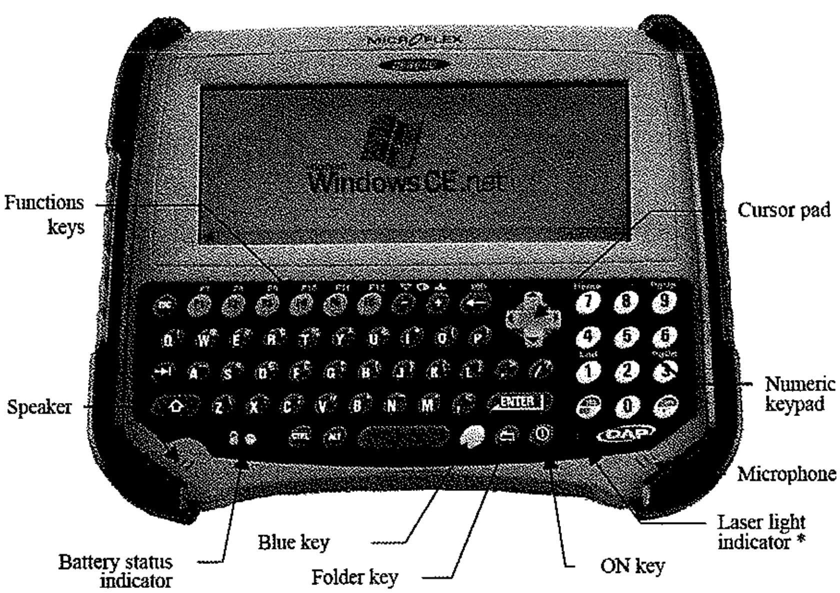
Instructions for installing the system and starting the data collection and GPS programs are in the following Installation and Operating sections.

HANDHELD COMPUTER



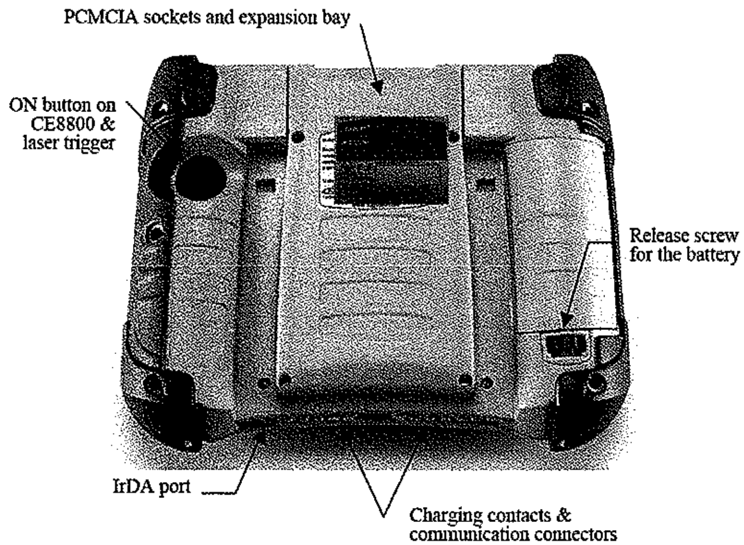
Handheld Computer **Docking Station** **AC/DC Power cord**

The handheld computer is a sealed computer that is used on the weather deck of the vessel to enter fish data. Below is a layout of the handheld computer with important features highlighted:

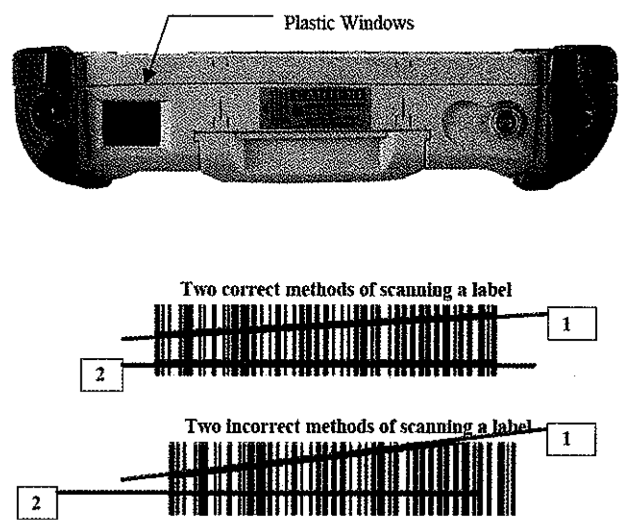


It comes equipped with an internal laser barcode scanner and a wireless networking card so that it can communicate with the laptop computer in the wheelhouse. Entering data is done by using the touch screen and the number pad after a barcode has been scanned into the system. To turn on the handheld computer **press** the **On** key. Once the computer is on the touch screen will become activated. To use the touch screen simply touch the screen where the icon or data box appears. To activate or open a program **touch the screen rapidly twice** on the program **icon**, which is similar to using the mouse button on the laptop. You can also touch the desired icon once to highlight it and then **press** the **Enter key** to open the program. To **turn off** the handheld you must **press** the **On key** again. This will put the system in stand-by and will conserve battery power (the unit has been programmed to go into standby mode after 3 minutes of inactivity while on battery power). The unit has been set up to remain active when placed in the Docking Station so it will not go into standby mode, however the screen will turn off. To reactivate the screen, when the system is not in standby, simply touch the screen or press the On key. To reactivate the system from the standby mode you will need to press the On key.

When a fish is caught it will need to be bar-coded in order to identify the samples in the lab. In order to scan a barcode tag you will need to use the internal barcode reader. To activate the barcode reader **press** the **Laser Trigger** on the rear of the right handle (shown below). The laser is located on the top of the computer behind the small plastic window. To **read a barcode** place the barcode tag in front of the laser window, about 6 to 12 inches away, and press the Laser Trigger, making sure that the laser is placed horizontally across the label (see below). When the barcode tag has been read successfully the computer will indicate this by beeping and the barcode number will appear in the data box on the touch screen.

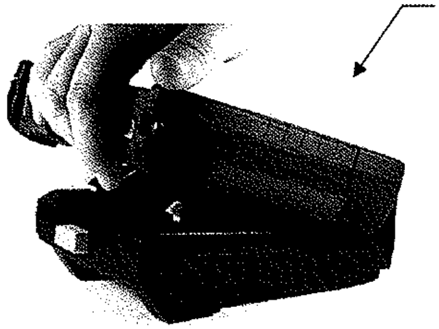


Rear of Handheld computer showing laser trigger and battery compartment



Top of Handheld showing laser window (top) and proper placement of laser for barcode scanning (below)

In order to recharge the battery on the handheld unit it must b[e] ... to be connected to the vessels power supply. To mount the ha[ndheld computer on the docking station] place the bottom of the unit into the dock and then gently press the top of the unit onto the station (see below). Once the unit is in place the charge light (see handheld picture above) should come on indicating that the unit is properly installed and the battery is charging.



INSERTION

Simply slide the base of the unit onto the base of the cradle, then push the unit downward.

The unit should be firmly held in place by the two yellow hooks.

To remove the unit, simply press the release button located on the top of the cradle and at the same time lift the unit free of the device.

> **WARNING**
> Ensure that the unit is fully inserted into the cradle and the latch activated, otherwise the charging pins may be damaged. If the unit can be removed without using the release button, the unit is not properly inserted.

To check battery condition click on **START** icon on lower left of handheld screen. Touch **Settings** to go to the **Control Panel** and touch the icon on screen. Go into **Power** (the one without the underline - _Power). Open this program and it will show battery power available. Hit **X** to close program.

GPS RECEIVER

Garmin GPS Receiver

USB to Serial Connector

Each system comes with a Garmin 17 HVS GPS receiver with a 30 foot long data/power cable that has a DB9 serial port connector and a DC cigarette lighter power plug. The DB9 serial port connector will be attached to a USB to serial connector. This will need to be attached to the computer (see installation instructions). The DC power attachment can be plugged into either a DC female cigarette lighter connector or into a AC to DC converter, depending on power availability on the vessel.

The GPS receiver needs to be mounted on the outside of the wheelhouse in a location where it is open to the sky for satellite reception. The cord needs to be run through an opening into the wheelhouse so that it can be connected to power and the laptop computer. If no permanent opening is available on the vessel the GPS cord can be run through the open door during the day and brought in at night if the door needs to be secured. See the installation instructions below to connect the GPS unit to the laptop.

SYSTEM INSTALLATION

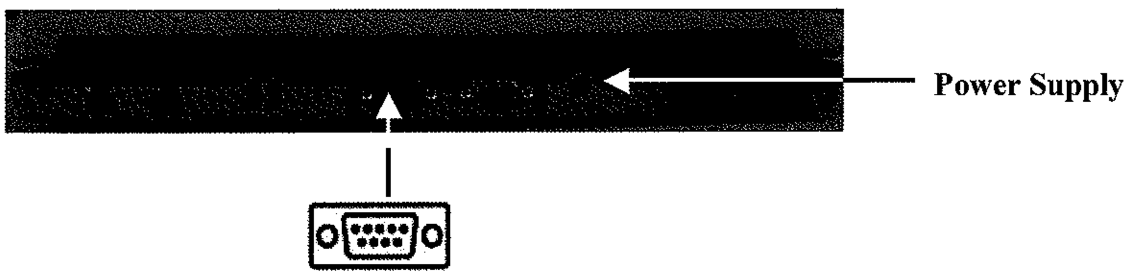
System installation is quick and easy requiring only several minutes. No tools are required to install the system on the vessel unless the power supply needs to be hardwired to the vessel (in which case you may need a pair of wire cutter/strippers and some wire nuts or electrical tape). The only required items for installation are a means to attach the GPS receiver (i.e. – cable ties or duct tape) in a location on the vessel that is open to the sky. Once you have checked that all system components are present you are ready to install the Electronic Fish Data Collection System on your vessel.

Continuous power must be supplied to the laptop computer and GPS receiver while fishing activities are taking place. The handheld computer docking station needs power supply only when the handheld computer is attached for recharging, although a continuous power supply is recommended so that the unit can be placed into the station and charged whenever it is not is use. Keep in mind that both AC and DC power options are available for these systems so please inform your Port Coordinator which power option you require for your vessel prior to installation.

To install the system on your vessel please follow these steps:

1. Place the laptop computer in a safe and secure position in the wheel house of the vessel where it will not get dropped or wet. Make sure all power cords reach the vessel supply.

2. Plug the AC or DC power cord into the computer (see below) and to the power supply, either a standard AC outlet or a DC cigarette lighter plug (Also shown is the DB9 Serial port connector):



3. Next attach the GPS receiver to a secure location outside by using cable ties or another secure attachment method so that it has a clear path to the sky for satellite reception. Run the GPS USB/power cord through an existing opening into the wheelhouse.

4. Plug the USB connector from the GPS receiver (see GPS receiver above) into the top USB port on the rear of the right side of the computer:

5. Plug the GPS cigarette lighter plug into an available power outlet which can be either an AC to DC converter or into a DC plug on the vessel. **Make sure the power is off to the GPS unit whenever you turn on the laptop and do not turn the GPS power on until the laptop is operating.**

6. Connect the DAP power cord to the rear of the DAP CBCE840 docking station and then into either an AC or DC outlet. Take the DAP Docking Station power cord and screw it into the receptacle

on the rear of the docking station. Make sure the connection is secure then plug the unit into the vessels power supply.

7. Place the DAP CE8640 handheld computer into the docking station for charging prior to use making sure the battery charging light on the handheld computer is visible (see Handheld computer above).

This completes the installation process. The following section will give you instructions on how to turn on the system and get it ready to start recording data.

SYSTEM OPERATION

Once the system is set up on the vessel it can be used to record data. In order to start the system follow these steps:

1. Turn **power on** to the laptop computer and enter password (if required).
2. Make sure **GPS receiver is connected** to computer with USB connector then turn on power to GPS on the cigarette lighter plug (light indicates power on). Make sure the power to the GPS unit is off when you turn on the laptop computer. If it is not you will need to turn off the power to the GPS, restart the computer and then turn the power back on to the GPS unit.
3. Start **Astoria GPS program** on laptop by moving the mouse pointer over to the screen icon and opening the program (see laptop computer above for opening or starting programs).
4. Make sure wireless network **CROOSNET (#1 – 4)** is enabled. If connection is not available then open up the **Intel Wireless Pro** program by double-clicking on the screen icon. Make sure the CROOSNET network appears on the wireless networks available screen. Click on **CROOSNET** (make sure it is highlighted in blue) and then click on **Connect** (at lower left of screen). Hit **OK**, then hit the **YES** button, when it asks to connect to a network already existing. Hit **Next** button until the **OK** button appears. Hit OK and network should be identified and connected.
5. Before taking handheld to deck turn on the unit by pressing the power button. Once the unit is on **check battery power** (see handheld computer above).
6. Test wireless connection by opening **Internet explorer** ,by double-clicking icon on top right hand corner of screen, on the handheld unit. Make sure Astoria tracking program is operating on handheld. You should see a large fish on the screen. To begin program simply touch the fish.
7. Once the power and connection has been checked the unit is ready to record data. The handheld can now be used on the deck of the vessel to record data during fishing.

Appendix 4

<u>FLEET MANAGER</u> Personal/Professional Services Contract

STATEMENT OF WORK:

a. **Authority** Pursuant to ORS 576.304 (4), the Commission may "Enter into contracts which it deems appropriate to the carrying out of the purposes of the commission as authorized by ORS 576.051 to 576.595."

b. **General Information** The Oregon Salmon Commission (OSC) with the Coastal Oregon Marine Experiment Station (COMES), Oregon Sea Grant, OSU Seafood Lab, and Oregon State University is working on a pilot project to collect and use genetic information to address the Klamath weak stock crisis for Oregon's ocean salmon fishery. This Collaborative Research on Oregon Ocean Salmon (CROOS) project, composed of Oregon-based fishermen and scientists, has applied to the Oregon Watershed Enhancement Board (OWEB) for funding the pilot project for this season. This funding is contingent on approval by the Legislative Emergency Board on June 23, 2006. If the funding is approved, the pilot project will take advantage of new genetic science technologies to gather more information on harvested stocks. The project will consist of fishermen participating in sampling Chinook fin-clip tissue, scales and length (for aging), date, location, and other oceanographic data. Four vessels will use a digital technology system for datalogging individually harvested fish. The rest of the vessels will collect the data and record it using paper-based logbooks. Data from all sampled fish will be recorded and tracked using barcodes. This job could yield much information about the ocean stocks. Up to 50 boats will be hired to collect the data.

c. **Work Elements**

1. Attend training session(s) to learn protocol and purpose of pilot project
2. Be responsible for port liaisons
3. Train port liaisons on requirements for vessel communication and answer questions as they arise
4. With scientific team, develop sampling protocols
5. Train vessels on sampling protocol
6. With Commission, plan fleet structure for number of boats fishing each opener
7. Communicate with port liaisons at least once a day during sampling periods
8. Communicate with scientific team and port liaisons
9. Keep daily records of vessels and days fished as reported from port liaisons
10. Maintain master list of vessels in project
11. Communicate progress of fleet sampling performances and relay instructions from the scientific team to the port liaisons and vessels when needed.
12. At end of each opener, communicate with port liaisons and scientific team on total boats fished, number of fish sampled
13. As this is a pilot project, work with the Commission and the scientific team to adapt the project and make changes as necessary
14. Assist the Commission and the scientific team with the final report

d. **Delivery Schedule**

Begin: This contract shall begin when all signatures are affixed and upon approval of funding.

End: This contract shall expire on __January 31, 2007__

<u>LIAISONS</u> Personal/Professional Services Contract

STATEMENT OF WORK:

a. **Authority** Pursuant to ORS 576.304 (4), the Commission may "Enter into contracts which it deems appropriate to the carrying out of the purposes of the commission as authorized by ORS 576.051 to 576.595."

b. **General Information** The Oregon Salmon Commission (OSC) with the Coastal Oregon Marine Experiment Station (COMES), Oregon Sea Grant, OSU Seafood Lab, and Oregon State University is working on a pilot project to collect and use genetic information to address the Klamath weak stock crisis for Oregon's ocean salmon fishery. This Collaborative Research on Oregon Ocean Salmon (CROOS) project, composed of Oregon-based fishermen and scientists, has applied to the Oregon Watershed Enhancement Board (OWEB) for funding the pilot project for this season. The pilot project will take advantage of new genetic science technologies to gather more information on harvested stocks. The project will consist of fishermen participating in sampling Chinook fin-clip tissue, scales and length (for aging), date, location, and other oceanographic data. Four vessels will use a digital technology system for datalogging individually harvested fish. The rest of the vessels will collect the data and record it using paper-based logbooks. Data from all sampled fish will be recorded and tracked using barcodes.

c. **Work Elements**
1. Attend training session(s) to learn protocol and purpose of pilot project
2. Be responsible for a small (5-15) pod of vessels collecting samples
3. Train each vessel in pod as necessary on sampling protocol and answer questions as they arise
4. Communicate with each vessel in pod at least once a day during sampling periods
5. Keep daily records of each vessel in pod and days fished
6. On project fishing days, report to fleet management at least once a day with general locations of boats
7. At end of each opener, communicate with fleet management on total boats fished, number of fish sampled
8. Since this is a pilot project, other duties may arise that are necessary for the successful completion of the project

d. **Delivery Schedule**
Begin: This contract shall begin when all signatures are affixed and upon approval of funding.
End: This contract shall expire on __December 31, 2006__

<u>VESSEL/FISHERMAN</u> Personal/Professional Services Contract

STATEMENT OF WORK:

a. **Authority** Pursuant to ORS 576.304 (4), the Commission may "Enter into contracts which it deems appropriate to the carrying out of the purposes of the commission as authorized by ORS 576.051 to 576.595."

b. **General Information** The Oregon Salmon Commission (OSC) with the Coastal Oregon Marine Experiment Station (COMES), Oregon Sea Grant, OSU Seafood Lab, and Oregon State University is working on a pilot project to collect and use genetic information to address the Klamath weak stock crisis for Oregon's ocean salmon fishery. This Collaborative Research on Oregon Ocean Salmon (CROOS) project, composed of Oregon-based fishermen and scientists, has applied to the Oregon Watershed Enhancement Board (OWEB) for funding the pilot project for this season. If the funding is approved, the pilot project will take advantage of new genetic science technologies to gather more information on harvested stocks. The project will consist of fishermen participating in sampling Chinook fin-clip tissue, scales and length (for aging), date, location, and other oceanographic data. Four vessels will use a digital technology system for datalogging individually harvested fish. The rest of the vessels will collect the data and record it using paper-based logbooks. Data from all sampled fish will be recorded and tracked using barcodes. Up to 50 boats will be hired to collect the data.

c. **Work Elements**
   1. Attend training session(s) to learn protocol and purpose of pilot project
   2. Participate in up to 4 salmon season openers on specific dates as directed by the Commission to collect sampling information
   3. Collect sampling data per protocol as developed for the project (see Exhibit D attached)
   4. On project fishing days, report to port liaison at least once a day with fishing location, sampling progress, number of fish sampled, questions
   5. At end of each opener, drop off samples per protocol (see Exhibit D attached)
   6. Invoice the Commission after each opener fished within fourteen days
   7. Upon receiving payment, if vessel has a crew, vessel shall pay crew member within seven days the designated amount (see below) in addition to their normal pay
   8. Since this is a pilot project, follow any revised protocol as necessary that will appear in an amendment to this contract

d. **Delivery Schedule**

   Begin: This contract shall begin when all signatures are affixed and upon approval of funding.

   End: This contract shall expire on __December 31, 2006__

Appendix 5

P.O. Box 983
Lincoln City, OR 97367

Ph/Fax 541-994-2647
njf@class.oregonvos.net

OREGON SALMON COMMISSION

Collaborative Research on Oregon Ocean Salmon (CROOS) Fishermen Survey (January 2007)

We appreciate the work that you did this past season on the CROOS pilot project.

Included in this mailing is this survey, return envelope, overall summary of the genetic findings, and your Federal 1099 for the 2006 income you received from this project.

To help us evaluate the fishermen's task and responsibilities in this project, we would like you to fill out this survey and **return it by Wednesday, January 31, 2007** in the self-addressed stamped envelope. Your responses are important to us and will become part of the final report and help us plan for future at-sea research projects. (If you still have any project equipment, please contact the Salmon Commission.)

Please rate each of the below on a scale of 1-5	Easy			Difficult		Not Applicable
1. Filling out the paper logs	1	2	3	4	5	n/a
2. Using the hand-held GPS units to record data	1	2	3	4	5	n/a
3. Using the datalogger (n/a if you didn't use one)	1	2	3	4	5	n/a
4. Attaching bar code tags	1	2	3	4	5	n/a
5. Writing information on the envelopes	1	2	3	4	5	n/a
6. Completing steps while fishing	1	2	3	4	5	n/a
7. Understanding the protocols for collection	1	2	3	4	5	n/a
8. Turning in sample envelopes/paper logs	1	2	3	4	5	n/a
9. Picking up supplies (envelopes/batteries/etc.)	1	2	3	4	5	n/a
10. Invoicing the Salmon Commission for payment	1	2	3	4	5	n/a
11. Downloading the GPS unit	1	2	3	4	5	n/a

Please answer the following questions:

12. Was the compensation adequate? Yes No

13. Would you be willing, with additional compensation, to fish outside of the "normal" area to gather samples/data? Yes (go to question 13a) No (go to question 14)

    13a. How much additional compensation on a daily basis would be enough?
    $100 $200 $300 Fill in Amount _________

Please answer the following question regarding the liaison positions:

14. How satisfied were you with:	Not Satisfied 1	2	3	4	Very Satisfied 5	Not Applicable
a. Ability to answer questions	1	2	3	4	5	n/a
b. Availability	1	2	3	4	5	n/a
c. Communication with vessels	1	2	3	4	5	n/a
d. Distributing & picking up supplies	1	2	3	4	5	n/a
e. Downloading GPS data	1	2	3	4	5	n/a
f. Willingness to help	1	2	3	4	5	n/a

15. Identify the aspects of the project that worked well or were the most successful: ______________

____

____

16. Identify parts of the project that didn't work or should be adjusted: ______________

____

____

17. Do you think this project will:	No Improvement 1	2	3	4	Significant Improvement 5	
a. Improve Science	1	2	3	4	5	Unsure
b. Improve Management	1	2	3	4	5	Unsure
c. Improve Marketing	1	2	3	4	5	Unsure
d. Improve Public Relations	1	2	3	4	5	Unsure

18. How satisfied were you with the overall project?	Not Satisfied 1	2	3	4	Very Satisfied 5	Not Applicable
	1	2	3	4	5	n/a

19. Do you think this project was useful?	Not Useful 1	2	3	4	Very Useful 5	Not Applicable
	1	2	3	4	5	n/a

20. Please write down any additional comments you have about the project: ______________

____

____

____

Thank you from Nancy Fitzpatrick, Oregon Salmon Commission; Jeff Feldner, Fleet Management; Renee Bellinger, OSU Genetics Lab.

CROOS Fishermen Survey
Results

Of the 77 surveys sent out, 41 were returned. 53% of the vessels participating in the project returned completed surveys.

	Easy			Difficult		n/a
1. Filling out the paper logs	54%	20%	24%			
2. Using hand-held GPS units to record data	71%	17%	5%			7%
3. Using the datalogger (n/a if didn't use one)	10%	2%	5%	5%		76%
4. Attaching the bar code tags	66%	24%	10%			
5. Writing information on the envelopes	56%	29%	15%	2%		
6. Completing the steps while fishing	27%	15%	44%	12%	5%	
7. Understanding the protocols for collecting	73%	25%	2%			
8. Turning in sample envelopes/paper logs	68%	27%	5%			
9. Picking up supplies (envelopes/batteries/etc)	63%	24%	12%			
10. Invoicing the Salmon Comm. for payment	85%	15%				
11. Downloading the GPS unit	36%	14%	10%			40%

12. Was the compensation adequate? Yes 100%

13. Would you be willing, with adequate compensation, to fish outside of the "normal" area to gather samples/data? Yes 88% No 7%

Amount of additional compensation		
	$100	2%
	$200	22%
	$300	24%
	$400	7%
	$450	2%
	$500	15%
	$900	2%
	$1,000	5%

14. Relating to the liaison positions, how satisfied were you with:

	Not Satisfied			Very Satisfied		n/a
a. Ability to answer questions	5%		2%	29%	61%	
b. Availability	2%	5%	22%	32%	37%	
c. Communication with vessels	2%	12%	24%	19%	29%	10%
d. Distributing and picking up supplies	7%	2%	5%	39%	44%	
e. Downloading GPS data	2%		7%	22%	39%	24%
f. Willingness to help	7%		2%	12%	76%	

15. Identify the aspects of the project that worked well or were the most successful:

- Data will help improving science management and marketing.
- All aspects of this project seemed to work really well.
- Drop box, Englund Supply pickup, GPS usage, use of Jen W. to make complete turnaround.
- The program seemed to work well and fairly smoothly for a new program.
- Fleet cooperation, availability of fleet manager and science community.
- I believe everything worked fine.
- After learning to use the GPS, it was rather easy. It gets a little hectic to keep up when fishing along, but doable!!
- The GPS (hand held) addition really helped. Filling out paper logs was a hindrance.
- I feel the project worked well because the CROOS staff provided everything possible to make it easy for the fishermen.
- Overall, I would say the entire project went well.
- Working together with the boats.
- Project worked well for its first year.
- Works fine on quota fisheries – 50 fish was a good number
- Being directly involved in a research project that may enhance the salmon industry.
- Tagging method was quick to attach and number envelopes. GPS system worked well for marking fish and was easy.
- Teamwork – high morale
- It all went pretty well.
- We like the GPS units – they made logging a lot easier.
-The whole deal went fairly smooth for me
- Everything was great for us – I just wish I could have caught a few more salmon.
- Fishing in an area that contained fish.
- In good fishing it will be more difficult to do this – need computers also.
- When the rains really came, it was hard recording info on envelopes. After learning how to look up past marks, this became a breeze. GPS units were great!
- Hand held GPS to mark where fish were caught helped a lot.
- I couldn't see anything wrong.
- I thought it all worked well, for the first year. I am sure there's room for improvement.
- Working with Nancy and the others – they were always there if you needed something
- Liaisons very helpful and cooperative – equipment and supplies were readily available. 'Can do' type folks from Nancy to Renee made this work!
- The project all worked well. The best part, in my opinion, was the added income in a low-income year.
- Most everything considering first time around for project.
- When fish are biting good, it's hard to stop catching them to take samples, they only bite so long.
- Meeting that showed how to collect data and run GPS. Being able to ask questions while in the field on radio and phone.
- Prompt payment – minimum of red tape.
- I believe everything worked fine.

16. Identify parts of the project that didn't work or should be adjusted:

- Datalogger entails too many connections, problems. Need more reliability.
- It was hard to do when everything is wet with rain, fog, wind.
- Just common sense adjustments which will get better through time.
- Need to sample south coast. How can we avoid rotten tissue samples? For a quick & dirty project, this went amazingly well! Why is the sport fishery especially south of Florence not included in the genetic study?
- It seemed it worked ok for me. If I had a question, Darus or Nancy were there to help.
- Communication regarding meetings, etc.
- Trying to write information on yellow envelopes while keeping everything clean and dry. Very difficult to do this by yourself if the fishing is good as you have to let the lines go for too long a time.
- Delivery sites for GPS download. Jen was great to do this at our convenience, but shouldn't be expected to open her home for all. Is there the possibility of an office?
- Nothing comes to mind.
- Not being allowed to fish south of Florence in deep water. Fishing inside the 30 fathom line was a waste of time and money. We have no data on salmon patterns south of Florence.
- I agree with the program – but you need more boats in a broader area – or just be directed more if the program can't afford more boats.
- Trying to keep the fish separated for the DNA.
- Trouble with data loggers (remote computer).
- Require minimum effort. Hours/fish caught/integrity
- Filling out fish log every hour – at times was a hassle.
- Collection of FAS heads.
- At sea contact with group representative needs adjustment, not much though.
- Working closer with the boats.
- Just keep it simple.
- Being allowed to fish weather permitting rather than fishing openers is a breakthrough!
- Had a problem keeping samples from getting everything else wet, filling out sample envelopes, etc. Need a better way to record.
- Difficulty of keeping daily contact at sea. Requirement to deliver downloadable tracklines or paper position logs would make this unnecessary.
- I would like to see the program expanded to fishing closed areas, so we can get an accurate impact on Klamath River fish in the closed areas by sport fishermen.
- Data loggers were too complex, out of Newport landings were difficult to track and do logistics, better communication with leaders.
- To gather data outside of normal fishing area, Coos Bay, Bandon, etc.
- Mostly believe everything workable.

17. Do you think this project will:	No Improvement			Significant Improvement		Unsure
a. Improve Science	2%	2%	17%	32%	43%	7%
b. Improve Management	5%	5%	17%	24%	22%	24%
c. Improve Marketing		10%	29%	27%	10%	19%
d. Improve Public Relations		5%	29%	34%	12%	15%

18. How satisfied were you with the overall project?

Not Satisfied			Very Satisfied		n/a
		10%	19%	68%	

19. Do you think this project was useful?

Not Useful			Very Useful		n/a
	2%	2%	22%	71%	

20. Please write down any additional comments you have about the project.

- I believe if fishermen really got into fish, it becomes a hardship to tag and report everyone. In this case, for example, 50 fish day, it would be easier to tag 2 out of 5 fish and with GPS download the science and configure from there.
- I believe this project is a step in the right direction.
- 2006 river of origin and harvest rates by river of origin should be offered to council tech team to compare to CWT data. Need some digital cameras to record at-sea activities. Project should have included a sampling of the 6,999 Chinook harvested by recreational fishermen south of Florence.
- To receive money, should have to clock in a certain amount of fishing hours.
- I though the project was interesting, I was disappointed in not being able to participate more (weather). I hope to be able to participate again. The project also helped out financially, the dismal season, and lack of time.
- I am appreciative to be a part of this worthy project from the pilot, and look forward to participating for the duration.
- If I had a better catch, I would have a better feeling about my contribution.
- The project only was able to track fish caught north of Florence due to season laws. It would be informative for future seasons to be able to do research south of Florence.
- For the first year, I think it went well and hopefully it will get better and become a very useful in-season management tool.
- As I fish by myself on a small boat, the GPS made the project much simpler for me, than writing data. As I averaged $750 to $1000 a day on fish, to fish outside open area's would require fair compensation.
- Well organized. Thank you very much.
- Good job!
- I felt the project went rather well considering lack of training, but it got easier as time went on. GPS, envelope samples, and tagging I feel is most important. Size of fish is questionable.

- Salmon for a very long time has been contested for resource ownership – public – private corporations – even large trawlers – sport, etc. So it is under overwhelming political pressure.
- It was a big help in making a better financial outcome to the season.
- I think the project was very interesting and it really helped financially.
- I am looking forward to any opportunities for 2007.
- Just thank you so much, it helped us get through a tough year. The people involved were very helpful. That makes it great.
- We need to gather data on fish on the southern coast, as well as the northern coast. Allow a few boats to fish these areas with no fathom restrictions. Let's broaden the scope of our research.
- I was happy to be a part of this. The time constraints on our season hurt the project and we need to be given longer fishing opportunities to really get a handle on where fish migrate. Just wish I was a better fisherman.
- The project was useful in that it was a way to financially assist commercial fishermen in a very difficult year. However, the information obtained was not really new. Our coded wire tag system has revealed pretty much the same results for years.
- To notify each vessel involved to know number of days of participation and to allow them to select days during reasonable weather and fishing conditions.
- Thank you for allowing me to participate.
- I think everybody involved with this program did a very good job trying to make it as easy as possible for the fishermen. For a first year project, they did good.
- It did help a lot of fishermen earn an income. The genetic stock information should be very important.
- Provides real time accurate scientific data – will management do what's right? This is the best management tool ever – hope it continues and provides us more quality fishing time in the future. Thank you all.
- Contract fishing in other areas needs to be discussed in a meeting. This is the most important aspect of the whole project from a management standpoint.
- Everyone involved seemed very helpful.
- The money that was paid really helped compensate because of poor fishing. Last year was the poorest salmon fishing I've seen in 35 years.
- The public access to the website needs to be updated.

Appendix 6

Project CROOS Website and GIS Development Proposal

A. CROOS Website/GIS Design:

Given the limited budget for the web design and GIS integration ($25,000) the scope of what should be attempted with the website by the end of this funding cycle needs to be determined. At the last CROOS meeting, the team discussed what could possibly be accomplished with the GIS salmon database by the end of this year. Below is a summary of these discussions broken down into the three areas of focus for GIS on the website:

Scientist and Fishermen Access: To provide a page on the website that will allow participating scientists and fishermen to access a limited amount of data (3 or 4 weeks). This data would be presented as a series of layers on a base map that can be turned on and off through the web interface. The purpose of this is to provide a functional GIS database on the web as a demonstration of what could be accomplished with the website and the tools available to us through the use of ArcGIS.

Consumer Access: To provide a web page that will allow consumers to enter the barcode number of a CROOS sample salmon and get information on catch history (what information needs to be determined by the industry). This would/could include a map display and an informational box.

General Access: Although not specifically addressed, this is a vital portion of the website. General access would refer to the informational pages on the website and what is displayed on them (i.e. the map on the current website). Should there be a series of maps that general users can explore or one or two maps (and will these be updated) in the text of the website that are not interactive.

The overall design of the website also needs to be addressed. Attached is a flow chart of the website with areas of responsibility for the different aspects of the project. In order to provide the web designer with an outline of what is intended to be accomplished (and a timeline), the CROOS group should go over this flow chart and make any changes/additions necessary. In addition the responsibilities of each participant should be outlined in relation to the website pages which address their area of focus.

B. Integration of GIS mapping tools into ProjectCROOS.com:

In order to provide the CROOS salmon database with ArcGIS mapping tools to participants and consumers on the website, there would need to be additional ESRI (maker of ArcGIS) applications available through OSU's ESRI site license program. This software is available to University researchers at no cost, however, small fees may be applicable for USB access keys ($50 each or 3 for $90). In addition to ArcGIS 9.1 (which has already been installed) the following ESRI software applications would need to be installed on a university server in order to provide ArcGIS generated maps and graphics through ProjectCROOS.com (or utilize a university server that already has the applications installed). Below is a list of the software (attached is an architecture of this platform):

- **ArcIMS** – GIS Internet Management Service – this program provides the interface between ArcGIS software running on the server and the internet, allowing for ArcGIS generated maps to be displayed on the website.

- **ArcSDE** – Advance Spatial Data Server – this program allows the user to access data from other commercial databases (MS SQL, etc.) for ArcGIS applications. ArcGIS geo-databases are currently configured using an enterprise database (ArcGIS Access – similar to MS Access). Although MS Access gives the capabilities currently required, it is limited when compared to MS SQL server database, which would allow for more advanced queries for the fishermen and scientist interfaces (as we see them in the future).

In addition to the ESRI software several other applications would be needed. These would include:

- **A web server application**: A number of these are open-source software, meaning they are free to use. The one that is currently being used by both the Goldfinger lab and OSU web services is Apache servlet engine (http://www.apache.org/). There is also a Microsoft product available through the university called Internet Management Services (IIS) that is being used as the web-server on the tracking system.

- **Server Database**: The option is available to use the ArcGIS Access enterprise database that comes with ArcGIS 9.1. This would allow the CROOS team to provide maps on the website without the need to use ArcSDE, however, it is limited in terms of future development. Many larger GIS applications are using more sophisticated database applications like MS SQL server or Oracle. These databases are more flexible and provide advanced tools for designing user interfaces that allow for complicated queries.

MS SQL Server (media and license) $350

Looking at ways to accomplish this, several meetings were held with outside contractors and scientists from COAS (Chris Goldfinger) who are working with GIS web applications. Through these discussions it became apparent that the COAS lab has been working on getting GIS application on their website for the past several years. They currently have a server (purchased by NOAA) that is housed in their office and have invested approximately $50,000 in GIS web applications. Chris is very interested in helping with this project and has indicated that it could "piggy-back" on his GIS application. Below is a list of options for integrating GIS with ProjectCROOS.com:

Option 1: **Outside contractor** – A meeting was held with Alsea Geospatial (a GIS consulting firm in Corvallis) about setting up the web architecture (as has already been done at the COAS lab). They can do the work and get the GIS applications running but the rough estimate of costs ranged in the $50,000 to $75,000 ranges. By using the current architecture in the COAS lab (which would accomplish the scientist/fishermen portion), both the scientist/fishermen page and the consumer page (with query) could be had for an estimated cost of around $10,000 to $15,000.

Option 2: Goldfinger collaboration – Chris Goldfinger has been developing a website with GIS application for his groundfish inventory project. He has expressed interest in working with the CROOS project. He has already invested a considerable amount if getting the GIS architecture up and running so that maps and simple queries can be run through their website. He currently houses his site on a NOAA purchased server. Chris talked with Liz Clarke, and CROOS will not be allowed to host its site on this server at this time. However, he is willing to let CROOS utilize the GIS applications he has already developed and hire his research assistant (Chris Romsos) to help Thompson and Bellinger with the set up of the project's salmon GIS database and layers so that they can be displayed on the web. The application also has some limited query abilities that could be incorporated into the site before the end of the year. Chris believes that the maps and layers can be displayed on the website by the end of October, if effort begins soon. Because the site would not be hosted on the NOAA server, the GIS applications would need to be developed on a local computer (which will also be a server). This would get the site up and running, and then the CROOS team could decide where the database would be permanently housed (on a university server).

Cost for Research Assistant (Romsos) $1,500 / week

Option 3: OSU webservices - web services can install and set up the CROOS GIS applications on their university servers (they do not currently have ArcGIS running on their servers). The costs of this process are not yet known but much of the installation would probably require a level 3 programmer at $102 / hour. If this is the avenue chosen, then a detailed scope of work would need to be submitted to them in order for them to provide an accurate estimate of costs. They expressed that it would be preferable for the CROOS project (cost wise) and them to have the GIS database and maps generated on a separate server and linked to the CROOS website (see hosting below).

C. Design and Hosting ProjectCROOS.com:

Todd Barnhart (Beartooth Creative) is currently designing the website, and CROOS will be paying for it to be hosted on a third-party server, outside of the university. There are several options available for designing and hosting the website. As mentioned above, in order to utilize the university's license agreement with ESRI, the GIS component of the website will need to be housed on a university server. There are several options for hosting and designing the site, which can still be hosted outside of the university.

Option 1 - Off-site: As it currently is, the website can continue to be hosted on a third party server and link to the GIS mapping applications located on a university server via the website. The design of the website can still be done by an outside contractor (Beartooth Creative, for example) of choice.

Website hosting:	**$20 / month**
Website Design – Todd Barnhart	**$40 / hour**

Option 2 - On-site: If the website is to be hosted within the university it can be hosted by OSU Web Services. They provide a full range of services from basic hosting to development and design. They have the ability to install the GIS applications on their servers (which they do not currently have) so that the website can be run from a central location without the need to link to other university servers. This would involve additional costs based on their rate schedule. There are several advantages to this. First, it would be located in one location on campus and would not require links to other servers. Second, they would be responsible for making sure the website functioned properly and getting it back up, in case of a crash, in a timely manner. They also provide other services on demand including back-up and recovery and special programming. However, it may be expensive to have them set up the GIS applications on their servers and it was "suggested" in the meeting with them that it would be preferable for us to set up the GIS applications on another server and link it to the website.

Start up fee (one time)	**$50**
Website hosting:	**$10 / month**
Website Design – depending on staff level	**$23 to $102 / hour**

D. GIS Training (Renee Bellinger)

It was decided at the last meeting that Renee Bellinger would utilize a portion of the budget for training on GIS applications. She is currently looking into training opportunities. The cost for the training and travel is not yet known but should be budgeted into the project when she finalizes her plans.

GIS Training Costs - Bellinger	**~$2000**

Computer and GIS Budget

Budget for website design	$5,000.00
Current Expenditures	$800.00
Amount Remaining	$4,200.00
Budget for Dataloggers	$5,000.00
Current Expenditures	$4,312.50
Amount Remaining	$687.50
Budget for GIS consulting	$20,000.00
Bellinger Training	($2,000.00)
Current Expenditures	$0.00
Amount Remaining	$20,000.00

Potential GIS layers for Scientist and Fishermen (20 layers)

1. Base map of US West Coast
    a. Bathymetric contours
    b. SST (7 day composites)
        i. SST (week 1)
        ii. SST (week 2)
        iii. SST (week 3)
    c. Chlorophyll (7 day composites)
        i. Chlorophyll (week 1)
        ii. Chlorophyll (week 2)
        iii. Chlorophyll (week 3)
    d. All fish
        i. All fish (week 1)
        ii. All fish (week 2)
        iii. All fish (week 3)
    e. All Klamath Fish
        i. Klamath Fish (week 1)
        ii. Klamath Fish (week 2)
        iii. Klamath Fish (week 3)
    f. All Sacramento Fish (or other)
        i. Sacramento fish (week 1)
        ii. Sacramento fish (week 2)
        iii. Sacramento fish (week 3)
    g. All Oregon Stocks
        i. Oregon Stocks (week 1)
        ii. Oregon Stocks (week 2)
        iii. Oregon Stocks (week 3)

Potential base maps and layer for Fishermen (for 1 vessel) (17 Layers)

1. Base map of US west coast
   a. Bathymetric contours
   b. Bathymetric relief
   c. SST (7 day composites)
      i. SST (week 1)
      ii. SST (week 2)
      iii. SST (week 3)
   d. Chlorophyll (7 day composites)
      i. Chlorophyll (week 1)
      ii. Chlorophyll (week 2)
      iii. Chlorophyll (week 3)
   e. Vessel track
      i. Vessel track (week 1)
      ii. Vessel track (week 2)
      iii. Vessel track (week 3)
   f. All fish
      i. All fish (week 1)
      ii. All fish (week 2)
      iii. All fish (week 3)
   g. Klamath Fish
      i. Klamath fish (week 1)
      ii. Klamath fish (week 2)
      iii. Klamath fish (week 3)

Appendix 7

Agenda Item I.2
Situation Summary
November 2006

SALMON METHODOLOGY REVIEW

Each year, the Scientific and Statistical Committee (SSC) completes a methodology review to help assure new or significantly modified methodologies employed to estimate impacts of the Council's salmon management use the best available science. This review is preparatory to the Council's adoption, at the November meeting of all anticipated methodology changes to be implemented in the coming season, or in certain limited cases, of providing directions for handling any unresolved methodology problems prior to the formulation of salmon management options in March. Because there is insufficient time to review new or modified methods at the March meeting, the Council may reject their use if they have not been approved the preceding November.

This year the SSC is expected to report on documentation of the Chinook and Coho Fishery Regulation Assessment Model (FRAM), Columbia River fall Chinook abundance forecasts, and a genetic stock identification (GSI) study proposal, which includes a request for consideration of an exempted fishing permit (EFP) (Agenda Item I.2.a, Attachment 1).

Council Action:

1. **Approve methodology changes as appropriate for implementation in the 2007 salmon season.**
2. **Provide guidance as needed, for any unresolved issues.**
3. **As appropriate, adopt FRAM documentation package for final editing and general distribution.**
4. **Provide direction on development of GSI study and EFP application.**

Reference Materials:

1. Agenda Item I.2.a, Attachment 1; Pilot Program to Apply Genetic Stock Identification in Pacific Salmon Fisheries in 2007.
2. Agenda Item I.2.d, STT Report.
3. Agenda Item I.2.b, Supplemental SSC Report.

Agenda Order:

a. Agenda Item Overview	Chuck Tracy
b. Report of the SSC	Bob Conrad
c. Agency and Tribal Comments	
d. Reports and Comments of Advisory Bodies	
e. Public Comment	
f. **Council Action**: Adopt Final Salmon Methodology Changes for 2007	

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10/25/06

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Pilot Program to Apply Genetic Stock Identification in Pacific Salmon Fisheries in 2007

Purpose and Goals

There are many distinct salmon stocks along the west coast of the United States. Although population sizes vary year to year, some of these stocks are relatively productive and could support a substantial fishery, while other stocks cannot withstand much fishing pressure at all. These stocks intermix in the ocean and, at the time of harvest, it is usually impossible to determine which salmon come from abundant stocks and which come from weaker stocks in need of protection. Salmon regulations are crafted each year to protect the weak stocks, using the best available information from Coded Wire Tags (CWTs) and modeling outputs based on past fishing seasons. Because of the need to protect weak stocks, this often results in severely constraining fishermen's access to abundant salmon stocks. For example, to protect Klamath River fall Chinook (KRFC), the 2006 salmon regulations resulted in some of the largest closures ever experienced in this fishery.

Genetic stock identification (GSI) technology for identifying Chinook stocks is developed to the point where it is potentially useful for fishery management. Genetics labs from Alaska to California have collaborated on a coastwide data base (GAPS) including more than 40 reporting groups comprising 165 individual Chinook stocks. The GAPS data base allows the identification, from a small piece of tissue, of the origin of most Chinook salmon in the northeast Pacific. As a result we can now determine the stock composition of ocean fisheries at a finer scale than with CWT data alone.

The long-term goal of this project is to increase the information available to managers on the temporal and spatial distribution of specific west coast salmon stocks. If it is proven that substantial variation in temporal and spatial distribution exists, this may allow commercial fishermen access to relatively abundant stocks of salmon while protecting weak stocks. The first step in applying GSI technologies to fisheries management is to explore and map the distributions of stocks in Council-managed fisheries. It is anticipated that Chinook fishing in 2007 will be highly restricted, similar to the 2006 season. This request is for an Exempted Fishing Permit that will allow us to begin mapping stock distributions in ocean fisheries in 2007 in times and areas outside of the regulation season. In addition, this proposal will allow us to test the feasibility of new techniques that could allow rapid-turnaround quota management in limited areas and times in the future. However, the biggest gains will ultimately come from an improved understanding of stock-specific marine distributions and migration pathways in relation to submarine topography and oceanic conditions. In the long term this constitutes a step toward ecosystem-based management for salmon.

Council Research and Data Needs

The draft 2006-2008 Research and Data Needs for the Pacific Fishery Management Council (Council) identifies as its highest priority the development of GSI for fisheries management applications. The report states:

> Advances in genetic stock identification, otolith marking, and other techniques may make it feasible to use a variety of stock identification technologies to assess fishery impacts and migration patterns: The increasing necessity for weak-stock management puts a premium on the ability to identify naturally reproducing stocks and stocks that contribute to fisheries at low rates. The CWT marking system is not suitable for these needs. The Council should encourage efforts to apply these techniques to management.
>
> Substantial progress has been made on this item in the past 6 years. A coastwide microsatellite database for Chinook has been developed. A similar database for coho salmon is under development, but needs resources to coordinate efforts for the entire coast. GSI techniques have improved so that samples can potentially be analyzed within 24-48 hours of arrival at the laboratory. GSI is actively being used in Canada to manage coho salmon fisheries off the west coast of Vancouver Island. Studies are under way to evaluate the potential usefulness of real time GSI samples in Chinook management, particularly in relationship to Klamath fall Chinook. There are proposals to develop operational alternatives to time-area management using these techniques, in combination with existing CWT marking, mass marking, otolith microchemistry, and other emerging stock identification techniques. These studies are now the highest priority for salmon management.

The report also identifies emerging issues related to this priority. From the report:

> Emerging issues are related to the high priority recently assigned to the implementation of GSI technologies in weak-stock fishery management. Research tasks and products necessary for this to be successful are:
>
> 1. Identification of the error structure of GSI samples taken from operating fisheries.
>
> 2. Development and application of technologies to collect high-resolution at-sea genetic data and associated information (time, location, and depth of capture, ocean conditions, scales, etc.)
>
> 3. Identification of stock distribution patterns useful for fisheries management and appropriate management strategies to take advantage of these distribution patterns.
>
> 4. Development of pre-season and in-season management models to implement these management strategies and integrate them with PFMC management.

The studies proposed here will work toward resolving these issues. The second and third items will be addressed directly. Work on the first item will also be progressing during the course of this study. The fourth item, development of new management models, is a future project that depends on results of the proposed study and similar sustained efforts over the next few years.

NMFS Strategic Plan for Fisheries Research

In the NMFS Strategic Plan for Fisheries Research, Section I.A. treats "Biological research concerning the abundance and life history parameters of fish stocks." From that section:

> Understanding aspects of the life history of fish stocks will be of increasing importance in the management of the Nation's living marine resources. Describing migratory and distribution patterns, habitat use, age, growth, mortality, age structure, sex ratios, and reproductive biology will be essential information for scientists and managers to optimize sustainability and yield of these resources... There is an increasing need to identify and characterize discrete stocks. This will allow scientists and managers to correctly structure stock assessments and design stock specific management measures for groundfish complexes, salmon species, coastal migratory and oceanic migratory species and reef fish. Stock identification involves many techniques, including mark-recapture, otolith shape analysis, parasite distributions, and biochemical genetic methods.

The improved understanding of ocean distributions that will result from conducting studies like this over a period of years will help us characterize discrete stocks and design stock-specific management measures. This is also directly related to Goal 1 of the Strategic Plan:

> GOAL 1: Provide scientifically sound information and data to support fishery conservation and management. (Ongoing)
>
> > Objective 1.3: Determine and reduce the level of uncertainty associated with stock assessments through improved data collection and advanced analytical techniques. (FSP Strategy 1.2.1)
> >
> > Objective 1.6: Collaborate with the Councils and other management authorities to develop fishery management regimes that will effectively control exploitation. (FSP Strategy 1.1.4)

Need for this EFP

The application of GSI technology to management has many aspects beyond the identification of stocks. Considerable preliminary work in 2006 toward implementation of this technology has been done in pilot projects in California and Oregon. Work in 2007 is designed (1) to extend the development of techniques and methodologies based on 2006 experience, (2) to provide relief to fishermen via payment for participating in sampling programs, and (3) to start to answer questions relative to distribution of Chinook stocks that may prove useful for management. It is too early to actively apply GSI technologies to fishery management on the west coast, although a simulation of a potential in-season weak stock quota management application may be conducted based on data collected during this study.

Projects in Oregon and California are currently evaluating techniques for sampling and analysis. The Oregon project has successfully collected data on the specific location, time, and depth of capture of individually identified Chinook salmon from 80 boats in the commercial troll fishery. The California project has incorporated a stratified random sampling design to estimate stock proportions in the recreational fishery. In 2007 we plan to apply these techniques more widely to gain experience with the methodology and to test its usefulness to answer some basic questions for fisheries management. Since restricted fishing opportunities, similar in scope to the 2006 season, are expected in 2007, this creates a need for fisherman relief and may be an obstacle to effective development of GSI applications to fishery management. While much data collection is anticipated within the regular season structure, we expect that an EFP will be needed to allow limited commercial salmon fishing outside of the legal season for the purpose of obtaining adequate sample sizes and testing specific fishing patterns in space and time. Impacts may be minimized in some fisheries through catch and release.

Project Organization and Personnel

To be developed

Objectives

The primary objective is to improve information on spatio-temporal distribution of west coast Chinook salmon for use in salmon management. To achieve this we propose to continue collecting time- and location-specific genetic samples, along with scales, otoliths, stomachs, and oceanographic data. The purpose of these collections would be to begin developing a database of stock distributions for comparison with the historical CWT database. This work will not have a direct impact on 2007 fisheries, but will support fishermen through payments to participate. It will be part of an ongoing process that could inform managers in future years. Because we anticipate that regulation fishing seasons will be highly restricted in 2007 we propose that sampling be extended to closed times and areas to collect more comprehensive data. It will also be necessary to sample in areas that would not normally be fished, even during open seasons. This component of the project includes development and testing of a statistical sampling design. The distribution of sampling between regular season fisheries and experimental fisheries will depend on how much fishing opportunity is permitted in 2007. Sampling in closed areas will be done through the EFP. The exact mix of regular season and experimental fisheries will, necessarily, be determined during the preseason planning process.

This data collection effort has great potential benefits to fishery management. Over time we expect to develop a data base similar to the CWT contribution rate data base but with fewer assumptions (e.g.; fewer hatchery indicator stocks representing natural production) and much higher resolution in space and time. This will enable us to examine migration routes, evaluate "hot spots" and see how long they persist, relate fish distributions to ocean conditions, and generally expand the range of information available to fishery managers. Compilation of such a database will require several years. We anticipate providing preliminary results to fisheries managers after 3 years of sampling, with continuing improvement in the information in future years.

With this data collection effort as a framework we also plan to begin testing three specific hypotheses:

1). Inshore/offshore differential in Klamath impacts

Spatial distribution of catch samples from the fishery will be analyzed to test the hypothesis that Klamath stocks are disproportionately distributed offshore. This has been proposed in the past, but no sufficient experimental data exist (Winans et al., 2001). CWT data, aggregated by area of catch, have insufficient spatial resolution to resolve this question. The observation has been that recreational fisheries tend to have lower Klamath impacts than commercial fisheries in the same time and area. This, combined with the observation that recreational fisheries tend to occur closer to shore than commercial fisheries, has led to the distribution hypothesis. It may be necessary to employ fishers to fish in areas where they would not routinely fish (i.e., commercial trollers in inshore areas). The experiment will need to be repeated over several seasons before it can be applied to management.

Potential benefit would come from improved knowledge of the local distribution of Klamath stocks, leading to possible fishing strategies to reduce impacts and increase fishing opportunities.

2). North-south distribution in San Francisco catch area

It may be that KRFC are more concentrated in the northern portion of the San Francisco catch area, providing an opportunity to fish with lower impacts in the south. We will contrast contribution rates of KRFC in the southern area from Pigeon Point to Point Reyes with the rate in the area from Point Reyes to Point Arena. To achieve a statistically interpretable result we will need to collect an adequate number of samples from each sub-area. What constitutes an adequate number of samples will be determined before the start of the fishery.

Potential benefit would include an increased opportunity to fish in the southern portion of the catch area. This kind of information, applied more generally, may be one of the major benefits of GSI monitoring of fisheries.

3). Rapid-turnaround weak stock quota management

It has been suggested that we could monitor catch composition in a fishery and manage for a numerical limit on weak stock (e.g., KRFC) impacts. There are several concerns with this approach: rapid turn around in this case is at least 48 hours longer than the time needed to implement quotas based on overall catch; it will be impractical in most cases to sample all landings, so a statistically valid sampling plan needs to be developed; accuracy of setting weak-stock quotas depends on accuracy of stock assessments and models of stock distribution (i.e., setting an appropriate quota will not be possible without the ability to produce more accurate stock abundance projections). With the results of the 2007 fishery we hope to simulate this management technique and explore the potential improvement in management precision. The intended benefit is to develop a tool that enables managers to allow fishing on abundant stocks to proceed without exceeding predicted impacts on stocks of concern.

Research Design and Methodology

Methodology

The advent of a "production version" of the GAPS microsatellite baseline, combined with global positioning system (GPS) technology, provides an opportunity for sampling ocean fisheries in a way not previously possible. The Cooperative Research on Oregon Ocean Salmon (CROOS) project has, in 2006, developed and tested sampling protocols that link genetic information from individual fish with GPS-determined time and location of catch and associated data. Additional data may include length, scales, stomachs, depth of capture, sea surface temperature, and a temperature/depth profile. Most of these data can be collected during the normal fishing operation. The basic technique involves a hand-held GPS unit that records the vessel location every 5 minutes when the boat is actively fishing. When a fish is caught a "waypoint" is entered on the GPS. The fish is measured, a small fin clip is placed in an envelope, and the envelope is labeled with the waypoint number and any other desired data (depth, sst, external marks, etc.). On landing the GPS data are downloaded to a computer and the envelopes are returned to the genetics lab for analysis. Each sample can then be associated with a specific waypoint in the GPS data. Another aspect of the CROOS project includes attaching a bar-code tag to the jaw of each fish to allow tracking through the market system. In addition, CROOS is developing data loggers that would make the fishing operation more streamlined and also reduce the necessity of entering data from the envelopes by hand.

The CROOS data collection protocol was tested in Oregon fisheries in the summer and fall of 2006. It is planned to expand use of the system to sample all fisheries described in this proposal.

All seven of the current management areas for Klamath River fall Chinook between Cape Falcon, OR and Point Sur, CA will be sampled (Figure 1). In addition, the San Francisco area will be divided into two sub-areas: a northern area (Point Arena to Point Reyes) and a southern area (Point Reyes to Pigeon Point), yielding a total of eight areas between Cape Falcon and Point Sur. Each of these eight areas will be further stratified into inshore and offshore areas. The dividing line between inshore and offshore areas is yet to be defined; definitions currently under consideration are 3 nautical miles, 6 nautical miles, or a 50 fathom depth contour. During all commercial fishery openings between Cape Falcon and Point Sur, 20 commercial fishing boats will sample in each management area, with boats divided equally between inshore and offshore strata. Boats contracted to obtain tissue samples will be allowed to retain all legal fish.

In addition, to the extent that funding and impacts on Klamath River fall Chinook allow, the same number of boats may be contracted under an EFP to conduct sampling in management areas when commercial fisheries are closed. During closed periods, boats would be contracted to fish using the same inshore/offshore stratification and collecting the same data as during open fisheries, but all fish sampled would be released. Hook-and-release mortality and dropoff mortality associated with this closed area sampling will be accounted for and included in the assessment of fishery impacts of management measures adopted by the Council in April. Sampling in closed areas will be limited to the minimum sample size necessary to achieve resolution in the estimated contribution rates down to about one percent: 400 fish per week in each management area, with 200 collected offshore and 200 collected inshore.

A total of approximately 10,000 samples will be drawn from the tissues collected and divided between the NMFS Santa Cruz, Montlake, and OSU labs for analysis. Each sample will be scored for the 13 standardized GAPS loci, and assigned a stock identity and associated assignment probability. The number of samples from each time/area strata will depend on the number of strata from which tissues are collected. Sampling only open areas in 2006 summer fisheries, with the inshore/offshore stratification and the north/south subdivision of the San Francisco management area, would have yielded a total of 50 unique strata and thus 10,000/50 = 200 samples per strata, the minimum necessary. Sampling closed areas and/or expanded fisheries would reduce the number of samples per stratum.

The GAPS-derived stock identity results will provide distribution data on all the reporting groups in the GAPS data base that are encountered in the fisheries, and will be used for example to test hypotheses concerning differences in fishery contact rates; in particular in KRFC area-specific contact rates inshore versus offshore, and in the San Francisco northern versus southern area. To test these hypotheses, the GSI sample identity results will be expanded to the total catch of the respective sample fleet, and then standardized (divided) by the total effort of the respective sample fleet. Differences in these stock-age-specific catch/effort ratios for a given time period (e.g., month) will reflect differences in the underlying contact rates (and sampling/measurement error), and these differences will be tested for statistical significance. It is not necessary to know the respective cohort abundance (contact rate denominator) to conduct such a test since the two quantities being compared are stock-age-time-specific (the abundance is the same for both).

Literature Cited

Winans, Gary A., Dan Viele, Allen Grover, Melodie Palmer-Zwahlen, David Teel, and Donald Van Doornik. 2001. An update of genetic stock identification of Chinook salmon in the Pacific northwest: test fisheries in California. Reviews in Fisheries Science 9: 213-237.

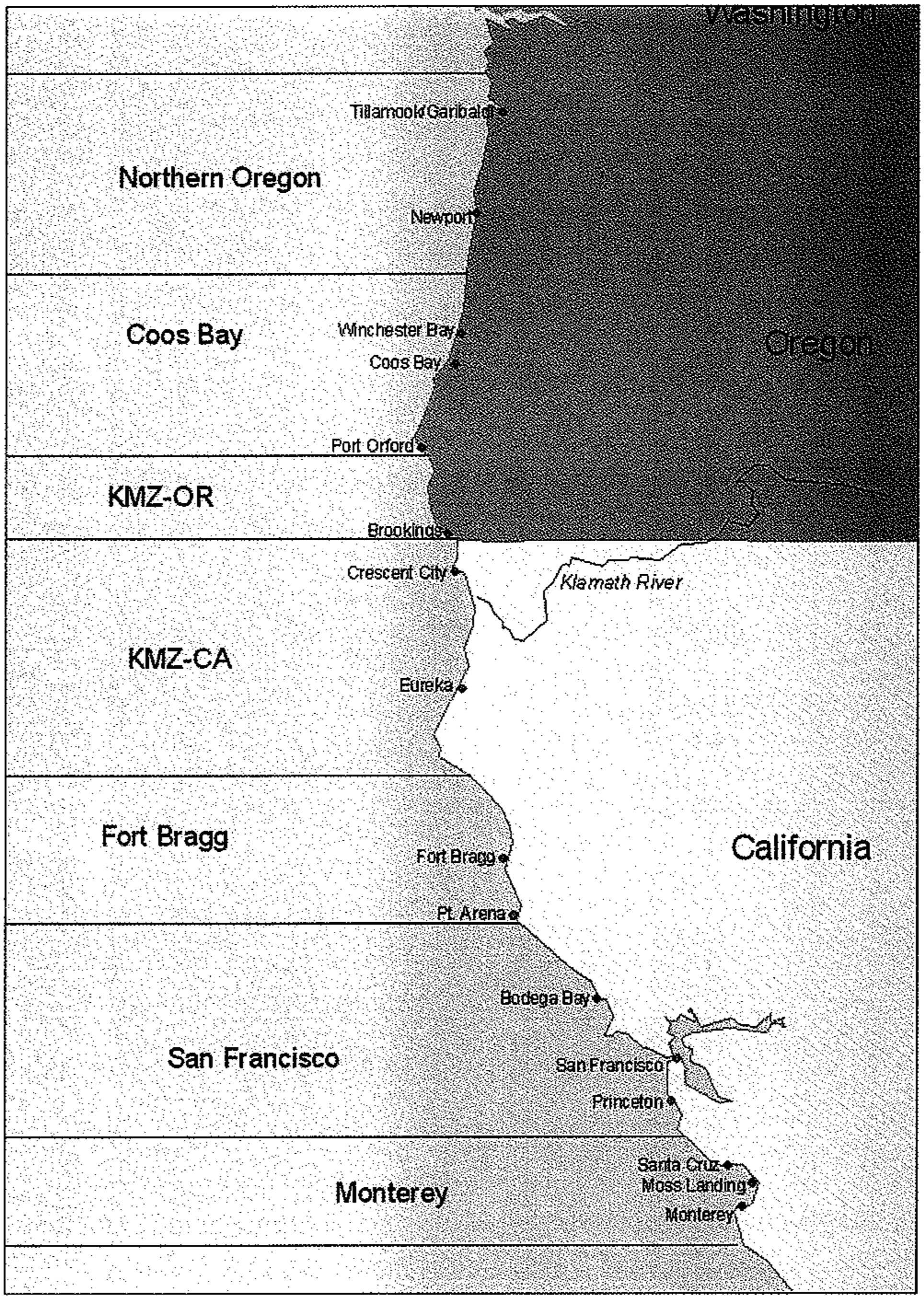

Figure 1. Klamath River fall Chinook management areas between Cape Falcon, OR and Point Sur, CA. The proposed study design includes dividing the San Francisco area into a northern and southern sub-area (Point Arena to Point Reyes, and Point Reyes to Pigeon Point), and in each area an inshore/offshore stratification.

SALMON TECHNICAL TEAM REPORT ON THE 2006 SALMON METHODOLOGY REVIEW

Columbia River Fall Chinook Ocean Abundance Forecasts:
The Salmon Technical Team (STT) reviewed proposed methodology for forecasting the pre-season ocean abundance of Columbia River Chinook stocks. Current methodology forecasts the return to the river mouth using datasets that can vary from year to year and reflect different ocean fishery impacts. These terminal run forecasts must be converted into ocean abundance forecasts for fishery management planning by the Council. The methods currently employed to perform these conversions are inconsistent and undocumented.

The Model Evaluation Workgroup (MEW) developed post-season estimates of ocean abundance from reconstructed age-specific terminal run sizes and estimates of ocean fishery exploitation rates derived from coded wire tags (CWT). Two methods of forecasting ocean abundance using simple linear regressions and log-log regressions were presented. These two proposed methods and the status quo were evaluated in a hindcasting exercise to compare their performance in forecasting ocean abundance using the metrics of root mean squared error and average percent error from post-season estimates of ocean abundance. The MEW document did not describe the methods and results with sufficient detail to permit full evaluation by the STT, but the MEW concluded that none of the three methods consistently outperformed the others.

The STT recommends that the MEW revise its report to correct errors, document the methods currently employed to convert terminal run forecasts to ocean abundance projections, and clarify the data and methods employed in its evaluation of forecasting alternatives. The MEW report does not provide a sufficient basis for changing forecasting from the methods currently employed. Therefore, the STT recommends no change in the methodology for forecasting Columbia River Chinook for the pre-season process for 2007. The STT also recommends that ocean abundance forecasts using all three methods be prepared for further evaluation.

Genetic Stock Identification (GSI) Exempted Fishing Permit (EFP) Proposal:
By combining GSI, Global Positioning System (GPS), depth, temperature, and biological data, the proposed study provides a means to gather important information regarding the timing and location of capture for individual fish. The potential for such data to serve as a basis for examining a variety of issues, such as estimation of stock compositions, detection of schooling behavior, and inferences regarding migration routes at a fine spatial and temporal scale, is promising.

However, the description of the proposed study lacks the definitive information regarding the methodology for analysis and interpretation of these data, which is necessary to evaluate the adequacy of the study design. For example, what are the specific elements to be estimated? What is the desired precision and accuracy of the statistics to be generated? What methods and assumptions are to be employed for estimating stock compositions and migration patterns? What are the error structures surrounding the collection and analysis of the data and uncertainty of parameters to be employed in the analyses?

The analysis, interpretation, and limitations of the results of GSI analysis and DNA fingerprinting and their future use in salmon fisheries management need to be carefully defined and explicitly described. Without such information, there is a serious potential for misunderstanding, misinterpretation, and misapplication of results.

Currently, salmon fishery management in the study area is based on constraining stock and age-specific impacts. GSI can provide direct estimates of the harvest of stock groups whose components do not have associated CWT tagged fractions. For example, GSI methodologies can provide an estimate of the total Sacramento River winter run Chinook ocean harvest and, when coupled with CWT, and age analysis, provide data that would allow fishery managers to differentiate the harvest of hatchery and natural winter run Chinook. However, GSI methods are not currently capable of accurately identifying all stock units currently managed by the Council. For example, GSI is currently not capable of discriminating between California Coastal Chinook (CCC) and Blue Creek Chinook, which is a tributary of the Lower Klamath River, or of discriminating between Klamath River fall Chinook (KRFC) and Klamath River spring Chinook. For purposes of current salmon fishery management, accurate data on aging must be combined with accurate assignment of individual fish to stocks of interest based on GSI data. The current management for CCC is linked to the age-4 ocean harvest rate of KRFC. In addition, brood strength and brood proportion natural are used to estimate the number of adults expected to return and spawn in natural areas of the Klamath basin. Although the collection of scale and otolith data are mentioned, the proposal's description does not indicate the number or percentage of fish from which scales or otoliths are to be collected or the methods to be employed to "ground truth" such data. Accurate aging by scale reading, for example, should by no means be assumed (see report of the PSC Expert Panel on CWT analysis). The collection and aging of scales from all fish identified as KRFC by the GSI analysis would need to be verified by some means, such as using CWT known-age scale reads. To meet the current management conservation objectives of the PFMC, fishery monitoring will need to rely on CWT recoveries from retention fisheries and the stock composition in nonretention fisheries will be limited to the stock groupings identified by GSI analysis.

Experimental designs for the collection of tissues will need to be further developed and consider factors such as controlling potential variation among boats in catch rates or fishing power. In addition, methods need to be developed to independently evaluate the accuracy of data collected at sea. For example, the use of vessel monitoring systems (VMS) could be used to further evaluate ways to track effort and area of catch in the proposed fisheries. The VMS information could be compared to the catch location data recorded during GSI-sampled fisheries. In addition, other methods may need to be explored to evaluate such factors as the cross contamination of genetic samples or other data collection and recording errors.

Experimental design, including methods for collection and analysis of GSI, age, and other necessary data, should be evaluated within a framework that considers the error structures for assigning individual fish to specific stocks and cohorts; such a framework is not presented in the proposal. Instead of providing such a framework, the proposal calls for the collection of samples that appear to be stratified by time, area, and fishery, but are arbitrary in size. The target number of tissues and other data to be collected by study cell appears to be related solely to budgetary and logistical considerations rather than including statistical design in the sample size requirements. For some strata, the collection of 200 samples would provide, at best, a glimpse of contributions of particular stocks and age groups of interest; uncertainty surrounding estimates of stock-age compositions of groups that comprise a small percentage of the exploited populations in such strata would be extremely high.

Lastly, the STT comments that no cost estimates or budget allocations are attached to the proposed study. There are indications that the cost of the study as presented could easily exceed $20 million. Budget information, such as the amount proposed for compensating participating fishermen to provide samples, process and analyze samples, or develop technology and methodology, overhead, and agency contributions, would be critical for evaluation and should be fully disclosed.

The STT recommends that careful experimental design and well thought out methods for assuring data quality due to the inherent difficulties of collecting data at sea will be required for success of this project. The scope of the research should be sufficiently narrowed to maximize on the potential for success and minimize the potential for misinterpretation or misuse of the data collected.

FRAM Documentation:
The STT has reviewed the set of five reports prepared by the MEW (FRAM Overview, User Manual, Technical Documentation, Base Data Development, and Programmers Guide). The STT believes that these reports sufficiently document the structure, parameters, and data employed by the FRAM models for Chinook and coho fishery planning.

PFMC
10/26/06

SALMON ADVISORY SUBPANEL REPORT ON SALMON METHODOLOGY REVIEW

The Salmon Advisory Subpanel (SAS) recommends that Council proceed with assisting and collaborating with industry, NOAA Fisheries, and respected academic fisheries research institutions on the development of a Pilot Genetic Stock Identification Program, as described in Agenda Item I.2.a, Attachment 1, November 2006.

It is expected that this project will be a collaborative effort evolving from experience gained in projects already underway in California, Oregon, and elsewhere, and will depend on securing funding from outside the Pacific Fishery Management Council.

It is understood that the scale and scope of the project will largely depend on the extent and timing of this funding. In preparation for this, draft budgets are being prepared and reviewed by the tentative collaborators in the project, and preliminary funding requests have been initiated to the Federal Congressional delegation. Some state funding could also be anticipated.

The SAS appreciates the concerns about this proposal which have been identified in the reports of the Salmon Technical Team and the Scientific and Statistical Committee. Most of these concerns have been anticipated and discussed in the work already being done in Oregon and California. Some have been already been addressed to varying degrees in those projects.

Full acknowledgement of these challenges further reinforces the "pilot stage" nature of this work. Definitive answers to some of these questions and satisfactory description of strategies to address them will only be possible when the depth of investigation and the duration of the work have been agreed upon. Final project definition will require anticipation of potential season opportunities, and planning must address these uncertainties.

It is clearly anticipated that methodologies and analytical techniques will be adapted and improved upon as the project proceeds.

The SAS agrees with the need to clearly identify this work as preliminary and experimental, in order that misunderstanding, misinterpretation, or misapplication of the results or data can be avoided.

In support of this project, the SAS recommends that the Council:

a. Proceed with the application for one or more Exempted Fishing Permits for the continuation of this research in the 2007.
b. Designate appropriate Council technical personnel or Council team members to assist in the collaborative research design process.

PFMC
11/17/06

SCIENTIFIC AND STATISITICAL COMMITTEE REPORT ON SALMON METHODOLOGY REVIEW

The Scientific and Statistical Committee (SSC) Salmon Subcommittee and the Salmon Technical Team (STT) conducted a joint Salmon Methodology Review on October 10, 2006. Topics included a comparison of alternative ocean abundance forecasts for Columbia River fall Chinook salmon, the status of Fishery Regulation Assessment Model (FRAM) documentation, and a genetic stock identification (GSI) pilot program.

There remain difficulties in interpreting the "Ocean Abundance Forecasts for Columbia River Fall Chinook Salmon" document. The current method was compared to methods independent of the FRAM model. None of the three methods was clearly superior to the others. Further evaluation is warranted before any new method is adopted.

For three years the Model Evaluation Workgroup (MEW) has been working on the FRAM documentation. As of summer 2006, they have produced an extensive set of documents. Due to the voluminous nature of the documentation, a full review of the documents has not yet been accomplished, but such a review or other appropriate next steps can now be planned. The time may be approaching for the model to be rewritten in a newer programming language. Among other things, this would allow for the incorporation of GSI data into the model. The SSC commends the MEW for producing this substantial body of documentation for the FRAM model. It is clear that these documents have made the FRAM more transparent, accessible, and useful.

The document "Pilot Program to Apply Genetic Stock Identification in Pacific Salmon Fisheries in 2007" outlines a program to collect tissue samples for genetic analysis from Chinook salmon caught in ocean fisheries off the coasts of Oregon and Northern California. The goal of this program is to provide data describing the distribution of Chinook stocks among various time and area strata during the 2007 through 2009 fishing seasons. A series of years with this stock-specific distributional data will provide important information to help in the conservation and management of Chinook stocks, especially for those stocks that have conservation concerns. Several years of data collection will be necessary before these data will be adequate for management support.

If salmon fisheries for Chinook are greatly restricted during the coming seasons, as occurred in 2006, the proposed project will need to apply for one or more exempted fishing permits (EFP) from the Pacific Fishery Management Council to allow the collection of tissue samples from all area and time strata identified in the experimental design for the project.

If the project goes forward, the SSC requests that future project operational plans presented to the Council address the following technical issues:

- There is a concern about the collection of samples by commercial boats with no on-board observer. Specifically, there is a concern that some fishers may incorrectly report data (e.g., the location of capture of sampled fish) or may non-randomly select fish for sampling. There should be some explanation of why this will not be a problem, or some methods should be considered for "ground-truthing" the data collected by the fishers, using either test fisheries, on-board observers, or other methods. Because a large number of different commercial boats will be used to collect the tissue samples, there is concern that a "boat-effect" may influence the results. For example, the fishing practices of a particular boat (gear used, method the gear is fished, location the gear is fished) may affect the stock composition of the Chinook caught by the boat. The possibility of a boat-effect needs to be considered during the analysis.

- To be useful for stock assessment, age data (i.e., scale samples) will need to be comprehensively collected as part of the sampling program. The area-and-time distribution information that the project provides for stocks will be much more valuable if it can be associated with specific brood years.
- The spatial and temporal resolution of the baseline will need to be reviewed to determine how useful the data from the project will be for management purposes.
- A more thorough analysis of experimental design should be undertaken to optimize the value of the data collection.

While the proposed project may provide information that could be valuable to salmon management, there are a number of issues that need to be better defined: (1) what types of information will the project provide for management, (2) how could this information be used by management, (3) what is the timeline for information being appropriate for management use, and (4) more details on the experimental design.

Until these issues are addressed, the SSC views the GSI pilot project as promising, but cannot conclude whether it will be able to accomplish all of its stated goals. The SSC supports the consideration of an EFP, if necessary, for the continuation of this research in 2007.

PFMC
11/15/06