PROJECT CROOS
Collaborative Research on Oregon Ocean Salmon

2007 Final Report

Annual Report to the Oregon Watershed Enhancement Board
by the Oregon Salmon Commission

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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

A major objective in salmon fishery management is ensuring access to healthy populations while also protecting weak stocks. Given limited understanding of the behavior and migration patterns of individual salmon stocks, it is difficult to manage salmon populations as distinct units. As a result ocean salmon managers are often compelled to institute large time/area closures to protect the weakest stocks. In 2006 this problem became acute when managers were forced to close most of Oregon and California's ocean troll salmon fishery to protect weak runs of Klamath River Chinook salmon. The result was the loss of 100's of jobs and millions of dollars in coastal income and declaration of a "salmon disaster" by the Governors of California and Oregon. In 2008 the problem became a catastrophic "salmon disaster" when projected low returns of Sacramento River fall Chinook forced closure of all Chinook salmon fishing south of Cape Falcon, Oregon, causing economic losses estimated up to $150 million in Oregon and California.

To address the challenge of inadequate science supporting management of multi-stock ocean salmon fisheries, the Oregon Salmon Commission, together with scientists from Oregon State University and federal and state agencies co-located at the Hatfield Marine Science Center, formed the CROOS group (*Collaborative Research on Oregon Ocean Salmon*). CROOS proposed a comprehensive pilot project to test the potential of using *genetic stock composition* (GSI) and the GAPS database (Genetic Analysis of Pacific Salmonids) to identify in "real time" spatial and temporal characteristics of individual salmon stocks. It was proposed that the availability of "real-time" data could potentially enable fisheries managers to 1) differentiate stocks in "real time" at refined spatial areas, 2) improve salmon conservation while allowing harvest of healthy stocks, and 3) integrate science and management of freshwater, estuarine, and marine salmon ecosystems. In June 2006, the Oregon Watershed Enhancement Board (OWEB), as part of a state-wide effort to provide salmon disaster assistance, agreed to fund a CROOS pilot project to test the potential application of GSI techniques. In 2007, OWEB again agreed to help support the CROOS project due to delays in federal support. The 2007 report summarizes activities that further develop the protocols, methods, and analysis first initiated in 2006. This report should be read as a companion piece to the 2006 Final Report to OWEB. Taken together, they provide a comprehensive summary of the project's objectives, methods, and findings.

Objectives

The primary goal of ProjectCROOS is to conduct collaborative research and develop protocols using "real time" GSI to improve science, management, and marketing of West coast salmon. Specific objectives include 1) developing partnerships and providing financial assistance to participating salmon fishermen, 2) developing sampling protocols for fishermen and fleet coordinators/managers, 3) conducting near "real time" GSI analysis, 4) conducting scale and otoliths analysis, 5) developing digital technologies and "traceability" systems, 6) designing a comprehensive web site, 7) developing methods for collecting oceanographic information, and 8) considering potential of GSI technologies for improving salmon management.

Findings and Results

Financial Participation The project provided financial assistance to almost a quarter of the fleet which participated in the Oregon salmon troll fishery in 2007. A total of 93 vessels participated (93 operators, 63 crew members) for a total of 853 days fished which produced 3,913 fish samples. More than $182,000 was distributed to vessel owners, operators, and crew.

Protocols Project managers continued to develop and improve detailed protocols for biological sampling, data collection and management, fleet training, and project coordination. These protocols will be valuable to support future GSI-based salmon research and management conducted along the West Coast.

Genetic Stock Identification (GSI) Over 3,900 tissue samples were delivered to the genetics laboratories including 800 to NMFS's Northwest Science Genetics Lab. 3,826 samples were accompanied by required sampling data compared to only 3,112 samples in 2006. Approximately 3,360 samples amplified to 7 or more loci were used to estimate stock mixture proportions and individual assignment to baseline populations. Probability values of stock assignment ranged from 28% - 100%.

Stock Mixture Proportions California Central Valley Fall and Feather River Spring contributed the greatest percent (monthly average across all zones) ranging from 26% in the North Oregon Coast (NOC) to 6% in the Klamath Zone. The 2007 average of 26% in the NOC was less than half the total in 2006 indicating the lower relative abundance of Central Valley fish in 2007. While Klamath averaged only 3% in the NOC it averaged greater than 31% and 48% in the South Oregon Coast (SOC) and Klamath Zone (KMZ) respectively. Rogue River fish averaged 6%, 17%, and 19% respectively in the three Zones (NOC, SOC, KMZ). Other relatively important stocks ranged from 1-13% depending on the specific stock and zone.

Stock Proportions Across Time Proportional stock composition showed significant variation across months and per zone. California Central Valley and Feather River Spring averaged almost 40% of the catch in SOC in early summer but decreased to less than 7% by late summer. Columbia River summer and fall chinook averaged 8% in late spring/early summer in the SOC but averaged less than 2% by late summer and fall.

100% Assignment of Coded Wire Tagged (CWT) Fish One hundred and ten of the 3,900 samples contained coded wire tags and of these 91 fish amplified to 7 or more loci. Genetic stock of origin was correct for 94% when individual assignments were compared to hatchery fish reared and released in the same place as their stock of origin.

Near "Real Time" Analysis Near real time genetic analysis was tested for only a few weeks (September 2007) in order to understand technical and logistical issues. Near real time analysis can be conducted within 24-48 hours after samples are received. Cost estimates for conducting near "real time" analysis range from $40-$50 per sample or approximately 60-80% higher than traditional GSI analysis. Results demonstrate potential for using GSI analysis for near real time management on weekly time scales.

Catch per Unit Effort Daily CPUE was generally higher in 2006 (5.95 fish per vessel-day) than 2007 (4.2). In 2007, daily CPUE during the months of June – October was greatest in the KMZ (7.49), followed by the SOC (5.21) and the NOC (1.65).

Scale Analysis and Age of Capture A total of 2,835 scales were mounted and ages were determined within 90% confidence for 2,456 fish. Scale readers correctly aged 95% of coded wire tagged fish. The age composition was 0.4% age-2, 54.0% age-3, 36.0% age-4, 8.2% age-5, and 0.6% age-6. Four-year old fish dominated in the NOC fishery and three-year old fish in the other zones. In general, there was a large change in the percentage of age-3 and age-4 fish between July/August to September.

Otolith Analysis Analysis of otoliths from a subset of Chinook salmon collected during 2005, 2006, and 2007 showed that 1) Chinook salmon from different stocks reside in ocean waters with different chemical characteristics, 2) the temperature history and information on migration of individual Chinook salmon can be determined from oxygen isotopes in otoliths, 3) 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 can be determined by evaluating otolith size and chemical composition. Results indicated earlier and lower size of out-migrant Sacramento River fish in 2004 compared to 2003 due possibly to larger Sacramento River flows in the winter of 2004.

Monitoring Wild Salmon Stocks in Near "Real Time" This project continues to demonstrate that stock composition of wild, as well as hatchery salmon captured in commercial fisheries, can be evaluated in near "real time" using GSI analysis.

Geographic Information Systems (GIS) Maps GIS-based maps continue to be developed that provide virtual "real time" information to fishermen, managers, scientists and other audiences. Maps are accessible at www.ProjectCROOS.com and new maps will be available on the *PacificFishTrax* website by March 2009.

Dataloggers Digital datalogging devices designed for fishing vessels proved to be successful in 2006 and 2007 but need improvements to meet actual needs and conditions found on small fishing vessels. Proposals were written to fund comprehensive R&D on developing dataloggers for use on small fishing vessels. Comprehensive testing is planned for 2008-2009.

Website Development The CROOS Project designed a working "prototype" capable of describing the project and reporting information to multiple audiences using a variety of tools, maps, and statistical analyses (www.ProjectCROOS.com). Based on market research and prototype experience, a new website, *PacificFishTrax.org* is entering final development. The new site will serve the "real time" needs of different audiences while meeting all project objectives including serving multiple West coast fisheries. A website management and financial plan will be completed by the end of 2008 and test marketing and evaluation of traceability using the "*Fishtags*" portion of the site will be conducted in 2009.

Oceanographic Research Oceanographic research examined characteristics of the at-sea distribution of salmon stocks for the 2006 and 2007 seasons. Although stocks from the NOC, SOC, and KMZ were relatively widespread, each was more closely associated with their region of origin than other areas. Large percentages of the Central Valley stock were more disposed to travel longer distances from their region of origin. Although mean capture distances from shore widely overlap for each distinct stock, some degree of separation is observed. The NOC stock was caught much closer to shore than other stocks. Nearest neighbor measurements for 2006 data indicated more associations within stocks than between stocks. Catch data from both 2006 and 2007 confirm the tendency of salmon to be aggregated in association with temperature fronts generated by summer upwelling of cold nutrient-rich water.

Development of a Coordinated West Coast Project The success of project CROOS, together with success of similar projects in California and Washington led to the organization of a West Coast GSI project. The west coast team is working together to develop a long term strategic plan including developing experimental fishing permits, applying for grants and contracts, and developing standard protocols for research methods, data sharing, and communication. The plan will be completed and implemented by the Spring of 2009.

Recommendations and Next Steps

Improving Project Protocols Although a wide range of protocols have been developed and tested, they will need continual adjustments and improvement in response to 1) fishery sampling outside of normal operating areas, 2) a continuous West coast season versus shorter openings, 3) improved catch rates, 4) new technologies, and 5) coordination of fleet management over the entire West Coast.

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 entire West coast. Expanded data should be used to identify stock distribution patterns, test relevant hypotheses, and integrate oceanographic information. This will be the core responsibility of the newly formed West Coast GSI group.

Collecting and Integrating Oceanographic Information   Oceanographic data will be critical for understanding salmon behavior and improving science and management. Future projects should combine vessel-based data collection with other sources of information including ocean observing systems and 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. Research must be conducted to evaluate alternative designs, examine common needs in other fisheries, and explore partnerships with private manufacturers.

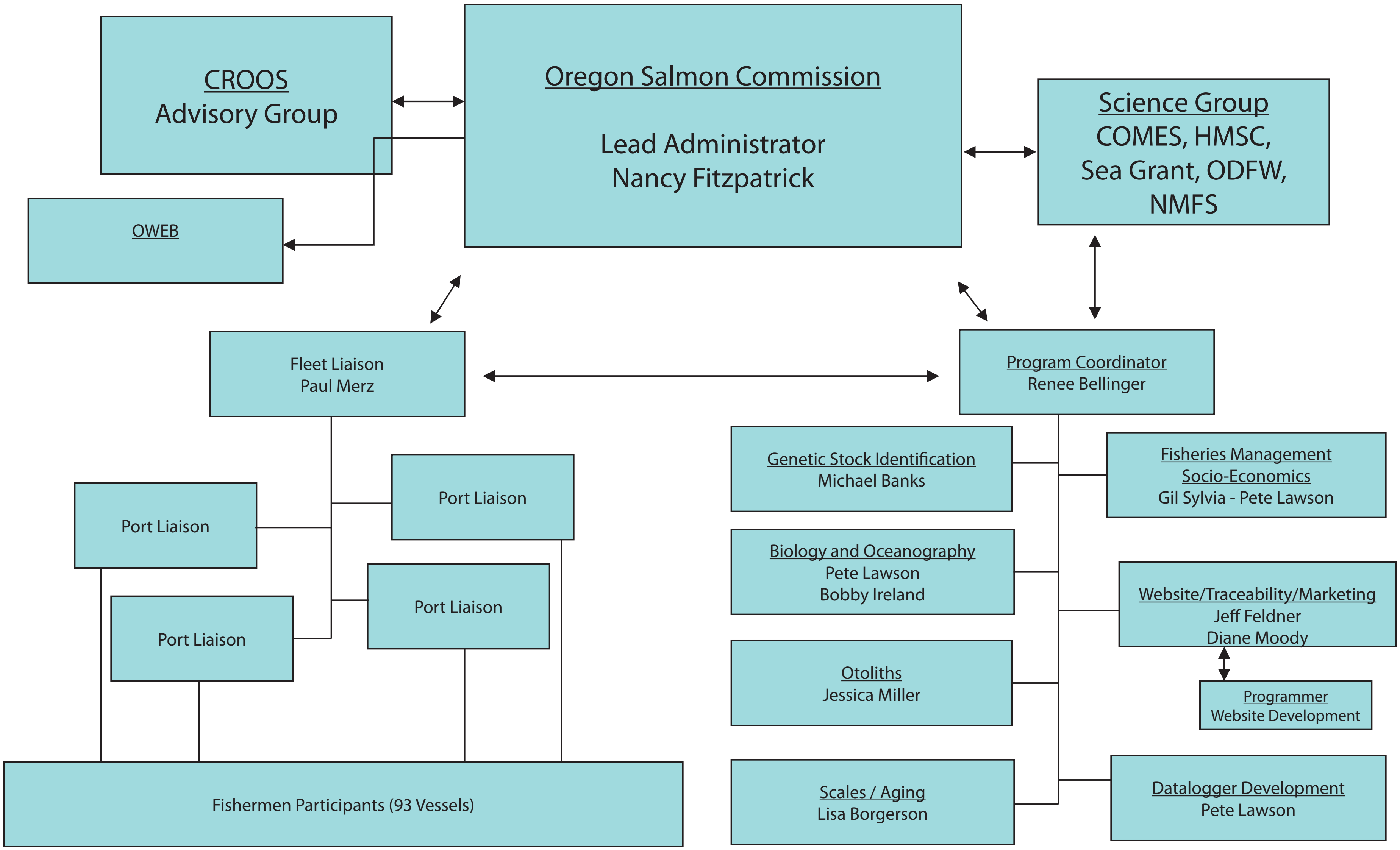
Designing a Multiuse "Real time" Website   The prototype GIS-based website constructed during the CROOS pilot project now serves as a foundation for a newly designed website nearing completion (*PacificFishTrax.org)*. Research should continue to evaluate the "real time" needs of different audiences including scientists, managers, fishermen, seafood markets, consumers, and the public.

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 minimizes fraud. 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 in-season management approaches. Bioeconomic models should evaluate GSI information and industry incentives for improving management of the salmon fishery.

Long term funding Project CROOS is a comprehensive and ambitious project evaluating new integrated approaches for improving the science, management, and economic development of the West Coast Chinook salmon fisheries. It will be critical to develop funding from multiple sources to support the full testing and evaluation of this promising approach along the entire West Coast.

Organizational Chart for CROOS Project



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Appendix

INTRODUCTION

By almost any standard, managing West Coast ocean salmon fisheries poses extraordinary challenges. Hundreds of stocks migrate thousands of ocean miles across two national and seven provincial and state boundaries. Stocks may swim hundreds (sometimes thousands) of miles up freshwater rivers to spawn and reproduce. Their progeny then remain in freshwater before they become juvenile smolts and return to the sea. Some stocks are raised in hatcheries until they become smolts and are released into the natural habitat. In the face of 1) reduced natural freshwater habitat, 2) man-made obstacles limiting migration, and 3) natural changes in the environment, providing commercial, recreational, and cultural-based fishing opportunities has become a daunting challenge.

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 2006, concern over the Klamath River fall run was the most constraining factor limiting 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. In 2008 the problem became catastrophic when projected low returns of Sacramento River fall Chinook forced closure of all Chinook salmon fishing south of Cape Falcon, Oregon, causing economic losses estimated up to $150 million in Oregon and California.

Currently, the estimated contribution of Klamath and Sacramento stocks 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:

- Conducting authentic collaborative research with industry and scientists based on mutual learning and respect
- Integrating fishing and research activities benefiting fishermen, scientists, and resource managers
- Integrating 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 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 had been held, contracts with fishermen signed, and operational protocols 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.

In 2007 OWEB agreed to again help fund Project CROOS, particularly in absence of delayed federal grant support. The project built on the 2006 pilot project, continued refining and improving methods to meet project objectives, and expanded sampling coverage. The project funding helped to support establishment of a West Coast project with partners in California and Washington using Project CROOS methods and protocols.

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 and refine 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 a Final Report.

Guide to Report

This comprehensive report summarizes the 2007-2008 OWEB sponsored CROOS research project. Together with the companion 2006-2007 OWEB report, this comprehensive document should prove valuable to salmon scientists, managers, and industry planning to conduct similar projects. The report describes project management protocols used in 2007, 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.

Section 1

Fleet Management

FLEET MANAGEMENT

Organization and Planning

Planning for managing the fleet operations for the CROOS project began in early January 2007. With the conclusion of the 2006 project, the CROOS Advisory Team reviewed the previous year and made changes accordingly to refine the fleet management and collection of samples.

The CROOS Advisory Team met on a number of occasions to refine the roles and responsibilities for a fleet manager/coordinator and the port liaisons who would report to that person. 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 six 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. Liaisons learned specifics on using the bar code reader and entering the information on the computer during a training session on May 24. Since each participating fisherman must go through a liaison to download his information, it also became the responsibility of the liaison to fill out and submit a billing invoice to the OSC for each fisherman. Several telephone conference calls were held with liaisons during the early season to refine and create new fishermen and liaison protocol amendments.

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

- The OSC May 2007 *Tagline* newsletter that is mailed to all licensed salmon troll permit holders who landed fish in 2005 (565);
    - 2007 licensed wholesale first purchasers of troll salmon (73)
    - Coastal ports (14)
    - Coastal gear/tackle stores (30)
    - Sea Grant Extension Agents (4)
- Posters distributed throughout the coastal ports
- Notification through the OSC Port Outreach Specialists

From this notification including a June 15 deadline, 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 participating fishermen was on a "first come-first served" basis.

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 a maximum of $400 per day of charter ($150/day per vessel, $50/day for one crew member, up to 20 samples/day at $10/sample). Paying for one crew member 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. Paying per sample would allow more fishermen to participate if the number of samples per boat was fewer than 20 per day.

Fishermen training sessions were held during June in Brookings, Port Orford, Coos Bay, Winchester Bay, Newport, and Garibaldi.

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 handheld GPS equipment was demonstrated. Each GPS unit would automate vessel track logging and standardize some of the other recordkeeping protocols (the location and time of capture of each fish were recorded and stored electronically). Contracts were explained and signed, and instructions were given for meeting with a liaison to download the GPS and deliver sample envelopes.

The 2007 commercial salmon season consisted of more fishing opportunities along the entire Oregon coast than the 2006 season. The project goal was to collect samples from along the entire length of Oregon from May through October, and determine the catch composition within certain main catch areas and time blocks specific to location (lat/long) and time.

The main catch areas would match the KOHM harvest areas:

- OR/CA border to Humbug Mt. (KMZ)
- Humbug Mt. To Florence (SOC)
- Florence to Cape Falcon (NOC)
- North of Falcon to OR/WA border

Time cells would be by calendar month.

The design plan was to sample 200 fish per harvest area focusing on the three areas South of Cape Falcon. Prior to the OWEB contract, some fishermen collected samples on a volunteer basis. Upon acceptance of the contract in mid-June, fishermen were then compensated for their sampling. The fleet manager and liaisons were key to sending a specific number of fishermen out of each port for sample collection.

Fleet Sampling Activities and Performance

Contracted data collection began on June 25, 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

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 manager 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.

When each chartered vessel returned to port to deliver fish, the fishermen were required to contact the liaison in their port area to download their GPS track logs and drop off their samples. The liaisons then emailed the computer information to the lab or sent it on a flash drive, and mailed the samples to the lab for processing. The liaisons also resupplied each fisherman with tags, envelopes, batteries, etc. and reset their GPS devices between each trip. The liaisons were 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

145 vessels were on the list with fishermen from the following counties;
Benton, Clackamas, Coos, Curry, Douglas, Lane, Lincoln, Linn, Marion, Tillamook, Yamhill
93 vessels participated (93 operators, 63 crew members)
853 days were fished
3,913 fish were sampled
$182,600 was distributed to vessels (operators/crew) for participation

Observations and Suggestions

Chinook fishing on the Oregon coast in 2007 was extremely poor and the overall catch rates were lower than expected. But valuable data was still collected and will add to the overall database.

As this was the second year of the project and data collection, the fishing fleet was more generally receptive toward the project and what they could learn about their catch. As the project progressed, there appeared to be an increase in enthusiasm about the goals and probability of success of the project. Some of this may have been due to the fact that fishermen were paid for their participation, but the types of questions and suggestions that project team members received over the course of the project seemed to indicate a positive attitude.

The fishermen were also intrigued to learn more about the stock composition of their individual catch as related to location of catch and time of year.

Future Planning

The fleet management team continues to meet with the overall CROOS Advisory 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 as fishing opportunities/seasons change.
3. More of the at-sea data recording tasks will need to be done digitally, i.e. with dataloggers. 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. Datalogger development is continuing, including investigating methods for applying various technologies.
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 Washington, and CROOS fleet management representatives have agreed to meet with them to assist in their planning for future GSI projects.
5. Communication protocols and daily check-in requirements will need to be clearly defined and explained at the training sessions. The possible roles of at-sea liaisons will need to be further defined. The use of a shore-based call-in line should be tested.

Section 2

Genetics

GENETICS

Introduction

The ecosystem-based approach to fisheries management poses a need to consider a myriad of dimensions. These include interactions among target fish stocks, their predators, competitors and prey species; the effects of weather and climate on fisheries biology and ecology; and the effects of fishing on fish stocks and their habitat (Ecosystem Principles Advisory Panel 1998). Salmon indigenous to North America provide excellent examples of challenges facing ecosystem based fisheries management since their life-cycle includes both freshwater and marine components and they form key species roles in these food chains, including provisioning of nutrients for these habitats and food for humans. The success of individual salmon populations (stocks) depends the outcome of these interactions, a gamble that includes multiple changing dynamics. In recent years, stocks of some salmon species have maintained large population sizes, while others have declined to numbers requiring intervention by fisheries managers as mandated by the Sustainable Fisheries Act amendments to the Magnuson-Stevens Fishery Conservation and Management Act (1996). The challenge to fisheries managers is to balance the protection of stocks requiring limited harvest while allowing access to other healthy stocks, and accounting for the effect fishing has on ecosystem processes. This writing covers research addressing these challenges with methods to inform fishermen, fisheries managers, scientists on the relevant details.

Genetic stock identification has been used in salmon management and research for over two decades (Milner et al. 1983, Teel et al. 1999, Shaklee et al. 1999), and can provide information on the origin of stocks being harvested. Estimates of stock mixture composition (Mixed Stock Analysis, MSA) can be used to assess impacts of fisheries in a given region during a limited time-frame. These mixture composition estimates can be applied by fisheries managers to guide decisions aimed at reducing harvest of stocks of concern. However, despite the wide-spread use of genetic markers in at-sea fisheries management, few studies have used these techniques to study the physical and biological processes that affect the stock-specific distribution and migratory patterns of salmonids.

The feasibility of applying genetic technologies to fisheries management depends on the relative uniqueness of fish stocks and the desired scale at which inferences of stock composition estimates are to be made. Alternate freshwater drainages where salmon spawn can act as primary delineating forces resulting in isolated populations 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, IA) and to estimate the percentage that a particular stock contributes to a total sample of a mixed-stock fishery using baseline genetic data (mixed stock analysis, MSA). The application of molecular genetic data to estimate stock-mixture proportions has made substantial contributions to Chinook management (Shaklee et al. 1999, Banks 2005, Beacham et al. in 2008). 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 and Eichert 2000, Pella and Masuda 2001, Banks et al. 2003, Kalinowski et al. 2007) 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 et al. 2000, Beacham et al. 2002, Baudouin et al. 2004, Banks 2005, Seeb et al. 2007, Banks et al. in prep).

The distribution of Chinook stocks off the coast of the Eastern Pacific has been estimated from coded-wire-tag (CWT) recoveries over several decades and results are used for cohort analysis incorporated into current fishery management models. 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 whole season have been compiled.

The Pacific Fisheries Management Council 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 aim to maximize fishing opportunity and catch 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 Chinook was the most constraining factor limiting fisheries harvest south of Cape Falcon to the Mexico/US Border (Pacific Fisheries 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), Council, state and tribal representatives to identify a scientific basis to allow a limited fishing season (Gutierrez 2006). Currently, the pre-season projection of Klamath fall Chinook contributions 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 estimated from relatively coarse time and space inferences drawn from CWTs. 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.

Genetic data may be used to complement CWT data to better resolve stock distribution. Coded-wire tags are predominantly placed in hatchery fish and it is presently unknown whether the behavior of hatchery fish is representative of natural stocks. 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 for all fish in the mixture. Recommendations by the Expert Panel on CWTs conclude that genetic stock identification (GSI) techniques could be used to augment the CWT program and assist in modeling stock abundance projections (Hankin et al. 2005). However, genetic data cannot be used to provide age estimates of fish for cohort reconstruction therefore ancillary data for ageing fish, such as scale analysis, is recommended to accompany GSI results. Since the year and stock of origin is known for CWT fish, samples from these fish can be used to assess the level of accuracy achieved by genetic and scale aging laboratories and to validate genetic estimates of mixture proportions.

Techniques are now available for rapid amplification and scoring of microsatellites, allowing near-real-time assessment of the origin of individual fish with unprecedented degrees of accuracy and confidence. Ten genetics laboratories across the West Coast partnered to describe Chinook salmon variation across the majority of their North American range, making available a dataset capable of providing estimates of stock compositions and individual origin of fish encountered in Eastern Pacific Fisheries. This standardized microsatellite baseline (GAPS; Genetic Analysis of Pacific Salmonids), funded by The Pacific Salmon Commission, can be used to identify 44 separate reporting groups represented by 160 stocks from California through Alaska (Figure 1 and Appendix 1, Seeb et al. 2007, Banks et al. in prep).

Information on specific harvest locations of fish and associated fishing effort can be used to make inferences of how ecosystem processes affect the distribution of specific fisheries stocks and their feeding behavior. 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 and weather permitting, sea surface temperature and chlorophyll maps are available from satellite imagery and surface currents and 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.

This project aims to disseminate fine-scale information on stock distribution and aggregation, in association with oceanographic conditions, to fishermen, fisheries managers, and scientists in near-real time. A prototype system to disseminate information via the world-wide-web for real-time management decisions and ecosystem-based research was tested in 2006. Initial components of a full-scale version will be online this summer. Providing stock mixture contributions and individual assignment of fish on fine-scale maps using near real-time genetic analysis will allow for evaluating the feasibility of finer-scale fisheries management both spatially and temporally. Methods developed in this project are applicable to ecosystem-based studies and fishery management for a wide range of species and contexts.

METHODS AND MATERIALS

Sampling Methodology

Data were collected during 2006 and 2007 Chinook salmon commercial troll fishing seasons in three Pacific Fisheries Management Council Chinook salmon management zones off the coast of Oregon: North Oregon Coast (NOC), Cape Falcon to the south jetty of Florence; South Oregon Coast (SOC), south jetty of Florence to Humbug Mountain; and the Klamath Zone (KMZ), from Humbug Mountain to the Oregon/California border. Data on fishing effort and individual fish harvest location were collected during regular commercial troll fisheries. The NOC was the only management zone open in 2006 due to concern over the Klamath stock, with the exception of limited state area fall "bubble" fisheries concentrating fishing effort at mouths of some rivers.

Spatial and temporal information on fishing effort and fish harvest location is key to assessing stock distribution and abundance and associating fish distribution with biological and physical oceanographic conditions. Three different methods to record locations of fishing vessels (track-logs) as they fished were tested in the 2006 pilot year: paper notebooks, electronic logbooks and hand-held Global Positioning System (Garmin GPS 60) units. At the start of the 2006 commercial fishing season all fishermen recorded date, time, and vessel latitude and longitude in hand-held notebooks at time-intervals of approximately 30 minutes. This proved to be labor intensive for the fishermen and required an excessive amount of time spent on data entry. Mid-season, hand-held GPS units were tested to automatically record fishermen's vessel track-logs (in 5-minute intervals) and fish harvest locations. Fishermen were instructed to turn GPS units on while gear was in the water and off while their gear was out of the water. By the end of the season all fishermen were equipped with hand-held GPS units and notebooks were discontinued. In 2007 GPS units were standard issue with sampling kits. Five electronic logbooks were tested by a subset of the fleet in 2006; these were not used in 2007. Electronic logbooks hold promise for long-term data collection, project operations, and real-time fisheries management, however further development and testing is necessary to reduce their cost and increase efficiency.

Pre-printed envelopes, each labeled with a unique barcode sticker, were provided to fishermen to record data on individual fish and to house tissue and scale samples. Inside each envelope was a barcoded metal tag that matched the envelope label and a slip of paper for storage of scales and tissue. Fishermen secured the barcode tag to the salmon head using a plastic zip tie threaded through a slit cut in the lower jaw. Eight to ten scales and a small (less than dime-sized) fin-clip from each fish were placed on the paper and returned to the envelope. Fishermen placed envelopes inside the wheel-house after biological samples were collected and data were recorded. Envelopes were dried as quickly as possible to minimize sample degradation. The sample envelopes contained the following data fields: Vessel, date and time, depth of capture, fork length (in inches), whether a fish was marked by a hatchery, GPS waypoint number, and a place for notes, and check marks for scales, DNA and stomach samples . Harvest location of fish was recorded by Fishermen using the "waypoint" function on the GPS unit. The GPS waypoint number was written on the envelope, thus date/time/latitude and longitude were automatically recorded. Electronic logbooks allowed for immediate data entry of fish's biological information by the fishermen while at-sea.

Some fishermen were provided temperature-and-depth data loggers to record oceanographic conditions while fishing. Temperature and depth data, coupled with latitude and longitude recorded by GPS units, will be used to assess if under-water fronts can be detected and the feasibility of incorporating these data into oceanographic models. If successful, effect of variation in oceanic conditions on feeding behavior, spatial distribution, and population specific oceanic distribution and aggregate patterns of Chinook salmon may be elucidated.

Barcode-tags can be used for traceability, tracking fish from harvester to processor to market, and ultimately, to the consumer. Uniquely tagging fish also allows for additional biological information to be gained as fish move through channels to the consumer. Oregon Department of Fish and Wildlife (ODFW) port-samplers routinely sample fish for presence of CWTs. Since all fish marked with CWTs are from known populations, these provide means to validate genetic stock identification methods and scale ageing analysis. All fish sampled by ODFW that contained CWTs and were marked with Project CROOS barcodes were noted and barcode numbers and ODFW snout ID number were provided to the Marine Fisheries Genetics Laboratory at Oregon State University. 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. Additional biological information was also gained from fish processing partners that retained tagged heads from processed fish for recovery of otoliths.

Each time a participant returned to port after fishing they were required to check in with a Port Liaison who, in turn, was responsible for downloading GPS track-logs and fish-encounter information and transferring these data, along with tissue and scale samples, to the genetics laboratory (2007 only). During 2006 a drop-box at the Newport Commercial Fishermen dock was initially used to collect samples from Fishermen. The role of Port Liaisons was developed to accommodate the need for centralized collection of samples and downloading GPS data as well as to provide quality control assurance and answer fishermen's sampling questions.

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 during select weeks in 2006 and 2007.

The Magnuson-Stevens Fishery Conservation and Management Act (1996) provides protection to Fishermen by requiring that any public data released be aggregated or summarized in a form that does not directly or indirectly disclose the identity or business practice of any person who submits information. The minimum aggregate of three contributors per aggregate (e.g. week, month or port) was, in some cases, difficult to achieve due to lack of fishing effort during stormy weather, short weeks due to fishery closures, ports with few participants or lack of participant availability. Data from fewer than three participants as an aggregate reporting group are either masked by not releasing sample sizes or excluded from analysis (noted when applicable).

Sample sizes

Fishermen collected 8,231 tissue samples from Chinook salmon harvested during the 2006 and 2007 commercial troll fishing season (Table 1). Samples missing latitude and longitude or date fields were excluded from weekly or monthly genetic and spatial analyses. The 2007 data set (n = 3,826 with complete data) was more complete than the 2006 data set (n = 3,112), because GPS units were issued to all fishermen and Port Liaisons provided quality control measures and accountability throughout the 2007 season.

Laboratory Analysis

Tissue samples were digested and extracted using two methods: silica membrane-based kits (OSU only, 2006, Qiagen® DNeasy™ kits; NWFSC, Wizard (Promega Corp) purification kits) following manufacturer's protocols and silica-fiber Pall-plates (OSU only in 2007, Ivanova et al. 2006) and standard chelex methodology (OSU only, 2006). 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 are as in Seeb et al 2007) or 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.

All tissue samples genotyped in 2006 were processed at the Marine Fisheries Genetics Laboratory, Oregon State University. In 2007 a subset of samples (n = 885) were distributed to the Conservation Genetics Laboratory at the Northwest Fisheries Science Center, National Marine Fisheries Service for genotyping. An additional n = 48 samples were extracted and genotyped by both laboratories to evaluate and ensure concordance of results and data standardization.

Cross-contamination of samples can occur during field or laboratory handling. Detection of contamination can be accomplished by evaluating allelic match scores, which are the percent of alleles that match between pairs of genotypes. Allelic match scores were calculated by Microsatellite toolkit (Park 2001) and samples with high allelic matches (80 – 100%) were further evaluated for contamination. If both samples of the pair were taken by the same fisherman on the same day or extracted in the same batch in the laboratory the samples were deemed contaminated. A total of sixteen pairs of samples (total n = 32 samples) met this criteria; of these, 11 pairs (five pairs in 2006 and six pairs in 2007; total n = 24 samples) matched 100% and five pairs of samples (total n = 10 samples) matched between 88 – 95%. One pair of samples (92% match, n = 2 total samples) was taken by different fishermen and extracted on different extraction plates. All samples less than 88% were taken by different fishermen and extracted in different batches therefore any allelic match was considered to be coincidental. One pair of samples matched 100%, however they were not sampled the same day or extracted in the same batch. The chance of a pair of Chinook salmon genotypes matching 100% is extremely unlikely (Kvitrud et al. 2005) therefore, despite the source of contamination being unidentifiable, these two samples were removed from the dataset.

Fish with incomplete genotypes have a greater chance of mis-assigning to the baseline due to less information contained in their genetic profile. Fish with less than seven of the 13 loci scored were excluded from genetic analysis. One test to this exception was applied to fish with genotypes at three to six loci: these fish were evaluated to see if any originated from winter run in the California Central Valley which is highly identifiable even with as few as three loci. None of the fish with three to six genotypes assigned to winter run therefore they were excluded from further analyses.

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 (Appendix 1, Teel et al. 1999, Seeb et al. 2007, 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 Feather River spring run into one reporting region because of known shortcomings in discriminating fall from spring run in the Feather River drainage. Central Valley spring run was therefore represented by all spring runs present in the GAPS baseline minus the Feather River.

Population based mixed stock analysis

Genetic-based estimates of stock mixture proportions (MSA) and confidence intervals (C.I.) were estimated using 100 bootstraps implemented in program ONCOR (Kalinowski et al. 2007), which was developed specifically to aid in fishery management of Pacific salmonids. Stock composition was estimated using mixtures containing fish samples by management zone and month (Table 2), and then averaging over all months to calculate season averages. Months with fewer than 50 fish were excluded from mixture analysis. State area fall “bubble” fisheries were analyzed separately and not included in yearly averages. The target sample size to assess stock mixture compositions and for individual assignment of fish was 200 – 400 samples per week per management zone. Banks et al. (in prep) determined that increasing fishery sample sizes from 100 to 400 fish has a strong effect 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. Due to the nature of fishing, e.g. fewer people fishing during stormy weather, seasons open for a short duration, or lack of participants, we were not always able to achieve target sample sizes (Table 1). Although samples size for some months were well below 800, confidence intervals provide limited means to evaluate margins of error.

Individual Assignment

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. However, individual assignments are necessary to assess stock-specific clustering behavior, accuracy of genetic and aging estimates for comparisons to known-origin CWT fish, and to study the otolith microchemistry of specific stocks of fish. Individual assignment (IA) probabilities were estimated using ONCOR (Kalinowski et al. 2007), constrained to include only mixtures of fish from a single management zone sampled during a single month that exceeded 50 fish samples. In two cases months yielded fewer than 50 fish and mixtures were combined over months to calculate IA: 1) June and July in the KMZ and 2) August, September and October in the NOC. The SOC yielded fewer than 50 samples in 2006 and was excluded from analysis.

Blind testing against CWT results

Accuracy of individual assignment rapidly declines with probabilities of less than 90% (Banks et al. in prep), therefore individual assignments of $< 90\%$ should be treated with caution. Accuracy of genetic stock of origin estimates was evaluated by comparing fish with IA $\geq 90\%$ to true stock-of-origin data obtained from CWT fish. All scales of fish that received IA estimates $\geq 90\%$ were sent to ODFW for scale aging analysis.

Evaluating appropriate "mixture" for mixed stock analysis

One of the goals of mixed-stock fishery analysis is to increase precision and reduce bias in stock composition estimates. Program ONCOR uses both genotype frequencies and mixture proportions of the fisheries sample to estimate the probability that a fish originated from a baseline population (Kalinowski et al. 2007). The spatial and temporal scale of samples included in a mixture dataset will influence MSA and IA results if the compositions of the combined mixtures are not similar. The effect of the temporal and spatial scale of mixture datasets on individual assignments (or conversely, on MSA) was evaluated by comparing individual assignments using a subset of the yearly data compared to results from the entire years' sampling season. Individual assignments of fish from weeks with $n > 175$ fish (considered to be an adequate sample size) sampled in a single management region (time-area-stratum, TAS) were compared to 1) individual assignments estimated from a mixture containing all samples taken during a single year and 2) individual assignments estimated from samples collected during a single month in a single management zone. Comparisons of assignment probabilities were graphically depicted using in a xy scatterplot generated in microsoft excel.

Evaluating stocks that disproportionately contribute low probability assignments
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 most 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 IA < .90 = 939; n IA ≥ .90 = 3945).

Catch Per Unit Effort in Temporal and Spatial Analyses

Variation in spatial effort by fishermen and harvest locations of fish were graphically visualized using ArcGIS 9.2. Fishing vessel locations were plotted in five-minute intervals and converted to a raster point density dataset using seven classes and geometric intervals (output cell = 0.0042, radius = 0.035; 2006 and 2007 data). Weekly fishing vessel locations were converted to raster point density datasets using five classes and geometric intervals (output cell = 0.0042, radius = 0.035). Fish distributions were plotted and converted to raster point density using six classes and geometric intervals (output cell = 0.01, radius = 0.001 for yearly and .003 and .02, respectively, for weekly area analyses).

Average daily catch per unit effort (daily CPUE) was calculated for each year by dividing the total number of legal-sized fish harvested by the total number of days fished. In 2006, these data were limited to July – October because volunteers collecting samples during the months of April to June only provided information for days when fish were caught.

Fine-scale differences in stock composition, CPUE, and stock encounter rates were evaluated on a weekly basis for three consecutive weeks in August 2007. First, data for each week were visualized using ArcGIS 9.2. Next, geographic breaks in fishing effort (in 5-minute intervals) and/or fish-harvest locations were used to separate distinct clusters within each week. Finally, for each cluster, stock composition, hourly CPUE, and stock encounter rates were estimated. Hourly CPUE was calculated by dividing the number of legal-sized fish harvested by the number of hours spent fishing. Stock mixture proportions were calculated separately for each cluster. Small mixtures (<100) may perform poorly due to insufficient information contained in the mixture dataset, therefore mixture proportions for clusters with fewer than 100 fish were calculated using individual assignment estimates from the monthly mixture to estimate stock mixture proportions. Stock encounter rates were calculated for each cluster as the proportion of a fish from a particular stock that one would encounter per hour of fishing. In other words, if the stock encounter rate for mid Oregon coast was 0.5, one mid Oregon fish would be caught per every two hours spent fishing in that particular cluster.

RESULTS

Feasibility of real-time analysis and synthesis of findings

By September/October of 2006 of our pilot year 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). 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 and simultaneously organize project logistics. By the end of the season (September/October 2006) protocols had been developed, minor laboratory issues had been resolved, and near-real-time analyses were achieved. In 2007 we performed two 24-48 hour simulations. The first trial was not successful owing to loss of time because of a faulty DNA extraction technique and need for re-optimization of PCR. The second attempt was successful with 198 samples processed from receipt in the mail to plotting individual assignments on a map within 48 hours (start date September 12th, 2007).

Global position system technology was successfully implemented to record fishermen's track logs and harvest locations throughout some of 2006 and during all of 2007 (Figures 2 and 3). Port Liaisons were essential for quality control and adherence to protocol guidelines, and were key to efficiently receiving data from fishermen and transferring samples of to the laboratory.

Stock identification and distribution

General distribution patterns

Three stocks dominated mixture proportions of Chinook salmon encountered off the coast of Oregon: California Central Valley fall/Feather spring runs (CACVfa/fsp), Klamath, and Rogue (Table 3 and Figures 2 and 3, also see Appendixes 2-5). Three coastal stocks, mid Oregon, northern California/southern Oregon, and California, contributed moderately to mixture proportions. The NOC had greater contributions from Columbia River/Deschutes and Puget Sound than other management zones (Appendixes 2-5). Stock diversity was greatest in the NOC and lowest in the KMZ (Table 4). Generally, mixtures were comprised of few stocks (5-7) contributing to a substantial portion of the proportional estimates (72.9% – 97.7%, Table 4).

Distribution patterns by stock, management zone, and changes over months

California Central Valley fall/Feather spring was the predominant stock in the NOC region during 2006 and 2007 (Table 3, Figure 4a). In 2006, CACVfa/fsp was present as a higher proportion of the overall mixture than in 2007 (59.7% and 25.7%, respectively). The highest estimated C.I. for CACVfa/fsp in 2007 (37.2%) did not overlap the lowest C.I. estimate for 2006 (45.2%). In 2007, the percent of CACVfa/fsp declined as the season progressed (Figure 4a). Data from the NOC in 2007 were limited to June and July therefore a direct comparison to 2006 is not available, however contribution rates were much higher in 2006 and remained high through October. Data were not collected in the SOC and KMZ in 2006.

In 2007, Klamath stocks dominated mixture proportions in the SOC (season average = 31.0%) and KMZ (season average = 47.8%; Table 3, Figure 4b). Monthly estimates of stock mixture proportions were similar for the SOC and KMZ during the months July – September. June and October were slightly anomalous, with the proportion of Klamath in the SOC dropping sharply in these months. While this may represent true changes in mixture proportions, this also could have been caused by low sample sizes during these months (n = 53 and 61, June and October, respectively) causing errors in estimates of stock mixture proportions. Alternatively, as the proportion of CACVfa/fsp peaked in the SOC during June, the relative proportion of Klamath would have decreased. During both 2006 and 2007, the Klamath was a minor contributor to the NOC. The Klamath composition in the NOC (season average = 3.0%, 0.2%-5.6%) was just under half of what was observed in 2006 (6.2%, 1.7%-10.15%).

The relative contribution from Rogue was similar in the SOC and KMZ management zones (season averages = 17.1% and 19.0%, respectively) and was generally highest in the south (Table 3, Figure 4c). In 2007, the average Rogue contribution was nearly equal to CACV fa/fsp (season average = 17.1% and 17.7%, respectively) in the SOC. The Rogue River stock was the second greatest contributor to harvest in the KMZ (season average = 19.0%). In the SOC (2007) and NOC (2006) the relative contribution from the Rogue increased as the fishing season progressed.

Coastal Oregon and Californian stocks were moderate contributors to the 2006 and 2007 harvest (Figures 2 and 3). Generally their contributions to the mixture proportions increased from north to south and as the season progressed (Figure 5a-c). The mid Oregon coastal stock was prevalent throughout all management zones, contributing season averages of 5.7% and 9.4% in the NOC (2006 and 2007, respectively), 11.3% (SOC), and 9.0% (KMZ; Table 3). The Northern California/Southern Oregon coastal stock contributed more in the SOC and KMZ (7.8% and 7.7%, respectively) than in the NOC (1.8% and 0.1%, 2006 and 2007, respectively). California coastal stocks were encountered more in the KMZ (7.9%) than in the SOC (4.7%) and NOC (2.0%, 1.1%, 2006 and 2007, respectively). The Upper Columbia River summer/fall was a substantial contributor at the start of the season in both 2006 and 2007 and generally decreased as a proportion of the stock as sampling moved south in 2007 (Table 3, Figure 6).

In 2006, samples were taken from June – October, while in 2007 samples were only taken during June and July. Limiting monthly averages to these months allows for direct comparisons between years. In this case, June-July, 2006 compared to June-July, 2007 yields nearly exact proportions of Klamath, Rogue, northern CA/southern Oregon, and California coastal stocks. Three stocks, CACV fa/fsp, mid Oregon coast, and the Upper Columbia River were notably different (Figures 4 and 5). Additionally, south Puget Sound comprised a greater proportion of the mixture in 2007 than 2006 (Appendixes 2 and 3).

Genetic estimates of mixture composition in the Elk River state area fall fishery was comprised primarily of Mid Oregon stocks, to which the Elk River belongs (Table 5). Proportional estimates in the Chetco fishery were dominated by Northern California and Southern Oregon Coastal stocks (79.2%), followed by the Mid Oregon coast and Rogue River (9.0% and 8.2%, respectively; Table 5).

Catch Per Unit Effort in Temporal and Spatial Analyses

Daily CPUE was generally higher in 2006 (5.85 fish per day) than 2007 (4.15 fish per day; Table 6). In 2007, daily CPUE during the months of June – October was greatest in the KMZ (7.49 fish per day), followed by the SOC (5.21 fish per day) and the NOC (1.65 fish per day). Data for 2006 may have been biased slightly high because during the project development phase in 2006 effort was available only for days when volunteers turned samples in. This affect should be minimal because 1) the month of June, at which time project logistics were being worked out, was excluded from CPUE calculations, and 2) most or all volunteers had received electronic logbooks and/or GPS units to track effort by July. Catch per unit effort calculations in 2006 includes a small proportion of data from state fall area "bubble" fisheries occurring in both the NOC and SOC (less than 2% of total data). Despite any potential bias present in the dataset, it appears that CPUE was much greater in 2006 than 2007 for the NOC.

Rates of fish harvested per hour and stock-encounter rates varied substantially, from a low of .05 to a high of 2.38 fish harvested per hour during three consecutive weeks in August (Figures 7-9). Hourly CPUE during the week of August 5-11 ranged from 0.19 – 2.38 fish/hour (Figure 7). The following week hourly CPUE ranged from .23 - 1.725 (Figure 8), while the third week ranged from .05 -.18 (Figure 9). Fish stopped feeding or moved out of the area during the third week. Low sample sizes in some clusters confound our ability to compare mixture proportions with high levels of confidence. However, these data demonstrate the capabilities of detailed MSA/IA, and do provide some cluster-by-cluster comparisons. In area 2, the proportion of Klamath fish increased slightly from the first to second weeks, but fish had moved out or nearly stopped feeding in the third week. The number of fish encountered per hour increased in week two in the 3rd cluster (Figure 7, 3A and Figure 8, 3B), suggesting that possibly fish had moved in from the north or south or that an environmental variable triggered a feeding response.

Stock encounter rates could be used to evaluate relative fishing impacts on specific stocks in an area. For example, in area 3 (Figure 7 and 8), the Klamath encounter rate increased from .4 to .76 over a two-week time-period. This may be an artifact of sample size, or could represent a true change in stock composition. Information such as this can be used to guide management decisions and evaluate trends of stocks moving into and out of areas, or changes in feeding behavior. There were clear differences in stock encounter rates across the three weeks, most notably in the third week when CPUE decreased drastically across the Oregon coast.

Blind testing against CWT results

Port-samplers removed a total of 110 snouts from barcoded fish thought to contain CWTs. Of these, 91 snouts contained CWTs and amplified at 7 or more loci; the remainder were either false-positives (did not contain a CWT) or failed amplification (Table 7). Genetic stock of origin was 94% correct when individual assignments were compared to hatchery fish reared and released in the same place as their stock of origin. Five fish with CWTs were recovered from hatchery fish with stock of origin that differed from where they were reared and/or released. Four of these, from the Rogue stock maintained on the Columbia River, correctly assigned and two mis-assigned. One fish from the Chetco stock, reared at a hatchery on the Elk River and later released in the Chetco, mis-assigned. A single fish assigned to the correct region but assigned to the wrong run time. One fish assigned correctly when analyzed as a mixture within a single week but not as when contained in a mixture including all fish sampled during the month (detailed below).

Evaluating appropriate "mixture" for mixed stock analysis

A total of fourteen weeks (seven each year) were used to compare individual assignments estimated using mixtures limited to single week in a management zone (n = 4884 fish) to monthly and yearly results. Analyzing mixtures by Time-Area-Strata (TAS) had the general affect of raising probabilities of individual assignments when compared to the yearly mixture (Figure 11). Individual assignments estimated using TAS mixtures differed from yearly results by an average of 5.6%, with fewer assignments changing in 2006 (3.86%, n = 90) than 2007 (7.17%, n = 183). The differences between methods were not due to fish with ambiguous or low assignments (IA < 90%) changing; indeed, 48% (n = 131) of assignments resulted in IA ≥ 90% using the TAS assignment methodology. The majority of samples that changed assignments were from the California Central Valley spring reporting group (IA by year) to fall (IA by TAS; 48%), followed by the Rogue River (10.6%), Mid Oregon Coast (8.1%) and Upper Columbia (4.0%). The Klamath region had 3.2% difference. Seventeen other stocks contributed to the difference in assignments. Mixtures using samples collected in single months (n = 13 months compared) were fairly similar to TAS results; only 80 of 4884 fish (1.6%) changed assignments and the majority had IA < 90% in both datasets.

Stocks that disproportionately contributed low probability assignments
Two stocks, the Rogue and Mid Oregon Coast, had disproportional proportions of fish with IA < 90% to the number of total fish assigned to each region (41.9% and 40.67%, respectively; Table 8). In other words, of all fish that assigned to the Rogue River, 41.9% had assignments less than IA < 90% and 58% assigned with IA ≥ 90%. Of fish that assigned to the Northern California / Southern Oregon region, 20.71% of assignments were IA < 90%. Three other regions, the Klamath, California Coast and CACVfa/fsp had close to 10% of fish assigning with IA < 90%.

DISCUSSION

Project CROOS's approach of associating genetic stock identification of individual fish with at-sea data harvest locations and oceanic conditions provides high level resolution for stock specific behavior studies of Pacific salmonids. This approach of 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. Thus the 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.

Central Valley Chinook returning to spawn in 2007 failed to meet escapement goals for the first time in 15 years and jack returns were also record low. Projected returns for 2008 were far below the management floor of 122,000. Consequently, a fishing failure was declared for 2008 with the NOC, SOC, and the entire California coast closed to commercial and recreational Chinook fishing. Poor ocean conditions in 2005, which was the year the majority of this year's returning spawners entered the ocean, along with a number of freshwater and estuary factors, were implicated in low returns (NOAA 2008). Genetic stock identification provided evidence of a marked difference between proportional contributions of Central Valley stocks in 2006 compared to 2007, which coincided with relative abundance of these stocks. True stock abundance can only be evaluated by combining fishing effort and stock encounter rates because relative percentages are affected by all stocks present in an area.

Genetic stock of origin estimates for fish with high assignment probabilities were 94% consistent with CWT results for fish reared and/or released at the same site as their stock of origin. Hatchery fish reared or released in a region other than their stock of origin may have a genetic heritage different from their original natal stock, which will confound genetic estimates of stock of origin. Four CWT fish originated from Rogue stock maintained on the Columbia River; two of these fish assigned to the Rogue River and two assigned to a different (wrong) stock of origin. This hatchery stock has a more complicated genetic relationship to baseline stocks than is typical of other hatchery stocks. Assignment errors between closely related populations, such as lower Columbia River spring and fall-run, are expected within normal confidence limits. The remaining mis-assignments were between populations that are not closely related (e.g. mid Oregon coast and the Canadian South Thompson River; Klamath and California Central Valley Coleman late fall run).

Varying mixtures in space and time resulted in changes in individual assignments. In the weekly and monthly comparison, individual fish tended to have low assignments in both datasets. This was different from yearly pooled mixtures (all management zones) compared to weekly mixtures, where fish assignment probabilities generally increase in the TAS dataset. In the year and TAS comparison, the percent of assignments that changed in 2007 was nearly double to 2006. This is likely because the majority of samples were collected in the NOC during 2006, while samples were collected coast-wide in 2007. Mixtures assume that mixed-stock fishery samples are taken from a homogenous mix; results will be biased if geographic or temporal differences exist within the mixed fishery sample.

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 present as a low percentage of a mixed-stock fishery sample can be difficult to detect because power declines for smaller contributions (Reynolds and Templin 2004). Four other factors also contribute to accuracy and bias of genetic estimates of mixture proportions are: 1) marker power, 2) genetic similarity of stocks, 3) baseline coverage and 4) reporting groups that are not representative of the genetic relationships. Marker power for the GAPS baseline has been evaluated by Seeb et al. (2007) 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 cross-assign. Closely related populations in the GAPS baseline have been grouped into reporting regions. In some cases, for management purposes, it is desirable to maintain separate reporting regions despite similarity of genetic signatures. When this is done, bias is introduced because measures of baseline accuracy decrease.

A number of factors contribute to decreased confidence in mixture proportions or individual fish assigning with low probabilities. Genetic similarity of stocks, stock transfers between basins (homogenizing the genetic diversity between basins), inadequate baseline coverage, and mixture input files can all affect proportional estimates. Genetic similarity of stocks can also bias overall mixture proportions. 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 in an attempt to establish southward instead of northward migrating stocks for harvest in Oregon and Washington. While populations from these three rivers are genetically distinct, fish with intermediate Coos or Columbia /Rogue genetic signatures may assign to the wrong stock of origin.

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.

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 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 CA/ S. Oregon Coast is represented only by the Chetco. We recommend genotyping additional Chinook salmon populations in Southern Oregon and Northern California for the GAPS baseline to improve baseline coverage. 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 will increase 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 ability to detect short-term fluctuations in the distributions of adult Chinook salmon. Clear differences exist in stock mixture proportions over time in different regions, which could be related to timing of migration of these stocks into or out of specific regions. Changes in stock-specific encounter rates, as illustrated during the month of August 2007, can be used to assess impacts on specific stocks as a function of effort. CWT data does not enable discriminating spikes in migratory timing and oceanic distribution such as those detected using genetic analyses, primarily because CWTs are not present in a sufficiently large number of fish and do not provide high-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 new data set grows over time it will allow us to address a wide range of management and science questions, and provide a foundation to measure short and long-term stock distributions and fishing patterns. Long-term datasets are needed to address consistency of stock patterns and to integrate genetic stock identification into fishery management.

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CITATIONS

Banks, M. A., E. Anderson, A. Antonovich, T. D. Beacham, M. R. Bellinger, S. M. Blankenship, M. Campbell, J. Candy, N. A. Decovich, J. C. Garza, C. M. Guthrie III, T. A. Lundrigen, P. Moran, S. R. Narum, Seeb, L. W., J. J. Stephenson, K. J. Supernault, D. J. Teel, W. D. Templin, K, Warheit, J. K. Wenburg, S. F. Young, and C. T. Smith. Power analysis of the GAPS baseline. In prep. for submission to Canadian Journal of Fisheries and Aquatic Science.

Banks, M. A. 2005. Stock identification for the conservation of threatened or endangered species. In: Stock identification methods Eds: Cadrin, S.X., K.D. Friedland and J.R. Waldman. Elsevier Press. pp 593-613.

Banks, M. A. and Jacobson, D. P. 2004. Which genetic markers and GSI methods are more appropriate for defining marine distribution and migration of salmon? North Pacific Anadramous Fish Commission Technical Report 5.

Banks, M.A. W. Eichert, and J.B. Olsen. 2003. Which genetic loci have greater population assignment power? *Bioinformatics* 19**:**1436-1438

Banks, M. A., V. K. Rashbrook, M. J. Calavetta, C. A. Dean, and D. Hedgecock. 2000. Analysis of microsatellite DNA resolves genetic structure and diversity of chinook salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Canadian Journal of Fisheries & Aquatic Sciences 57: 915-927.

Banks, M.A. and W. Eichert. 2000. WHICHRUN (version 3.2) a computer program for population assignment of individuals based on multilocus genotype data. *Journal of Heredity* 91**:**87-89.

Banks, M. A., M. S. Blouin, B. A. Baldwin, V. K. Rashbrook, H. A. Fitzgerald, S. M. Blankenship, and D. Hedgecock. 1999. Isolation and inheritance of novel microsatellites in chinook salmon. Journal of Heredity 90: 281-288.

Baudouin, L, S. Piry, and J. M. Cornuet. 2004. Analytical Bayesian approach for assigning individuals to a population. Journal of Heredity 95:217-224.

Beacham, T. D., B. McIntosh, and C. MacConnachie. 2002. Microsatellite identification of individual sockeye salmon in Barkley Sound, British Columbia. Journal of Fish Biology 61:1021-1032.

Beacham, T. D., I. Winther, K. L. Jonsen, M. Wetklo, L. Deng, and J. R. Candy. 2008. The application of rapid microsatellite-based stock identification to management of a Chinook salmon troll fishery off the Queen Charlotte Islands, British Columbia. North American Journal of Fisheries Management. 28:849-855.

Bellinger, M. R., T. Mullins, S. Haig and E. Forsman. 2005. Phylogenetic relationships among *Phenacomys* voles as inferred by Cytochrome-b. Journal of Mammalogy 86:201-210.

Bury, R. B. and C. A. Pearl. 1999. Klamath-Siskiyou herpetofauna: biogeographic patterns and conservation strategies. Natural Areas Journal 19:341-350.

Cairney M., J. B. Taggart, and B. Hoyheim. 2000. Atlantic salmon (Salmo salar L.) and cross-species amplification in other salmonids. Molecular Ecology 9: 2175- 2178.

Ecosystem Principles Advisory Panel. 1998. Ecosystem-based fishery management. Report to Congress as mandated by the Sustainable Fisheries Act amendments to the Magnuson-Stevens Fishery Conservation and Management Act 1996. National Marine Fisheries Service Ecosystem Principles Advisory Panel. Available at: http://www.nmfs.noaa.gov/sfa/EPAPrpt.pdf

Greig, C., D. P. Jacobson, and M. A. Banks. 2003. New tetranucleotide microsatellites for fine-scale discrimination among endangered Chinook salmon (Oncorhynchus tshawytscha). Molecular Ecology Notes 3: 376-379.

Gutierrez, C. M. 2006. Declaration concerning the Klamath River fall Chinook salmon fishery. The Secretary of Commerce. http://www.commerce.gov/opa/press/Secretary_Gutierrez/2006_Releases/July/Klamath.pdf

Hankin, D. G., J. H. Clark, R. B. Deriso, J. C. Garza, G. S. Morishima, B. E. Riddell, C. Schwarz, and J. B. Scott. 2005. Report of the Expert Panel on the future of the coded wire tag recovery program for Pacific salmon. Pacific Salmon Comm. Tech. Rep. No. 18: 230 p. Available at: http://www.psc.org/pubs/CWT/EPfinalreport.pdf

Ivanova, N. V., J. R. deWaard, and P. D. N. Hebert. 2006. Glass fiber plate DNA protocol: manual protocol employing centrifugation method. http://www.dnabarcoding.ca/DNAextraction/Glass_fiber_DNA_extraction_manual.pdf

Kalinowsi, S. T., K. R. Manlove, and M. L. Taper. 2007. ONCOR A computer program for Genetic Stock Identification. . Department of Ecology, Montana State University, Bozeman MT 59717. Available for download from http://www.montana.edu/kalinowski

Kvitrud, M. A., S. D. Reimer, R. F. Brown, M. R. Bellinger and M. A. Banks. 2005. Pacific harbor seals (*Phoca vitulina*) and salmon: genetics presents hard numbers for elucidating predator-prey dynamics. Marine Biology 147:1459-1466.

Magnuson-Stevens Fishery Conservation and Management Act. 1996. Public Law 94-265. Available at: http://www.nmfs.noaa.gov/sfa/magact/

Milner,G. B., D. J. Tee1, and F. M. Utter. 1983. Genetic stock identification study. Bonneville Power Administration, Agreement DE-A179-82BP28044MOOl), Coastal Zone and Estuarine Studies Division, Northwest and Alaska Fisheries Center, National Marine

Fisheries Service, National Oceanic and Atmospheric Administration, 101 electronic pages (BPA Report DOE/BP-I0002). http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

Nicholas, J. and D. G. Hankin. 1988. Chinook salmon populations in Oregon's Coastal river basins: Description of life histories and assessment of recent trends in run strength. Oregon Department of Fish and Wildlife, Informational Report 88-1. 359 pp.

NOAA National Marine Fisheries Service (2008, March 4). Unfavorable Ocean Conditions Likely Cause Of Low 2007 Salmon Returns Along West Coast. ScienceDaily. Retrieved May 20, 2008, from http://www.sciencedaily.com /releases/2008/03/080303145253.htm

Olsen, J. B., P. Bentzen, and J. E. Seeb. 1998. Characterization of seven microsatellite loci derived from pink salmon. Molecular Ecology 7: 1083-1090.

Pacific Fishery Management Council. 2006. Review of 2005 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, Oregon 97220-1384.

Park S. D. E. 2001. Trypanotolerance in West African cattle and the population genetic effects of selection. PhD. thesis, University of Dublin. Available from http://animalgenomics.ucd.ie/ sdepark/ms-toolkit/.

Pella, J. and M. Masuda. 2001. Bayesian methods for analysis of stock mixtures from genetic characters. Fishery Bulletin 99:151-167.

Pella, J. and M. Masuda. 2006. The Gibbs and split-merge sampler for population mixture analysis from genetic data with incomplete baselines. Canadian Journal of Fisheries and Aquatic Science 63:576-596.

Rannala, B. and J. L. Mountain. 1997. Detecting immigration using multilocus genotypes. Proceedings of the National Academy of Science 94:9197-9291.

Rexroad, C. E., III, R. L. Coleman, A. M. Martin, W. K. Hershberger, and J. Killefer. 2001. Thirty-five polymorphic microsatellite markers for rainbow trout (Oncorhynchus mykiss). Animal Genetics 32: 317-319.

Reynolds J. H and W.D. Templin. 2004. Detecting specific populations in mixtures. Environmental Biology of Fishes 69:233-243.

Seeb, L. W., A. Antonovich, M. A. Banks, T. D. Beacham, M. R. Bellinger, S. M. Blankenship, M. Campbell, N. A. Decovich, J. C. Garza, C. M. Guthrie III, T. A. Lundrigen, P. Moran, S. R. Narum, J. J. Stephenson, K. J. Supernault, D. J. Teel, W. D. Templin, J. K. Wenburg, S. F. Young, and C. T. Smith. 2007. Development of a standardized DNA database for Chinook salmon. Fisheries 32:540-552.

Shaklee, J. B., T. D. Beacham, L. Seeb and B. A. White. 1999. Managing fisheries using genetic data: case studies from four species of Pacific salmon. Fisheries Research 43:45-78.

Soltis, D. E., M. A. Gitzendanner, D. D. Strenge and P. E. Soltis. 1997. Chloroplast DNA intraspecific phylogeography of plants from the Pacific Northwest of North America. Plant Systematics and Evolution 206:353-373.

Teel, D. J., P. A. Crane, C. M. Guthrie III, A. R. Marshall, D. M. VanDoornik, W. D. Templin, N. V. Varnavskaya, and L. W. Seeb. 1999. Comprehensive allozyme database discriminates chinook salmon around the Pacific Rim. (NPAFC document 440) 25p. Alaska Department of Fish and Game, Division of Commercial Fisheries, 333 Raspberry Road, Anchorage, Alaska USA 99518.

Table 1. Total number of samples collected during 2006 and 2007 commercial troll Chinook salmon fishing seasons, total numbers with complete data (date sample taken and latitude/longitude), and total numbers with complete data that were genotyped and that amplified at seven or more loci (excludes sate area fall "bubble" fisheries in 2006 and 2007)

Samples	2006	2007	Total n
n collected	4318	3913	8231
n with complete data	3936	3853	7789
n genotyped with complete data	3112	3826	6938
n with 7 or more loci amplified**	2695	3658	6353

** excludes state area fall "bubble" fisheries, Tillamook extension (November only), and other months where samples cannot be reported due to aggregate minimums required by Magnuson-Stevens Act (see text for details)

Table 2. Total number of samples contributing to estimates of stock compositions and individual fish assignments during 2006 and 2007 Chinook salmon commercial troll fisheries.

Month	North Oregon Coast		South Oregon Coast	Klamath Zone
	2006	2007	2007	2007
May			252	
June	195	197	53	25
July	959	191	399	284
August	242	42	1589	226
September	931	33	123	78
October	368	46	61	59*
November		**	**	
Total	2695	509	2477	672

* Chetco River state area fall fishery

** sample numbers not released due to aggregate minimums required by Magnuson-Stevens Act (see text for details)

Table 3. Monthly stock mixture proportions (MSA) and confidence intervals for the North Oregon Coast (NOC; 2006 and 2007), South Oregon Coast (SOC, 2007 only) and Klamath (2007 only) management zones estimated using the GAPS standardized microsatellite baseline v2.1 and program ONCOR (Kalinowski et al. 2007).

Stock	Management Zone and Year	May	May CI Low	May CI High	June	June CI Low	June CI High	July	July CI Low	July CI High	August	August CI Low	August CI High	Sept.	Sept CI Low	Sept CI High	Oct.	Oct. CI Low	Oct. CI High	Montly Ave	CI Range Low	CI Range High
CACV fa/Fsp	NOC 2006				0.574	(0.490	,0.633)	0.614	(0.575	,0.639)	0.700	(0.619	,0.736)	0.584	(0.553	,0.607)	0.514	(0.452	,0.559)	0.597	0.452	0.736
	NOC 2007				0.318	(0.235	,0.372)	0.195	(0.131	,0.219)										0.257	0.131	0.372
	SOC 2007	0.358	(0.283	,0.393)	0.414	(0.292	,0.514)	0.178	(0.143	,0.211)	0.072	(0.060	,0.083)	0.024	(0.000	,0.049)	0.016	(0.000	,0.050)	0.177	0.000	0.393
	KMZ 2007							0.118	(0.069	,0.156)	0.045	(0.015	,0.073)	0.026	(0.000	,0.064)				0.063	0.000	0.156
Klamath R.	NOC 2006				0.044	(0.017	,0.090)	0.049	(0.036	,0.058)	0.050	(0.018	,0.076)	0.084	(0.062	,0.097)	0.082	(0.049	,0.105)	0.062	0.017	0.105
	NOC 2007				0.027	(0.005	,0.050)	0.034	(0.002	,0.056)										0.030	0.002	0.056
	SOC 2007	0.237	(0.163	,0.277)	0.057	(0.019	,0.134)	0.471	(0.383	,0.490)	0.489	(0.432	,0.500)	0.435	(0.336	,0.520)	0.173	(0.081	,0.278)	0.310	0.019	0.520
	KMZ 2007							0.458	(0.380	,0.504)	0.442	(0.360	,0.491)	0.534	(0.374	,0.616)				0.478	0.360	0.616
Rogue R.	NOC 2006				0.041	(0.002	,0.065)	0.030	(0.015	,0.045)	0.014	(0.000	,0.041)	0.096	(0.070	,0.121)	0.166	(0.104	,0.189)	0.069	0.000	0.189
	NOC 2007				0.054	(0.018	,0.092)	0.068	(0.021	,0.105)										0.061	0.018	0.105
	SOC 2007	0.056	(0.021	,0.105)	0.158	(0.019	,0.230)	0.118	(0.075	,0.181)	0.175	(0.149	,0.218)	0.151	(0.074	,0.218)	0.368	(0.201	,0.500)	0.171	0.019	0.500
	KMZ 2007							0.218	(0.142	,0.275)	0.231	(0.151	,0.305)	0.121	(0.028	,0.226)				0.190	0.028	0.275
Mid OR Coast	NOC 2006				0.015	(0.000	,0.054)	0.050	(0.027	,0.070)	0.040	(0.011	,0.075)	0.092	(0.067	,0.119)	0.087	(0.059	,0.141)	0.057	0.000	0.141
	NOC 2007				0.117	(0.067	,0.160)	0.071	(0.054	,0.134)										0.094	0.054	0.160
	SOC 2007	0.081	(0.041	,0.126)	0.056	(0.000	,0.130)	0.082	(0.051	,0.125)	0.109	(0.091	,0.144)	0.161	(0.070	,0.245)	0.192	(0.081	,0.333)	0.113	0.000	0.333
	KMZ 2007							0.069	(0.040	,0.120)	0.106	(0.055	,0.180)	0.095	(0.029	,0.204)				0.090	0.029	0.204
N CA / S OR Coast	NOC 2006				0.005	(0.000	,0.016)	0.010	(0.001	,0.016)	0.016	(0.000	,0.038)	0.041	(0.023	,0.050)	0.020	(0.007	,0.039)	0.018	0.000	0.050
	NOC 2007				0.000	(0.000	,0.011)	0.019	(0.000	,0.043)										0.010	0.000	0.043
	SOC 2007	0.022	(0.003	,0.041)	0.060	(0.000	,0.131)	0.048	(0.024	,0.069)	0.068	(0.051	,0.080)	0.129	(0.050	,0.180)	0.140	(0.057	,0.234)	0.078	0.000	0.234
	KMZ 2007							0.042	(0.016	,0.072)	0.071	(0.037	,0.114)	0.117	(0.035	,0.184)				0.077	0.016	0.184
CA Coast	NOC 2006				0.005	(0.000	,0.015)	0.011	(0.003	,0.017)	0.024	(0.004	,0.051)	0.037	(0.026	,0.049)	0.025	(0.011	,0.039)	0.020	0.000	0.051
	NOC 2007				0.000	(0.000	,0.000)	0.021	(0.005	,0.043)										0.011	0.000	0.043
	SOC 2007	0.020	(0.004	,0.036)	0.019	(0.000	,0.057)	0.051	(0.030	,0.079)	0.073	(0.057	,0.083)	0.058	(0.022	,0.103)	0.063	(0.000	,0.128)	0.047	0.000	0.128
	KMZ 2007							0.062	(0.033	,0.083)	0.086	(0.048	,0.124)	0.090	(0.026	,0.153)				0.079	0.026	0.153
U Columbia R. su/fa	NOC 2006				0.107	(0.068	,0.161)	0.043	(0.028	,0.063)	0.042	(0.010	,0.088)	0.002	(0.001	,0.014)	0.005	(0.000	,0.022)	0.040	0.000	0.161
	NOC 2007				0.113	(0.061	,0.167)	0.142	(0.079	,0.217)										0.128	0.061	0.217
	SOC 2007	0.088	(0.051	,0.130)	0.071	(0.000	,0.195)	0.016	(0.005	,0.034)	0.003	(0.001	,0.012)	0.020	(0.000	,0.048)	0.017	(0.000	,0.069)	0.036	0.000	0.195
	KMZ 2007							0.013	(0.000	,0.029)	0.009	(0.000	,0.033)	0.000	(0.000	,0.027)				0.007	0.000	0.033

CA = California; CACV fa/fsp = California Central Valley fall and Feather River spring; CI = Confidence Interval; fa = fall; N = north; OR = Oregon; R = River; S = south; su = summer; U = Upper

Table 4. Chinook salmon stock diversity in the North Oregon Coast (NOC; 2006 and 2007), South Oregon Coast (SOC, 2007 only) and Klamath (KMZ, 2007 only) management zones estimated using the GAPS standardized microsatellite baseline v2.1 and program ONCOR (Kalinowski et al. 2007). Number (n) of total stocks is defined as any stock that registered in the confidence interval, even if that stock was not included in the final estimated mixture proportion. Details on stocks composition estimates and confidence intervals can be found in Appendixes 2-5.

Management Zone	n total stocks (from lower C.I.)	n stocks contributing to mixture proportion	n stocks contributing to ≥ 1% of mixture proportion	n stocks contributing to ≥ 4% of mixture proportion	Proportion stocks that contributed at least 4% to mixture comprise of total mixture
NOC – 2006	39	25	13	5	82.5
NOC – 2007	38	28	19	7	72.9
SOC	33	26	9	6	89.6
KMZ	24	14	6	6	97.7

Table 5. Monthly stock mixture proportions (MSA), using confidence intervals (as percents) for two bubble fisheries conducted at the mouths of the Chetco and Elk Rivers, during 2007, estimated using the GAPS standardized microsatellite baseline and program ONCOR (Kalinowski et al. 2007).

	Chetco, October 2007		Elk November 2007	
	% Stock	Low and High CI	% Stock	Low and High CI
Central BC Coast	0.0	(0.0, 3.3)	0.0	(0.0, 0.0)
Klamath R.	0.9	(0.0, 4.5)	0.0	(0.0, 0.0)
Mid Oregon Coast	9.0	(3.0, 26.6)	98.4	(90.9, 100.0)
N California / S Oregon Coast	79.2	(54.9, 84.8)	0.0	(0.0, 0.0)
N Oregon Coast	0.0	(0.0, 3.2)	0.7	(0.0, 5.8)
N Puget Sound	1.0	(0.0, 4.3)	0.0	(0.0, 2.7)
N Thompson R.	0.0	(0.0, 0.0)	0.0	(0.0, 3.7)
Rogue R.	8.2	(1.6, 19.0)	0.0	(0.0, 0.8)
S BC Mainland	0.0	(0.0, 2.2)	0.0	(0.0, 0.0)
S Thompson R.	0.0	(0.0, 0.0)	0.0	(0.0, 3.7)
U Columbia R .su/fa	1.7	(0.0, 8.4)	0.0	(0.0, 0.0)
U Skeena R.	0.0	(0.0, 0.3)	0.0	(0.0, 0.0)
Washington Coast	0.0	(0.0,2.8)	1.0	(0.0,5.7)

BC = British Columbia, fa = fall, N = North, R. = River, S = South, su = summer, U = Upper

Table 6. Total number of days fished from July – October, 2006 and June – October, 2007 during the Chinook salmon commercial troll fisheries season, number of legal-sized fish harvested per day, and average daily catch per unit effort (CPUE).

Month	North Oregon Coast		South Oregon Coast	Klamath Zone
	2006*	2007	2007	2007
Total days fished	697	316	443	94
n legal-sized fish harvested	4078	522	2,310	704
Average catch per day (daily CPUE)	5.85	1.65	5.21	7.49

* Incomplete record of effort (days fished) during project development phase. Yearly total for 2006 includes some catch and effort data from state area fall bubble fisheries that occurred in the North and South Oregon Coast management zones (< 2% of data).

Table 7. Results for genetic stock identification (GSI) stock of origin estimates (GAPS baseline v2.1 and Program Oncor, Kalinowski et al. 2007) compared to known coded-wire-tagged Chinook (details on individual fish in Appendix 6).

CWT fish history / notes on GSI results	n fish	Stock of origin correctly identified using genetic estimates?
Hatchery, release site and stock the same	73	yes
Hatchery, release site and stock the same	4*	no
Stock correct, run-time incorrect	1	no
Hatchery, release site and stock different	2	yes (n/a)
Hatchery, release site and stock different	4	no (n/a)
Individual assignment < 90%	4	yes (n/a)
Individual assignment <90 %	3	no (n/a)
Failed amplification	5	
No tag	14	
Total	110	

* one fish assigned correctly using weekly individual assignment but incorrectly with monthly individual assignment

Table 8. Stocks that disproportionally contributed to low assignments (individual assignments < 90%) and represented at least 4% of the total dataset (2006 and 2007 combined).

GAPS reporting region	# Fish IA < 90	Total # fish Assigned to Region**	Proportion fish with IA < 90% to total number assigned to region	Proportion the region contributed to total mixture
Central Valley fa fsp	209	1909	10.95%	29.79%
Klamath R.	155	1592	9.74%	24.84%
Rogue R.	313	747	41.90%	11.66%
Mid Oregon Coast	242	595	40.67%	9.28%
N California/S Oregon Coast	64	309	20.71%	4.82%
California Coast	25	265	9.43%	4.13%
Regions contributing to < 4% of total mixture*	427	992	<4%	15.48%
Total fish	1435	6409		

* 31 other Regions contributed less than 4% each to the sum of 15.48% to the total mixture (2006 and 2007 combined).
** includes fish not reported elsewhere due to aggregate minimums required by Magnuson-Stevens Act (see text for details)

Figure 1. Reporting regions (numbers) and populations 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).

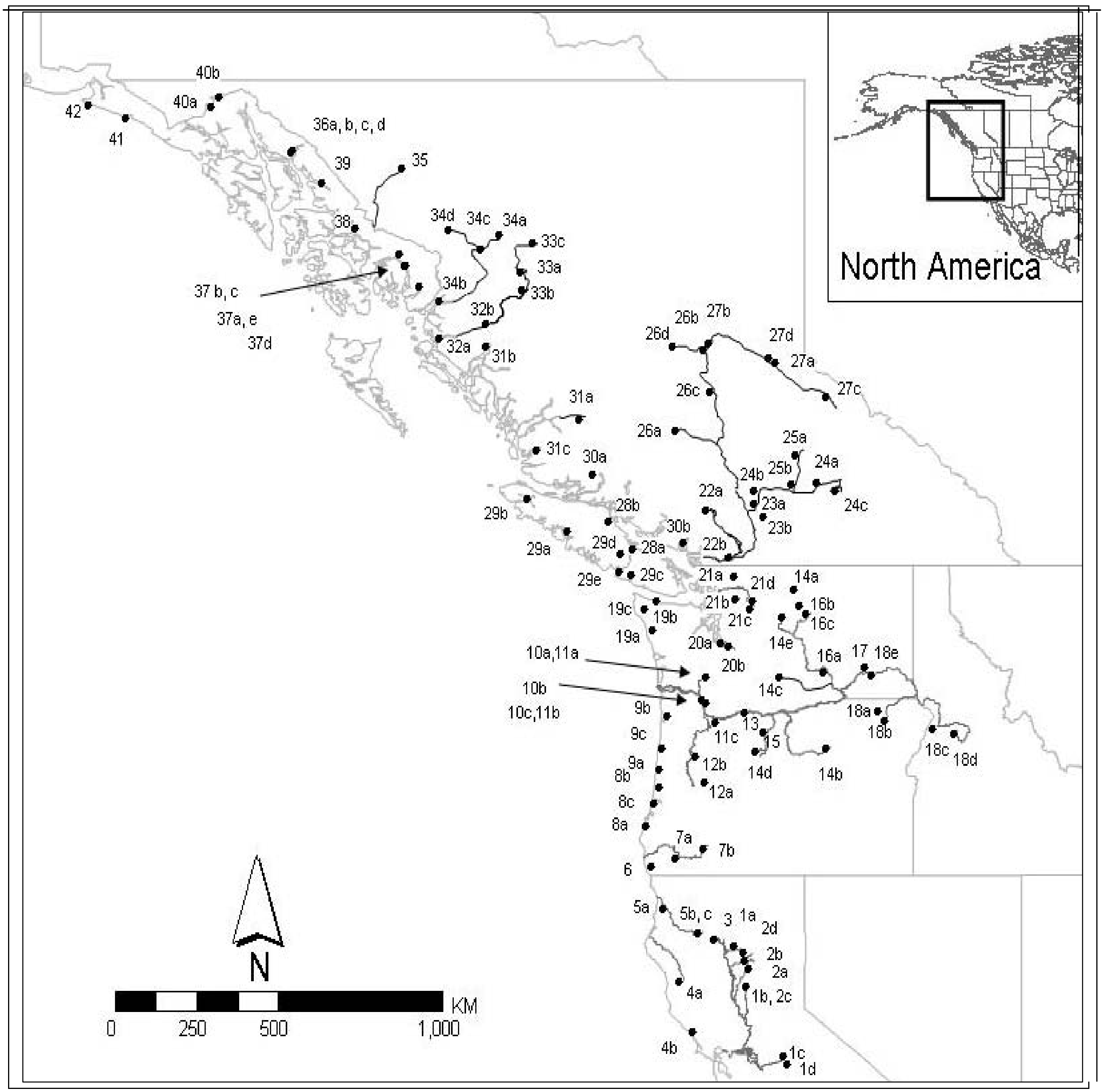


Figure 2. Fishing effort and fish harvest locations plotted as density for sampling conducted during the 2006 CROOS commercial troll fishing season. Yearly stock composition was calculated using the average of all month stock mixture proportions estimated with GAPS baseline v 2.1 and program ONCOR (Kalinowski et al. 2007).

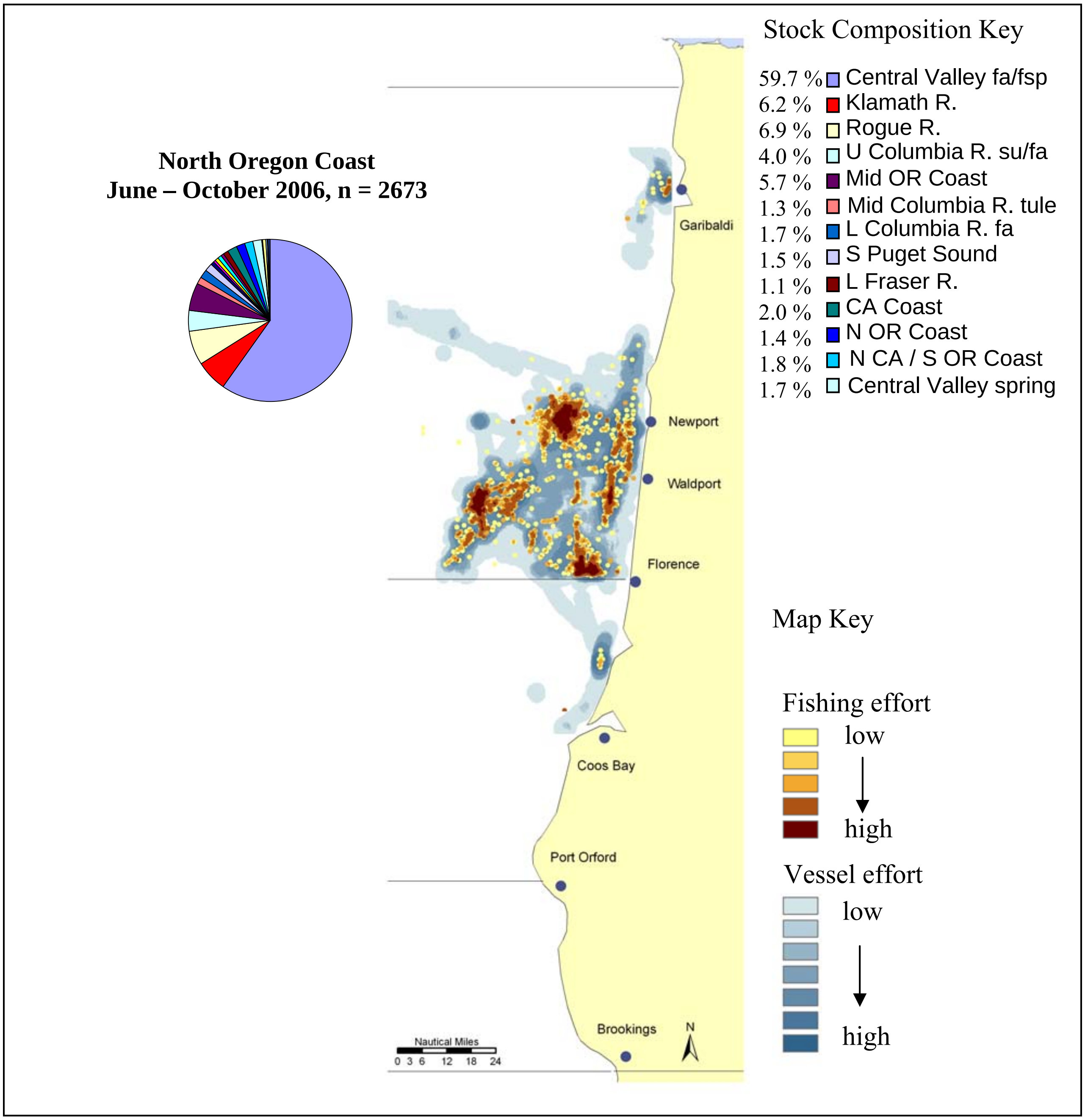


Figure 3. Fishing effort and fish harvest locations plotted as density for sampling conducted during the 2007 CROOS commercial troll fishing season. Yearly stock composition was calculated using the average of all monthly stock mixture proportions estimated with GAPS baseline v 2.1 and program ONCOR (Kalinowski et al. 2007).

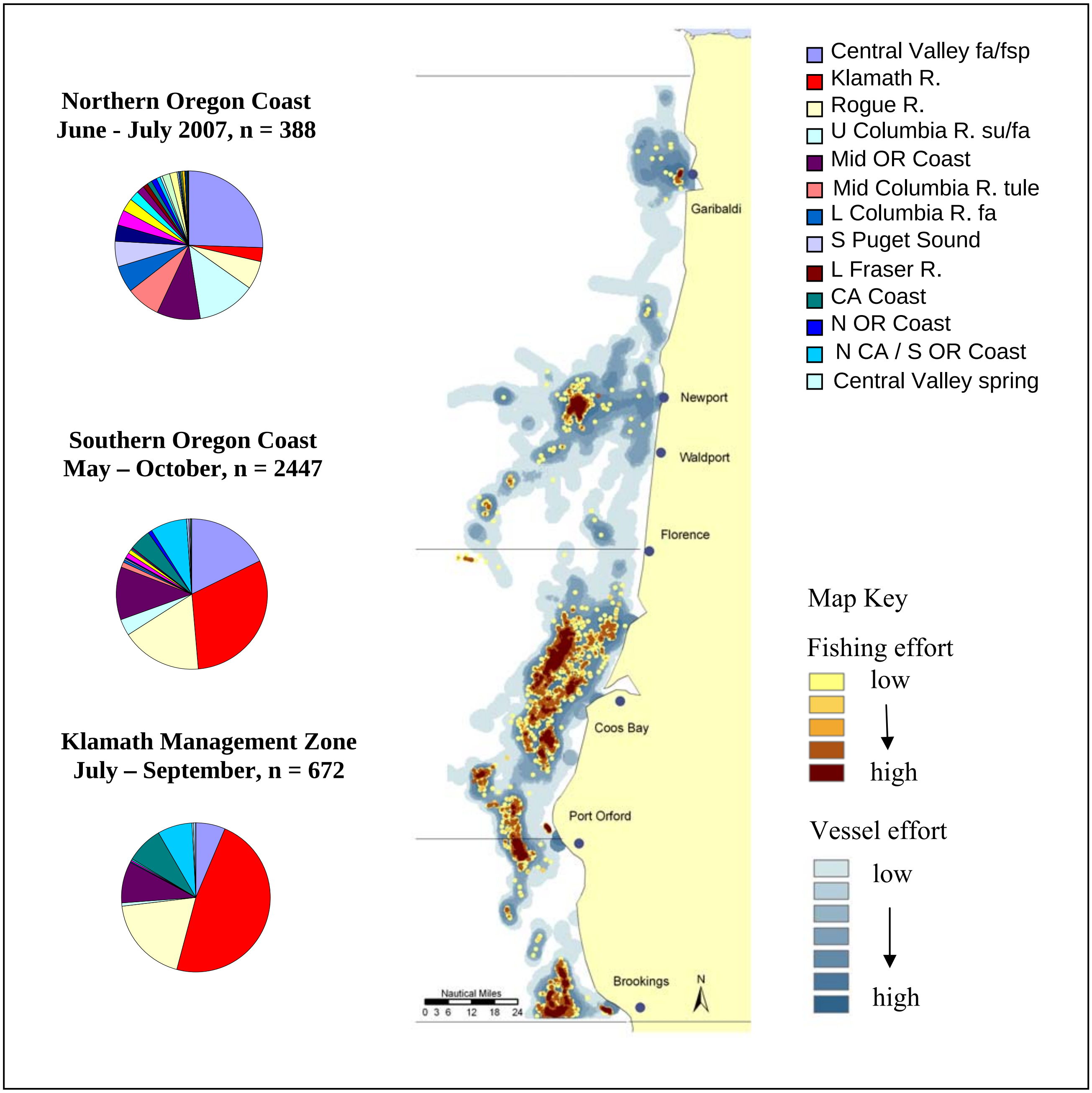


Figure 4. Top three stocks contributing to estimates of stock mixture proportion encountered during 2006 and 2007 Chinook salmon commercial troll fisheries. Stock mixture proportions were estimated using GAPS baseline v 2.1 and mixed stock analysis implemented in program ONCOR (Kalinowski 2007). (a) The California Central Valley fall and Feather River spring runs, (b) the Klamath River, and (c) the Rogue River.

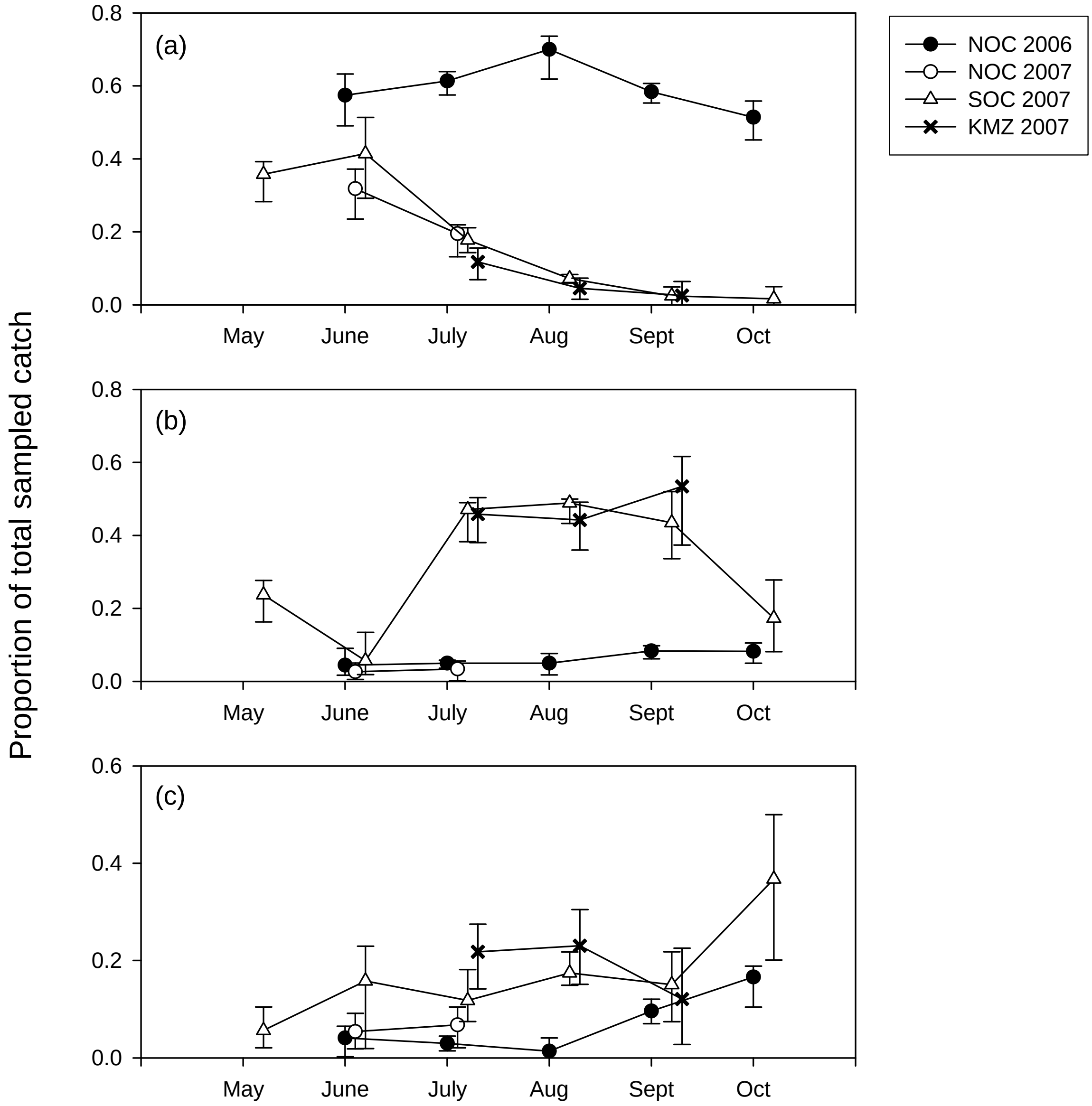


Figure 5. Top three minor contributors to stock mixture proportions during 2006 and 2007, estimated using GAPS baseline v 2.1 and mixed stock analysis implemented in program ONCOR (Kalinowski 2007). (a) Mid Oregon Coastal, (b) Northern California/Southern Oregon Coastal, and (c) California Coastal.

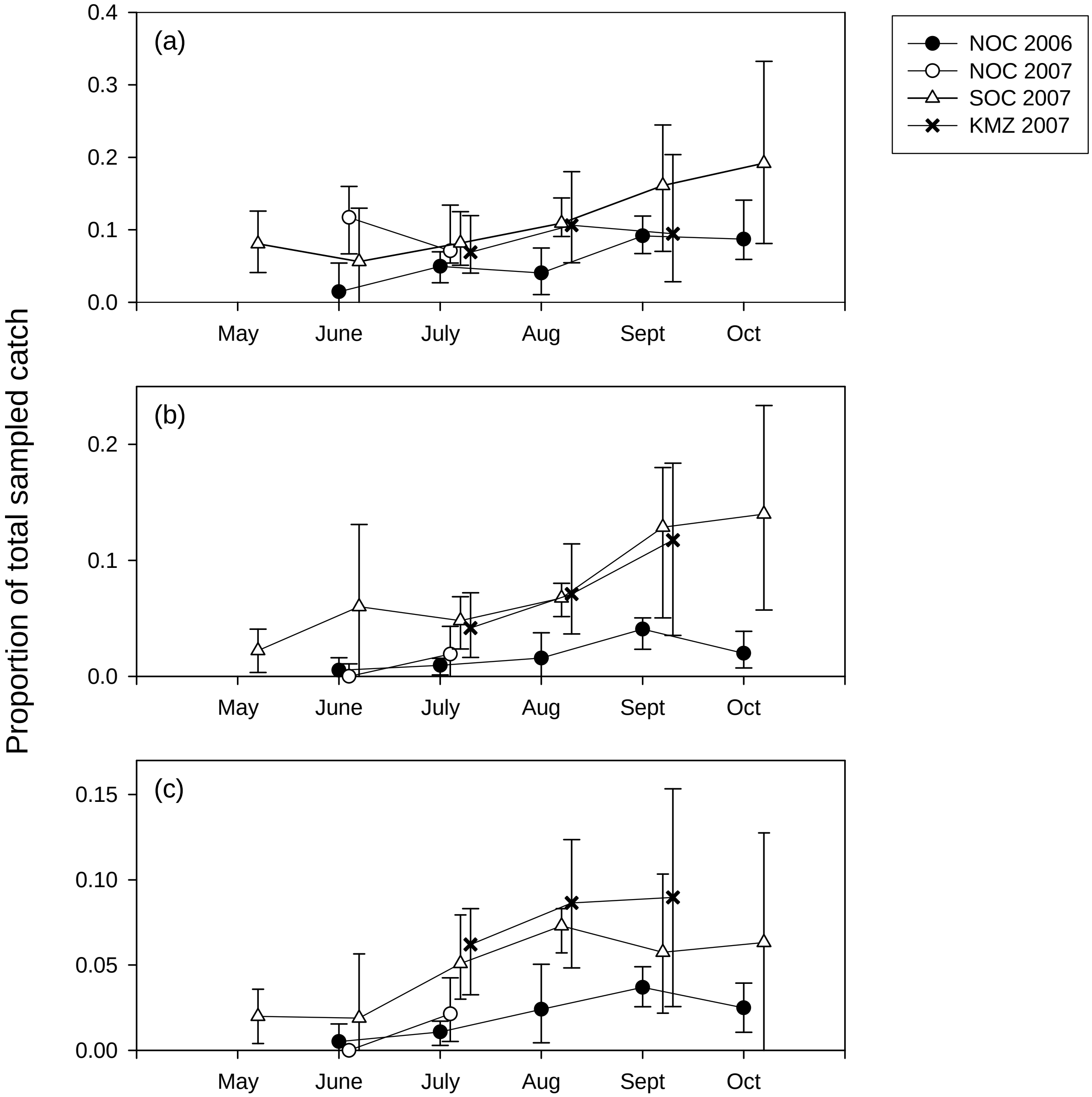


Figure 6. Upper Columbia River summer/fall, the Columbia River stock that contributed the most to compositional estimates of stocks harvested off the coast of Oregon during the 2006 and 2007 commercial Chinook troll fishing season. Mixed stock analysis was performed using GAPS baseline v 2.1 and program ONCOR (Kalinowski 2007).

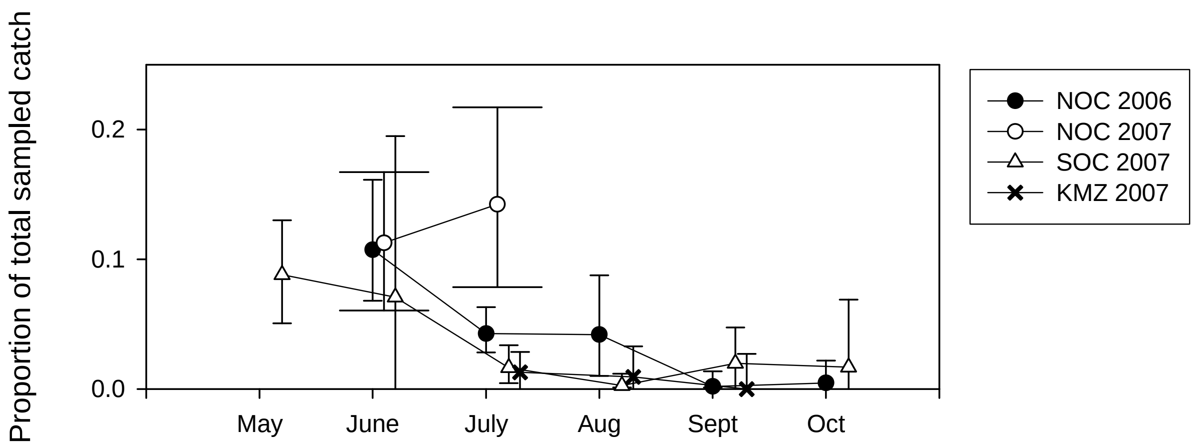


Figure 7. August 5-11, 2007 catch per unit effort (CPUE, rate of fish harvest per hour) and proportional estimates of stock encounters in four areas estimated using mixed stock analysis (clusters 2 and 4) or individual assignment (clusters 1 and 3), GAPS baseline v 2.1 and program ONCOR (Kalinowski et al. 2007).

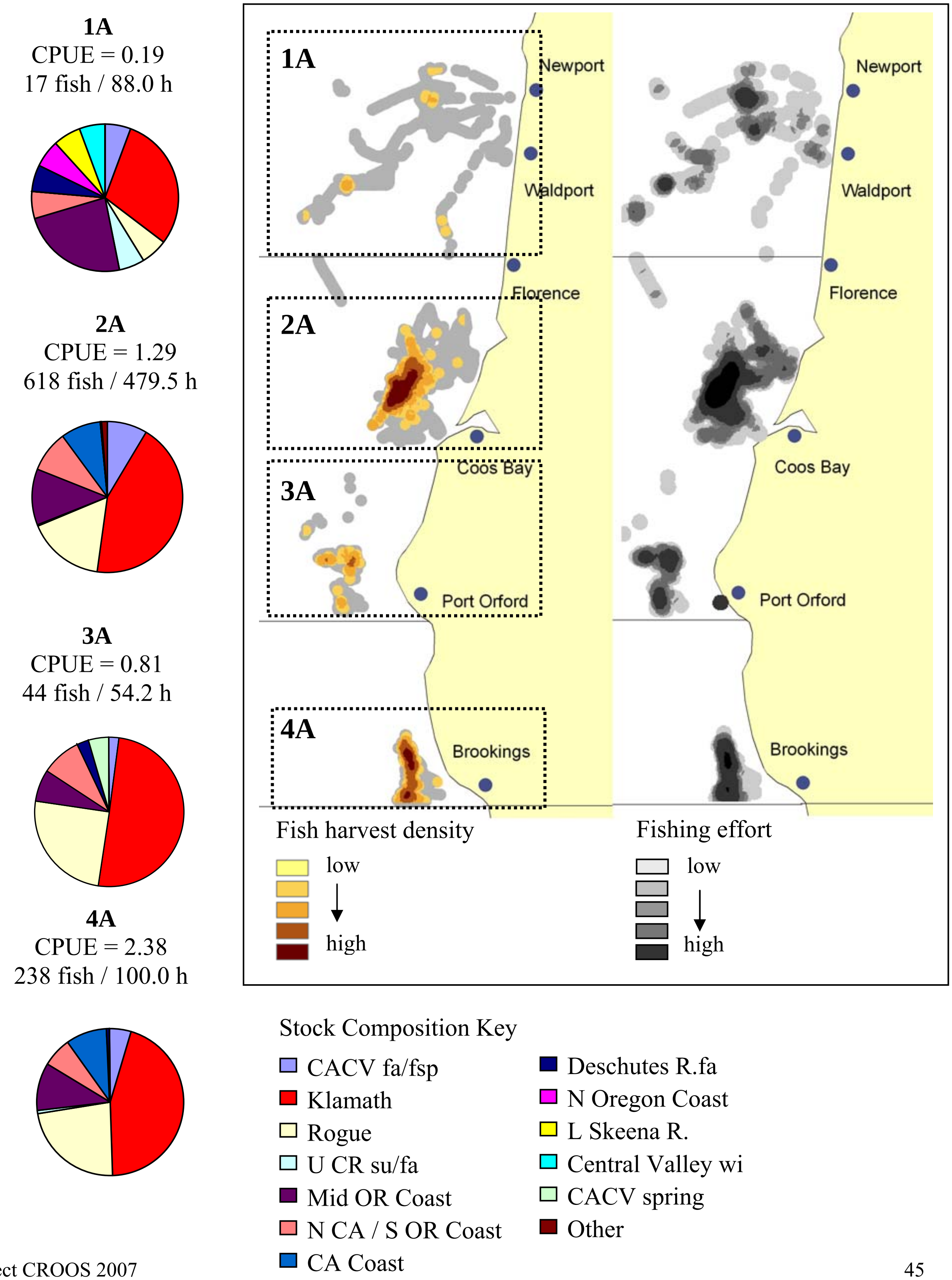


Figure 8. August 12-18, 2007 catch per unit effort (CPUE, rate of fish harvest per hour) and proportional stock encounters based on compositional estimates for three areas using mixed stock analysis (cluster 2 and 3) or individual assignment (cluster 1), GAPS baseline v 2.1 and program ONCOR (Kalinowski et al. 2007).

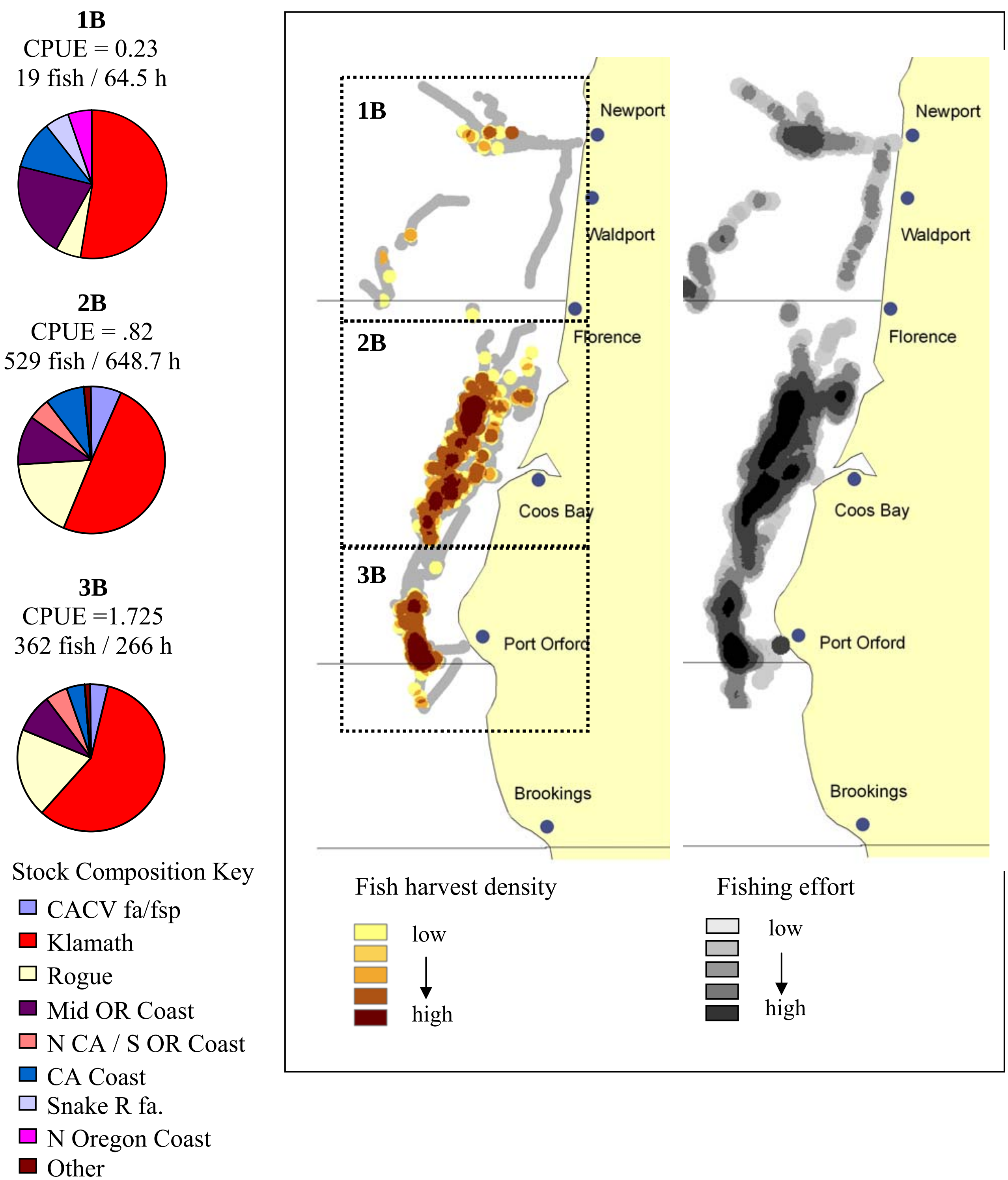


Figure 9 August 19-25, 2007 catch per unit effort and proportional stock encounters estimated using individual assignment, GAPS baseline v 2.1 and program ONCOR (Kalinowski et al. 2007).

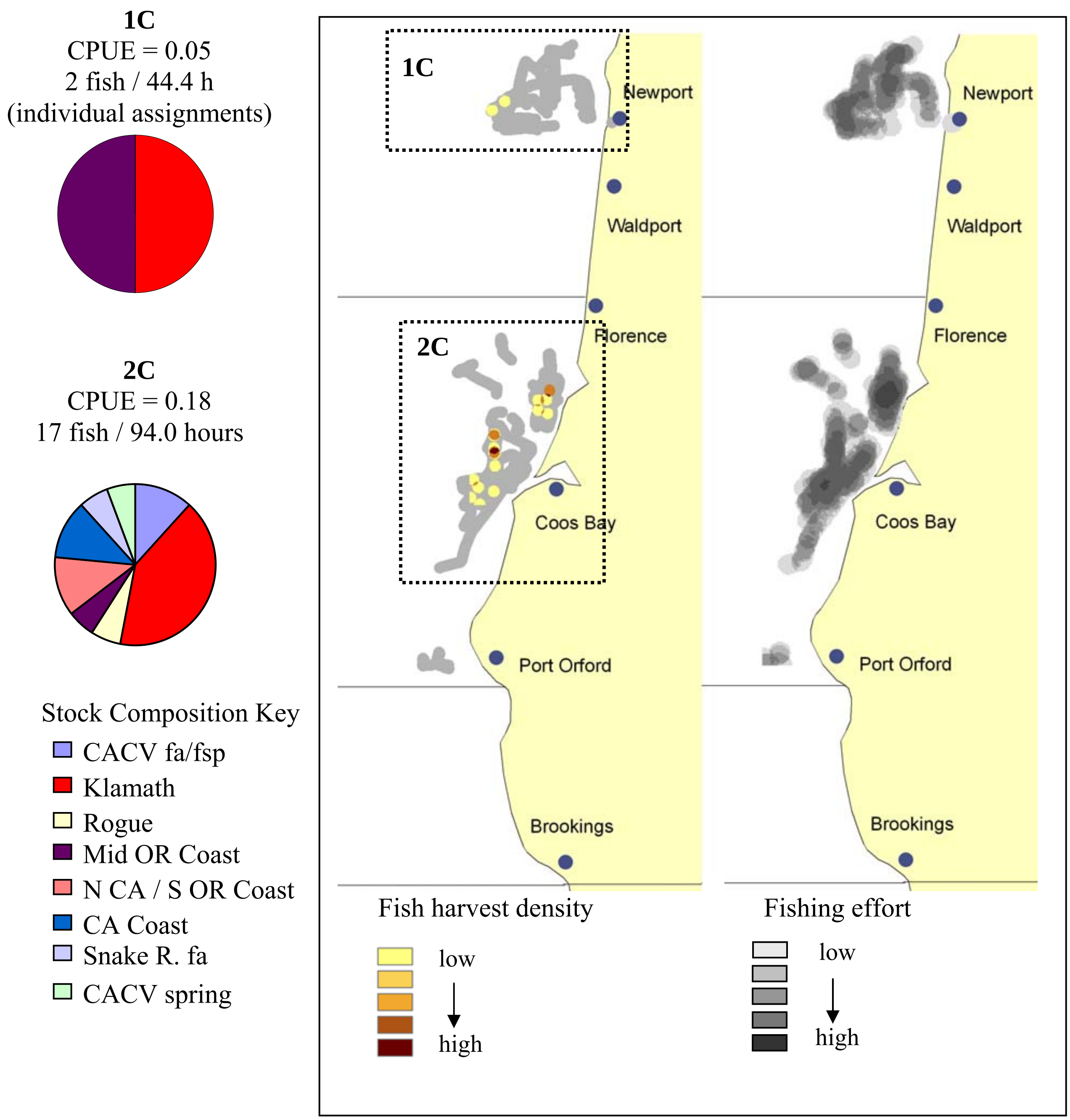
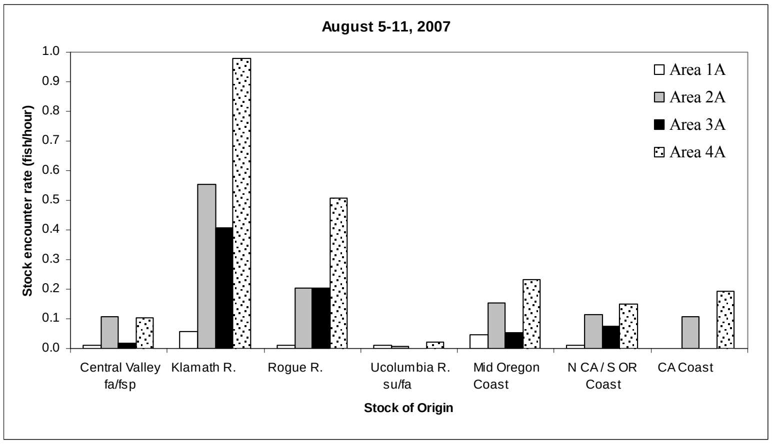
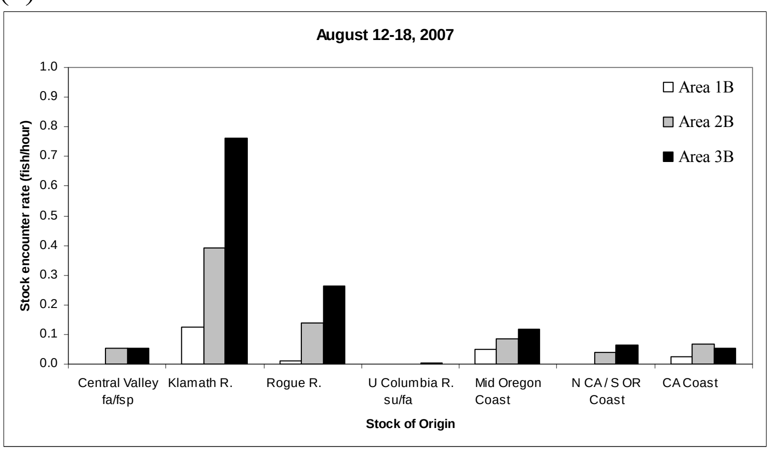


Figure 10. Stock encounter rates during three weeks of commercial Chinook salmon fishing in August, 2007: (a) August 5-11, (b) August 12-18, and (c) August 19-25. Stock encounter rates per hour were calculated as the number of fish by stock harvested per hour using mixture proportions estimated with GAPS baseline v 2.1 and ONCOR (Kalinowski et al. 2007).

(a)



(b)



(c)

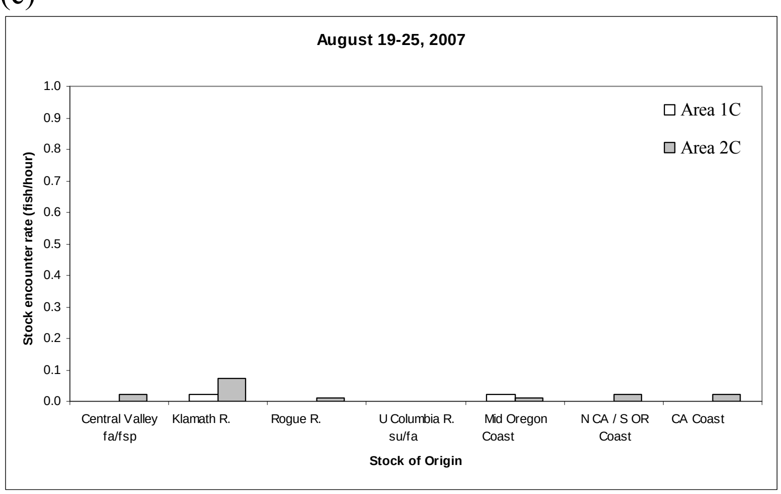
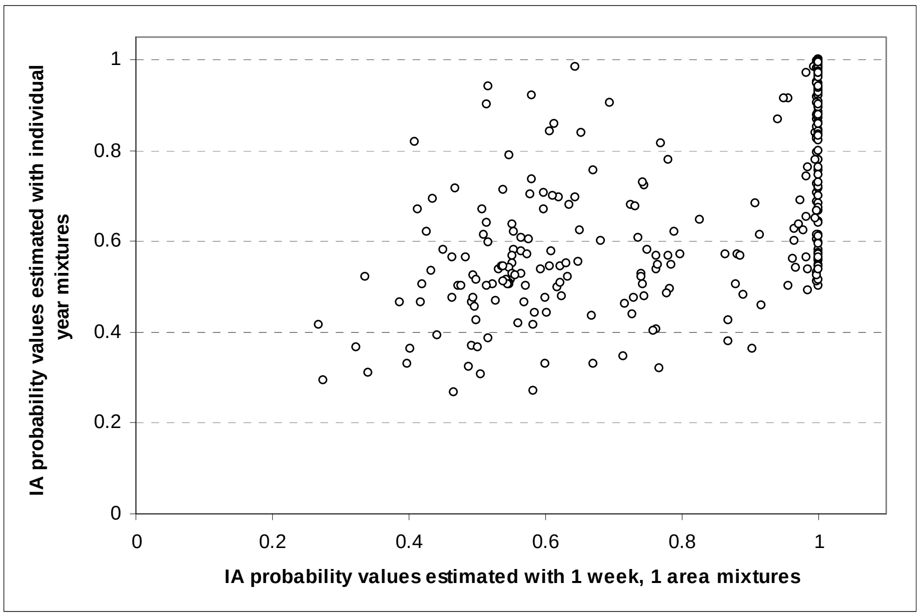
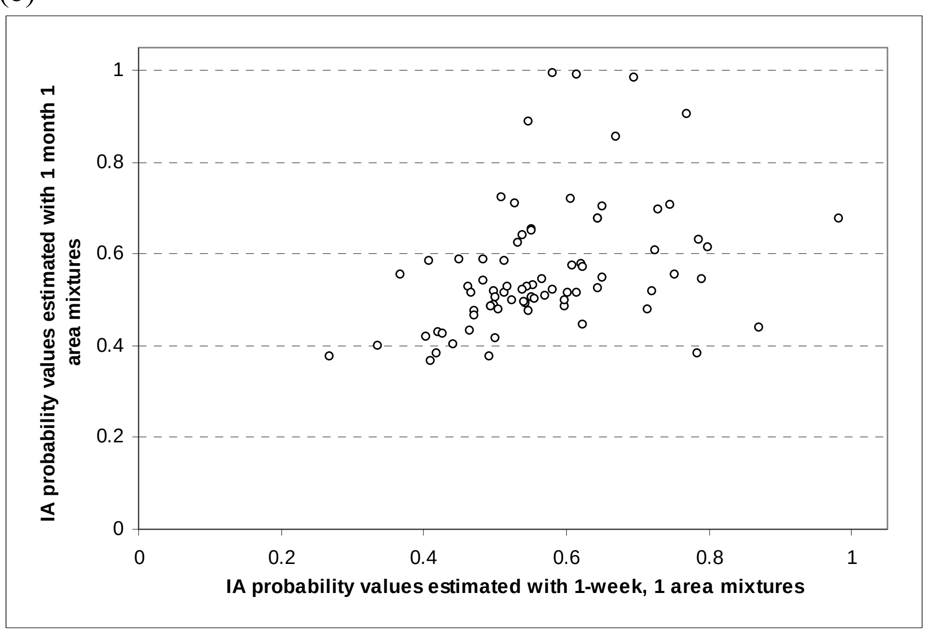


Figure 11. Pairwise comparison of probability values for individual fish that changed assignments when the temporal and spatial scale of the mixture sample was varied. (a) Individual fish that changed assignments in yearly (all management zones combined) mixtures compared to a mixture containing a single week in a single management zone (total n = 4884, of which n = 273 changed assignments) and (b) single month and management zone compared to single area and week (total n = 4884, n = 80 changed assignments).

(a)



(b)



Section 3

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 stock size forecasts, status assessment, identification of hatchery strays, and growth analyses. We analyze about 15,000 scale samples annually. We analyze scales from more Chinook salmon than any other species. For the Project Collaborative Research on Oregon Ocean Salmon (Project CROOS), we determined the total age of Chinook salmon that were sampled from the ocean troll fishery of 2006 and 2007 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. In this report we present the results from the 2007 fishery.

METHODS

In 2007, samples were collected from Chinook salmon caught in the ocean off Oregon south of Cape Falcon. Three management areas were defined: The North Oregon coast (NOC) covered Cape Falcon to Florence; the South Oregon coast (SOC) was bounded by Florence to the north and Humbug Mt to the south; and the Klamath Management Zone (KMZ) covered the area from Humbug Mt. to the Oregon-California border. The scales were taken 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 a unique bar code assigned to each fish. Sampling data were recorded on the envelope and in hand-held recorders. After the genetic analysis was completed for each fish, we were given scale samples from those fish that had greater than or equal to 0.90 percent probability of membership in a specific stock group. From each sample we mounted one to four of the scales in the best condition 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 1). If the winter has been harsh, an annulus may also appear to have scarring which is caused by resorption of the scale. For 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 calendar year than the fish that are spawned in August through December. Because 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 staff read the scale collection independently and then 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. Each reader made a second reading of a subset of the samples based on their stock assignment if it was judged to have a possible yearling-smolt life history; specifically the northernmost stocks and Columbia River stocks. Field data were taken into consideration for the third, joint reading.

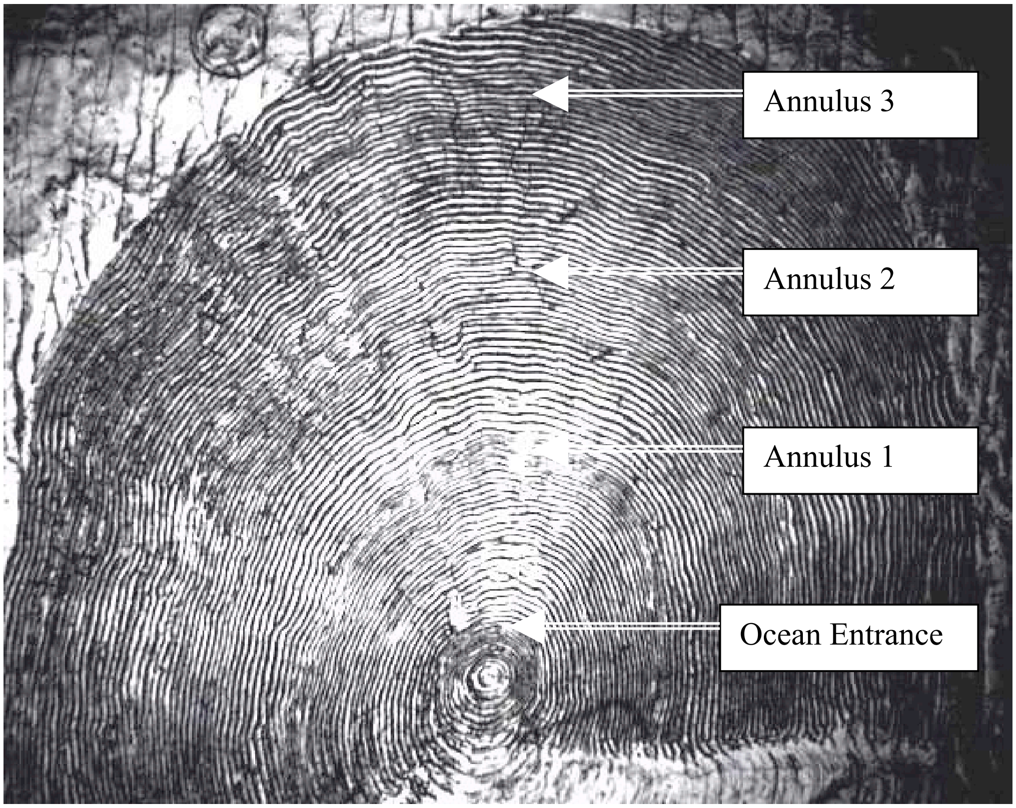


Figure 1. Scale of an age-4 Chinook salmon caught in the ocean off Oregon.

We randomly mounted 36 “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 36, the tag code and know age was withheld from the field data that was available during our third, joint reading. An additional five known age samples were also read without knowledge of any field data but were not a part of the general collection because their probability of genetic classification was less than 90 percent

RESULTS AND DISCUSSION

We mounted 2,835 scales samples and were able to determine the age of 2,456 fish from the general fishery. We were unable to read 62 scales because they had been regenerated after the original scale had been lost. Regenerated scales have no circuli or annuli in the regenerated portion. An additional 317 scales were exluded because they did not meet the acceptable minimum probability (90%) of group inclusion in the genetic analysis. Additional scales were read from the November “bubble” fishery off the Elk River, and 35 were from the October “bubble” fishery off the Chetco River. The sample size will not be provided for the Elk River bubble fishery because less than three fishers participated and disclosure of the sample size may violate the confidentiality requirement of the Magnuson-Stevens Fishery Conservation and Management Act.

We aged 41 scale samples from fish containing coded wire tags (CWT) for the 2007 analysis. One sample was of late fall stock from Coleman National Fish Hatchery. This fish was spawned in January or

February of 2004 so was calculated to be age-3 in the summer of 2007. We aged this fish as age-4 since it carries the same scale pattern of Chinook salmon that were spawned from August to December in 2004. We do not consider this to be an aging error. We incorrectly aged 2 fish (Table 1) and correctly aged 95.1% of the CWT samples. A list of the CWT fish read for this analysis is found in Appendix 1.

Table 1. Reading results for coded wire tagged Chinook salmon sampled from the commercial fishery off Oregon for Project CROOS in 2007.

Scale Reading Age	Known Age			Number of scales aged
	Age 3	Age 4	Age 5	
3	20	1	0	21
4	1	15	0	16
5	0	0	4	4
Total	21	16	4	41

The age composition for the 2007 ocean commercial fishery was 0.04 percent age-2, 54.2 percent age-3, 36.9 percent age-4, 8.2 percent age-5, 0.6 percent age-6, and 0.04 percent age-7. Age compositions from NOC, SOC, KMZ, the Elk River bubble fishery (ERB), and the Chetco River bubble fishery (CRB) are given in Table 2. The age composition of the NOC was significantly different from the age compositions of both the SOC and KMZ groups ($p<0.05$). The age compositions of the SOC and the KMZ were similar to each other with large age-3 components.

Through the summer, the age composition also changed (Table 3). Coast wide, the age-4 fish comprised a majority of the catch in May and June. In July, August, and September the age composition shifted to a strong age-3 component. In October the age composition was almost evenly split between age-3, age-4, and age-5 fish.

Table 2. Age composition of Chinook salmon sampled in different management areas of the ocean troll fishery in 2007.

Management Area	Percentage at Age						Number of Scales Read
	2	3	4	5	6	7	
N. Oregon Coast	--	33.9	42.5	20.9	2.4	0.3	292
S. Oregon Coast	0.1	57.9	36.2	5.5	0.3	--	1,696
Klamath Mgt Zone	--	57.9	35.3	6.8	--	--	468
Elk R. Bubble	--	23.3	53.5	18.6	4.6	--	na
Chetco R. Bubble	--	31.0	27.6	41.4	--		29
Total	0.04	54.2	36.0	8.2	0.6	0.04%	

Table 3. Monthly age composition of Chinook salmon sampled in the ocean troll fishery in 2007

Month	Age 2	3	4	5	6	7	Number of scales read
May	--	21.5	63.3	14.6	0.6	--	158
June	--	29.7	54.8	14.8	0.0	0.7	155
July	--	56.3	34.7	8.8	0.2	--	579
August	0.1	60.7	34.2	4.7	0.3	--	1,324
September	--	68.0	24.6	5.7	1.7	--	175
October	--	35.4	32.3	27.7	4.6	--	65
Total	0.04%	55.0%	36.8%	7.6%	0.5%	0.04%	2,456

Most of the shifts in age composition either by time or area can be explained by the differences of individual stocks and their prevalence in the fishery at a given time. The more Northern stocks tend to have a larger component of older fish while the Southern stocks are younger (Table 4). In 2003, 2004, and 2005, the age-3 component of the Klamath stock escapement was 48 percent, 37 percent and 65 percent, respectively (Klamath River Technical Advisory Team 2004, 2005, 2006). In the 2007 ocean fishery, the Pacific Fishery Management Council (PMFC) estimated that the Klamath stock could be comprised of as much as 94.4 percent age-3 fish (PFMC 2007). Historically, stocks from California's Central Valley have also had a large component of age-3 fish in their spawning populations. Fisher (1994) estimated that age-3 fish comprised 77 and 57 percent of the fall and late-fall runs, respectively. In the ocean fishery of 2007, the Central Valley stocks were mostly comprised of age-4 fish. This was likely the result of low survival of the three year old age class of 2007 (Pacific Fisheries Management Council 2008) rather than a change in the age-composition of these stocks.

Between May and August, in all three general management zones, the monthly fluctuations between age-3 and age-4 were attributable to a strong presence by either the Klamath or Central Valley stocks (Genetics Science Section, this report). This situation also existed in September in the SOC and KMZ. Table 5 shows age compositions by area and time. During June and July in the NOC and during May and June in the SOC, there was a notable age-5 component that was probably related to the catch of Upper Columbia River summer/fall stocks and Mid Oregon Coast stocks. In the NOC during September and October, there were increases in age-4 or age-5 fish in the age composition at a time when North and Mid coast Oregon fish were returning into the area to spawn (Nicholas and Hankin 1988). In October in the SOC, increases in age-4 and age-5 fish were due to presence of Rogue and Oregon mid-coast fish in the fishery. While the Rogue stock was usually the second or third contributor to the catch in most areas or months (Genetic Science section, this report), it did not show a strong influence in the age composition because by age, it was similar to the California stocks and was masked by the presence of strong Klamath or Central Valley groups.

The Elk River bubble fishery occurs within the SOC area but within three miles of shore in November. Not surprisingly, 98.4 percent of the catch was of Mid Oregon coast stock of which Elk River hatchery and wild fish are components. The age composition during this fishery was similar to the historic age composition (excluding age-2 fish) for Elk River hatchery and wild stocks (Nicholas and Hankin 1988)

Table 4. Age composition of stocks of Chinook salmon sampled in the ocean troll fishery off Oregon in 2007. Stock is identified by genetic analysis. These data may not represent the full age composition of these stocks upon escapement to their stream of origin.

Stock	Age 2	3	4	5	6	7	Number of scales read
Alaska- Stikine	0.0	0.0	50.0	50.0	0.0	0.0	2
Fraser	0.0	25.0	62.5	12.5	0.0	0.0	8
Mid Fraser	0.0	0.0	0.0	100.0	0.0	0.0	7
S Thompson	0.0	20.0	20.0	60.0	0.0	0.0	5
Skeena	0.0	0.0	0.0	100.0	0.0	0.0	2
W Vancouver Is.	0.0	0.0	100.0	0.0	0.0	0.0	1
British Columbia/SE Alaska	**--**	**11.5**	**36.6**	**53.9**	**--**	**--**	**26**
Hood Canal	0.0	50.0	50.0	0.0	0.0	0.0	2
N Puget Sound	0.0	50.0	50.0	0.0	0.0	0.0	2
S Puget Sound	0.0	47.4	52.6	0.0	0.0	0.0	19
WA Coast	0.0	0.0	0.0	50.0	0.0	50.0	2
Washington	**--**	**44.0**	**48.0**	**4.0**	**--**	**4.0**	**25**
Deschutes Fall	0.0	21.4	71.4	7.2	0.0	0.0	14
L. Columbia Fall	0.0	34.8	47.8	17.4	0.0	0.0	23
L. Columbia Spring	0.0	33.3	50.0	16.7	0.0	0.0	6
Mid Columbia Tule	0.0	63.7	31.4	2.9	0.0	0.0	35
Mid-Upper Columbia Spr.	0.0	0.0	100.0	0.0	0.0	0.0	1
Snake Fall	0.0	57.1	28.6	14.3	0.0	0.0	7
U Columbia Summer/Fall	0.0	14.0	40.0	44.0	2.0	0.0	50
Willamette	0.0	0.0	0.0	100.0	0.0	0.0	1
Columbia River	**--**	**34.3**	**42.4**	**22.6**	**0.7**	**--**	**137**
N OR Coast	0.0	10.0	23.3	53.3	13.3	0.0	30
Mid OR Coast	0.0	30.0	52.4	15.0	2.6	0.0	227
Rogue	0.0	49.1	42.2	8.7	0.0	0.0	275
N CA/S OR	0.0	37.5	43.8	18.7	0.0	0.0	176
Oregon Coast	**--**	**38.4**	**45.1**	**15.1**	**1.4**	**--**	**708**
Klamath	0.1	72.3	25.9	1.6	0.1	0.0	1232
CA Coast	0.0	49.2	40.4	9.3	1.1	0.0	184
Central Valley	0.0	26.4	65.7	7.9	0.0	0.0	216
California	**0.1**	**63.6**	**32.8**	**3.3**	**0.2**	**--**	**1632**

The Chetco bubble fishery occurred in October within 3 miles of shore near the mouth of the Chetco River. In this fishery, the largest age component was age-5, while the major stock component was N. California/S. Oregon which includes Chetco stock. The historic age composition (excluding age-2 fish) for Chetco stock has over 23% age-5 fish (Borgerson and Bowden 2001).

Comparison of 2006 and 2007 results

In 2006, the fishery was restricted to the NOC. The June and July age compositions were similar in both years with strong age-4 components while the major stock was Central Valley. Further comparison between the years is difficult because of poor samples sizes in the remaining months of 2007 and the fact that the entire August sample of 2006 was collected during the first three days of the month, while samples were taken throughout the month in 2007.

Table 5. Age composition of Chinook salmon sampled monthly in different management areas of the ocean troll fishery in 2007.

Mgt Zone	Month	Age 2	3	4	5	6	7	Number of scales read
NOC	June	--	31.8	50.9	16.4	--	0.9	110
	July	--	33.6	43.9	21.5	0.9	--	107
	August	--	65.5	27.6	3.5	3.5	--	29
	September	--	31.8	27.3	27.3	13.6	--	22
	October	--	8.3	29.2	54.2	8.3	--	24
NOC season total		**--**	**29.2**	**48.4**	**19.4**	**2.7**	**0.3**	**292**
SOC	May	--	21.5	63.3	14.6	0.6	--	158
	June	--	26.5	61.8	11.8	--	--	34
	July	--	65.4	30.2	4.4	--	--	275
	August	0.1	61.2	33.9	4.5	0.3	--	1,104
	September	--	70.8	27.0	2.2	--	--	89
	October	--	55.6	33.3	8.3	2.8	--	36
SOC season total		**0.1**	**57.9**	**36.2**	**5.5**	**0.3**	**--**	**1,696**
KMZ	June	--	18.2	72.7	9.1	--	--	11
	July		55.8	36.1	8.1	--	--	197
	August	--	57.1	37.2	5.7	--	--	191
	September, October	--	78.1	23.4	6.3	--	--	69[a]
KMZ season total		**--**	**57.9**	**35.3**	**6.8**	**--**	**--**	**468**
ERB	**November**	**--**	**23.3**	**53.5**	**18.6**	**4.6**	**--**	**NA[b]**
CRB	**October**	**--**	**31.0**	**27.6**	**41.4**	**--**	**--**	**29**

a October sample size was 5.
b Due to confidentiality requirement of the Magnuson-Steven Act, sample size cannot be given.

Appendix Table 1. List of scale samples from Chinook salmon with Coded wire tags (CWT) analyzed from the 2007 ocean fishery.

Hatchery	Stock	Tag Code	CWT Age	Scale Age	Date	Ocean Area	Fork Length
CEDC Youngs Bay Net	Cole Rivers H.	93949	3	3	7/27/07	SOC	70.5
CEDC Youngs Bay Net	Cole Rivers H.	93948	3	3	7/18/07	SOC	66.8
Klaskanine S Fk Pond	Cole Rivers H.	620227	3	3	8/13/07	SOC	67.4
Big Creek.	Cole Rivers H.	93960	4	4	5/18/07	SOC	75.9
Lewis River	Lewis River -NF	631878	5	5	7/15/07	NOC	91.1
Lyons Ferry	Snake R-Lower	631769	4	4	8/4/07	SOC	68.0
Dryden Pond	Wenatchee R	631980	5	5	5/17/07	SOC	91.1
Wells	Wells H.	631394	5	5	5/17/07	SOC	82.3
Rock Creek	Umpqua	93713	4	4	8/6/07	SOC	77.8
Bandon	Coquille R.	92349	3	3	8/12/07	SOC	68.0
Elk River	ELK R (ELK R HT)	94132	3	3	7/18/07	SOC	68.0
Elk River	ELK R (ELK R HT)	93961	4	4	8/6/07	SOC	71.1
Elk River	ELK R (ELK R HT)	93961	4	4	11/14/07	SOC	77.8
Elk River.	ELK R (ELK R HT)	93961	4	4	11/14/07	SOC	82.6
Elk River	ELK R (ELK R HT)	93961	4	4	11/14/07	SOC	81.4
Indian Creek Pd (STEP)	ROGUE R LWR	92115	4	4	8/7/07	SOC	79.0
Indian Creek Pd (STEP)	ROGUE R LWR	93820	5	5	8/6/07	SOC	89.9
Cole Rivers	COLE RIVERS H.	94011	4	4	8/14/07	SOC	75.3
Iron Gate	Klamath River	601020505	3	3	8/13/07	SOC	70.5
Iron Gate.	Klamath River	601020502	4	4	9/10/07	KMZ	77.8
Trinity River	Trinity River	65322	3	3	7/27/07	SOC	65.6
Trinity River	Trinity River	65325	3	3	8/5/07	SOC	69.3
Trinity River	Trinity River	65325	3	3	8/13/07	SOC	72.9
Trinity River	Trinity River	65322	3	3	8/15/07	SOC	68.0
Trinity River	Trinity River	65322	3	3	8/9/07	SOC	70.5
Trinity River	Trinity River	65324	3	3	8/6/07	SOC	68.0
Trinity River	Trinity River	65327	3	3	8/10/07	SOC	79.0
Trinity River	Trinity River	65325	3	3	8/6/07	SOC	80.2
Trinity River	Trinity River	65327	3	3	8/14/07	SOC	70.5
Trinity River	Trinity River	65327	3	3	8/14/07	SOC	70.5
Trinity River	Trinity River	65326	3	3	6/8/07	SOC	68.0
Trinity River	Trinity River	65327	3	3	9/10/07	KMZ	68.0
Trinity River	Trinity River	65325	3	3	8/13/07	SOC	68.0
Trinity River	Trinity River	65327	3	3	8/13/07	SOC	72.3
Trinity River	Trinity River	65318	4	**3**	8/10/07	SOC	74.1
Trinity River	Trinity River	65318	4	4	7/29/07	SOC	70.5
Trinity River	Trinity River	65317	4	4	5/6/07	SOC	69.4
Trinity River	Trinity River	65316	4	4	8/7/07	SOC	74.1
Trinity River	Trinity River	65318	4	4	8/12/07	SOC	65.6
Feather River	Feather River	62438	3	**4**	8/13/07	SOC	72.9
Coleman NFH	Coleman NFH	52273	3	4 [a]	7/28/07	SOC	92.3

[a] Not considered a scale reading error. See Methods Section for explanation.

REFERENCES

Borgerson, L.A and R.K. Bowden. 2001. Scale Analysis. Oregon Department of Fish and Wildlife, Fish Research Project F-144-R-12, Annual Progress Report, Portland.

Fisher, F.W. 1994. Past and present status of Central Valley Chinook salmon. Conserv. Biol. 8:870-873.

Klamath River Technical Advisory Team. 2004. Klamath River Fall Chinook Age-Specific Escapement, 2003 Run. U.S. Fish and Wildlife Service, 1829 South Oregon Street, Yreka, CA, 96097.

Klamath River Technical Advisory Team. 2005. Klamath River Fall Chinook Age-Specific Escapement, River Harvest, and Run Size Estimates, 2004. U.S. Fish and Wildlife Service, 1829 South Oregon Street, Yreka, CA, 96097.

Klamath River Technical Advisory Team. 2006. Klamath River Fall Chinook Age-Specific Escapement, River Harvest, and Run Size Estimates, 2005. U.S. Fish and Wildlife Service, 1829 South Oregon Street, Yreka, CA, 96097.

Nicholas, J.W., and D.G. Hankin. 1988. Chinook salmon populations in Oregon coastal river basins: Description of life histories and assessment of recent trends in run strengths. Oregon Dep. Fish Wildlife, Fish Div. Info. Rep., No. 88-1, 359 p.

Nicholas, J.W., and L.A. Van Dyke. 1982. Straying of adult coho salmon to and from a private hatchery at Yaquina Bay, Oregon. Oregon Department of Fish and Wildlife, Information Reports (Fish) 82-10, Portland.

Pacific Fishery Management Council. 2007. *Preseason Report II: Analysis of Proposed Regulatory Options for 2007 Ocean Salmon Fisheries.* (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384

Pacific Fishery Management Council. 2008. *Preseason Report I: Stock Abundance Analysis for 2008 Ocean Salmon Fisheries.* (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Section 4

Otolith Structural and Chemical Analyses

OTOLITH STRUCTURAL AND CHEMICAL ANALYSES OF CROOS CHINOOK SALMON

Background & 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 in trees. 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 (Thresher 1999, Campana and Thorrold 2001). Certain elements, such as strontium and barium, and isotopes, which are forms of the same element that have different atomic masses, provide different types of information about the life of an individual fish. Studies that examine a suite of elemental ratios, such as Ba:Ca, Sr:Ca, and 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 concentration of Sr:Ca across the otolith growth axis, information on when an anadromous fish, such as Chinook salmon, entered the ocean can be determined. By measuring the oxygen isotopic ratio in otoliths, we can generate relative information about the temperature of the water in which the salmon lived. All of these chemical analyses can be combined with microstructural analyses, the counting of daily or annual increments within the otoliths, to provide information about discrete periods in the life of a fish. 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. 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 2006-07 CROOS project were 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 otolith chemistry can provide information about stock-specific ocean migration and mixing in Chinook salmon.
2) If there is stock-specific variation in the oxygen isotopic ($\delta^{18}O$) history of Chinook, which can also provide relative temperature histories for 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.
4) If the size-at-brackish/ocean entrance can be estimated using otoliths of adult Chinook salmon in order to examine variability within and among different stocks.

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: Scott Boley (deceased) of Gold Beach was responsible for coordinating the majority of the collections. 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 locations. 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, about 30%, which reduced the number of otoliths for analysis to 194.

Polished otolith sections were mounted onto glass slides, cleaned, and transported to OSU's WM Keck Collaboratory for Plasma Spectrometry in Corvallis for elemental analysis. Elemental data (^{25}Mg, ^{43}Ca, ^{55}Mn, ^{86}Sr, ^{138}Ba, and ^{208}Pb) were collected along the otolith growth axis (Figure 1). 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 usually be identified by examining the strontium concentration across the otolith growth axis (Figure 1). When combined with microstructural analysis, the elemental composition of the otolith during discrete periods of an individual's life, such as the last year of life in the ocean, can be determined.

One potential concern was the adequate identification of annuli, or the visible winter check marks on otoliths, to ensure accurate ageing and identification of comparable years of ocean residence. Chinook otoliths are opaque and can be difficult to age (Murray 1994). However, Murray (1994) reports that readability can be greatly improved by storing otoliths in 60:40 glycerine and buffered isotonic saline for three months: fresh and archived otoliths developed distinct annuli after 3 months in glycerine and saline. Here, age determination using otoliths occurred using the moderately thin transverse section (Figure 1) in which annuli appeared relatively distinct. Age determination using scale analysis was completed by ODFW and occurred in 82% of the fish for which otoliths were available. For the 133 fish for which scale and otolith ages were both completed, agreement between methods was very good (92%). The ability to age thinner otolith sections, however, was much lower due to the exposure of many confounding check marks.

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

Examination of stock-specific differences in elemental chemistry was completed for stocks with adequate and balanced sample sizes ($n \geq 10$) for statistical analysis. Therefore, the analysis included Central Valley (*n* = 21), Rogue River (*n* = 10), and Mid-Columbia Tule (*n* = 11). The elemental composition during the last two ocean years (Figure 1) was determined and differences among stocks were compared with Analysis of Variance (ANOVA). For the last year at sea (2006), Mg:Ca and Sr:Ca concentrations were significantly different among stocks ($p < 0.05$) and Mn:Ca was marginally non-significant ($p = 0.10$). For the year prior to capture (2005), Mg:Ca and Sr:Ca concentrations were also significantly different among stocks ($p < 0.01$). The ability to group stocks by otolith elemental composition was explored using discriminant function analysis (DFA) and determining jack-knifed classification accuracies, which provide a more robust estimate of classification ability for small sample sizes. For the last year at sea (2006), Mg:Ca, Sr:Ca and Ba:Ca were significant variables in the DFA model ($F > 3.0$) and, for the year prior to capture (2005), Mg:Ca, Mn:Ca, and Sr:Ca were significant variables in the model ($F > 2.6$). In both cases, nearly 70% of the fish were correctly classified to stock (Table 1). In order to further test the robustness of the predictions, fish were randomly assigned to three groups in the same proportion as the actual dataset and classified to determine random accuracy of assignment, which was ≤43% (Table 1).

These data indicate that, on average, the majority of fish from these three stocks resided in waters with different chemical characteristics, resulting in some consistent differences in otolith elemental composition. This analysis includes only one year of data and, therefore, must be considered preliminary. Related research examining stock-specific migration patterns using CWT data is on-going (Laurie Weitkamp, NOAA, pers. com.) and will provide valuable comparative information on movement patterns.

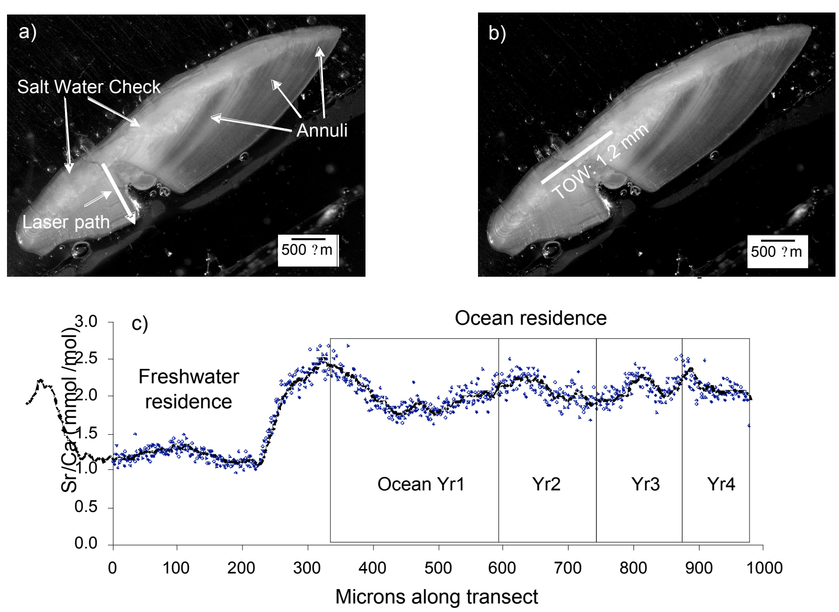


Fig. 1. a) Transverse section of otolith from a 68-cm Mid-Columbia Tule Chinook with an ocean-type life history. Laser path for elemental analysis, time of entrance into saline waters, and three ocean annuli are identified. b) Same otolith as in (a) with a transect representing the total otolith width (TOW) at time of entrance into brackish/oceanic waters. c) Sr/Ca concentrations across the laser path of otolith in (a) and (b).

Table 1. Results of the discriminant function analysis (DFA) to classify fish using otolith elemental composition. Jacknifed assignment accuracies are presented for the actual dataset; randomized estimates are presented in parentheses. Mg:Ca, Mn:Ca, and Sr:Ca were used for the 2005 assignments and Mg:Ca, Sr:Ca, and Ba:Ca were used for the 2006 assignments.

Stock	2005	2006
Central Valley (*n* =21)	71% (48%)	67% (33%)
Rogue (*n* = 10)	60% (30%)	70% (33%)
Mid-Columbia Tule (*n* = 11)	64% (18%)	73% (64%)
Total	69% (36%)	69% (43%)

Objective 2: Examine variation in oxygen isotopic composition of Chinook salmon from different stocks.

Chinook otoliths from two stocks, the Rogue River and Mid-Columbia Tule, were used to collect otolith carbonate for determination of oxygen isotopic composition ($\delta^{18}O$). Otolith carbonate was collected from the otoliths of four fish. Each carbonate sample was collected from four to eight time periods within each ocean year, which represented from 30 to 90 d per sample. 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. The $\delta^{18}O$ incorporated into the otolith depends on the $\delta^{18}O$ concentration, salinity, and temperature of the water; the relationship between temperature and the fractionation rate has been described empirically for otoliths in several species (Kalish 1991a, b, Radtke et al. 1996, 1998, Thorrold et al. 1997). The comparison of $\delta^{18}O$ among otoliths from different fish can provide relative information on the similarity of the water masses in which these fish resided and, assuming uniform $\delta^{18}O_{water,}$ relative information on past temperature histories. The reconstruction of past temperature histories depends on robust estimates of $\delta^{18}O_{water}$ (Zahn et al. 1991). Without empirical data on $\delta^{18}O_{water}$ at relatively fine spatial scales, these estimates remain relative as they assume constant $\delta^{18}O_{water}$. Differences in $\delta^{18}O_{otolith}$ indicate that fish resided in waters with different temperatures and/or waters with different $\delta^{18}O$ values. Either way, the data provide an indication of whether individuals from within a stock had been in waters with similar characteristics when compared to individuals from other stocks.

Isotopic results are presented in per mil (‰) using the standard isotopic delta notation (δ) relative to Pee Dee Belemnite (PDB) scale. During ocean residence, otolith $\delta^{18}O$ ranged from 0.33 to -0.94 ‰. Using Radkte et al.'s (1998) equation for temperature fractionation and Zahn et al. (1991) estimate for $\delta^{18}O_{water}$ (salinity = 30.1), estimated water temperatures ranged from 8.3 to 14.6ºC. These values are similar to those reported from archival tag data for Chinook (Hinke et al. 2005a, Hinke et al. 2005b) although the salinity estimate is likely too low. These differences may be due to variation in the temperature fractionation relationship for Chinook salmon and can be improved with additional data on species-specific fractionation information and/or improved data on salinity and $\delta^{18}O_{water}$.

The data from four fish indicate a very similar $\delta^{18}O$ profile for the two Rogue River fish, a 3-yr and a 4-yr old, and quite different histories for the Mid-Columbia Tule, also a 3-yr and a 4-yr old (Figure 2). These preliminary data indicate that otolith $\delta^{18}O$ may well provide a marker that can provide information on stock-specific migration patterns. Given the assumption of constant $\delta^{18}O_{water,}$ the fish remained in a fairly narrow temperature range, resulting in overall mean of 11.24 ºC (±1.5). This is also similar to Hinke et al.'s (2005a; 2005b) overall mean of 10.0ºC. These data are from just four fish so few conclusions can be drawn at this stage. The feasibility of acquiring otolith carbonate at these temporal scales (30 to 90 d) has been demonstrated and reasonable temperature approximations generated, which demonstrate the potential of this methodology to provide more detailed information on stock-specific migration patterns in Chinook salmon. Improved information on ocean temperature histories can aid in identification and definition of Chinook ocean habitat and provide more robust information for realistic ocean growth models.

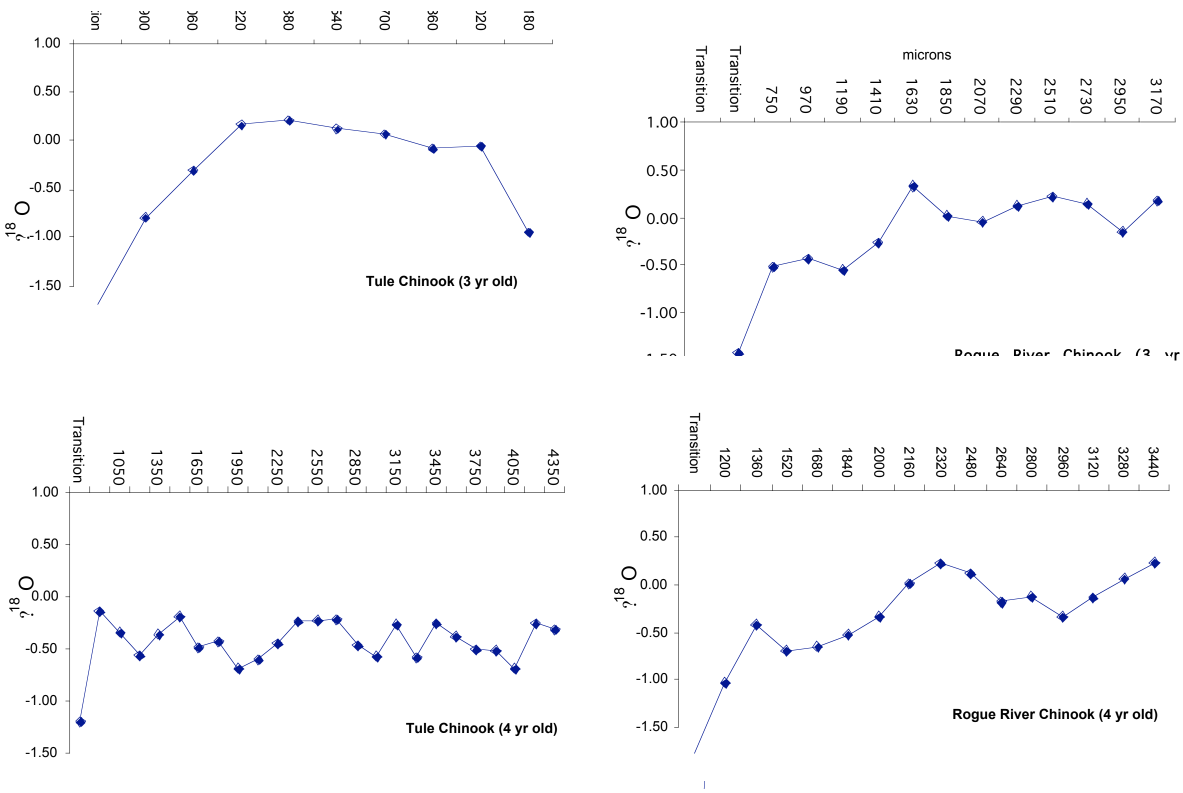


Figure 2. $\delta^{18}O$ values along the ocean growth transect for four Chinook salmon. Microns along transect from the freshwater-marine transition to the otolith edge are identified on the x-axis and $\delta^{18}O$ on the y-axis.

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 Feather River, 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 ($^{87}Sr/^{86}Sr$) 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. For fish from basins with relatively high river $^{87}Sr/^{86}Sr$ ratios, such as the American River, maternal rum-timing may be difficult to discriminate.

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. Core $^{87}Sr/^{86}Sr$ of fall-run offspring were consistently >0.7080 while core $^{87}Sr/^{86}Sr$ of spring-run offspring were <0.7080. Offspring of spring and fall fish from rivers within other basins with lower $^{87}Sr/^{86}Sr$ ratios than seawater are likely to have significantly different core $^{87}Sr/^{86}Sr$ ratios.

The $^{87}Sr/^{86}Sr$ ratios in the otoliths of a subset (n = 15) of the Central Valley Chinook that were classified as spring or fall run but with low assignment probabilities, <60%, were collected using a NuPlasma MC-LA-ICPMS and the New Wave DUV193 excimer laser at the WM Keck Collaboratory in Corvallis, Oregon. We followed the general method of Woodhead et al. (2005) to correct for potential Kr and Rb interferences and monitor for Ca argide/dimer formation. Background interferences by Kr isotopes and contributions from any other gas species present within the plasma and sweep gas supplies were corrected by measuring an on-peak baseline prior to ablation of otoliths. Measured backgrounds were then subtracted from measured intensities during otolith ablation. Mass biases were corrected by reference to a $^{86}Sr/^{88}Sr$ ratio of 0.1194 and isobaric interference of ^{87}Rb on ^{87}Sr was corrected for by measuring beam intensity for ^{85}Rb and calculating the contribution of ^{87}Rb. Ablation used a pulse rate of 10 Hz, a 70-μm diameter spot size, and the laser spot was translated across the sample at a rate of 2 μm sec^{-1}. Using this ablation protocol, total Sr intensity during data collection was consistently ≥ 1 V. Measurements are reported per block, each block was comprised of two, 2 s cycles. $^{87}Sr/^{86}Sr$ data were averaged across the $^{87}Sr/^{86}Sr$ plateau within the otolith core; each individual core otolith mean value was based on 10 blocks. Each block represented a 4 s average and the laser was moving at 2 _m sec^{-1}, therefore each block represents a track length of ~8 _m of new material. The ablation pit was, on average, 50 _m in depth.

Core $^{87}Sr/^{86}Sr$ concentrations were successfully determined for ten unknown Central Valley Chinook. There was uncertainty regarding whether the core was adequately sampled in some (n = 5) of the otoliths and, therefore, the results are not reported here. For the 10 remaining otoliths, 90% displayed core $^{87}Sr/^{86}Sr$ ≥ 0.70800, indicating a likely fall-run origin, while one otolith displayed core $^{87}Sr/^{86}Sr$ = 0.706087, indicating a potential spring-run origin. Based on genetic stock identification, this fish was grouped into the Central Valley fall/Feather River spring classification, there is a high probability this fish was a Feather River spring Chinook. The 0.70800 cut-off is based on data from Oregon runs and further validation of core $^{87}Sr/^{86}Sr$ from Chinook of known origin within a basin under consideration would be prudent prior to widespread interpretation of otolith $^{87}Sr/^{86}Sr$ data. However, the data generated from

Oregon hatcheries and CROOS Chinook otoliths combined demonstrates the feasibility of using otolith core $^{87}Sr/^{86}Sr$ to determine maternal run time.

Objective 4: 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 size and time at which a juvenile Chinook enters the ocean may 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 as sub-yearlings. A small percentage of individuals from some rivers, such as the Rogue and Umpqua, display a yearling life history. Currently, estimates of size-at-ocean entrance are available for only about 20% of Oregon's coastal Chinook populations. Although there may be optimal mean size or migration timing that optimizes survival, it is likely that what is optimal varies with fluctuations in environmental conditions. Additional information on the size-at-ocean entrance and how it relates to overall survival will be useful for hatchery management, such as release strategies and flow prescriptions, as well as habitat restoration and management efforts.

Although several approaches can be used to determine early life history (such as CWT), a promising avenue of research is to reconstruct individual migratory histories using otolith structural and chemical analyses. Past research has demonstrated that, due to the greater concentration of Sr:Ca typically present in seawater compared with most river systems, otolith Sr:Ca concentrations are greater during seawater residence (Secor et al. 1995, Secor et al. 2001, Kraus and Secor 2004). Therefore, otolith Sr:Ca can often be used to discriminate among freshwater and marine residence in diadromous fishes. In most freshwater water systems, Sr:Ca concentrations are significantly lower than ocean waters (3-4 vs. 8 $mmol•mol^{-1}$, respectively, thus allowing for determination of migration between fresh and oceanic waters (Bacon et al. 2004, Zimmerman 2005). There are some locations, such as river systems within the Sacramento-San Joaquin basin, that have Sr:Ca water concentrations >4.5 $mmol•mol^{-1}$, which may result in elevated otolith Sr:Ca and complicate determination of ocean entrance. The examination of Ba:Ca, in addition to Sr:Ca, in the otoliths offers a promising method for separating river and ocean residence in fish from rivers with high Sr:Ca concentrations, such as the lower San Joaquin River. Ba:Ca water concentrations are typically greater in freshwater than ocean environments (100 to >1000 vs. 5.5 $\mu mol•mol^{-1}$, respectively) and this difference is reflected in otolith chemistry (Elsdon and Gillanders 2005). Available data for the Sacramento-San Joaquin system supports the assumption that the freshwater environments have greater concentrations of Ba:Ca than ocean waters (Weber 2002).

Structural Analysis

Titus et al. (2004) developed fish size-otolith size relationships for juvenile Chinook salmon from the American River in Central Valley, California. They determined otolith size at both hatching and at first feeding (n = 36), and determined total otolith width (TOW) was the best determinant of fish length (FL mm). Although there is regional and interannual variation in growth among west coast Chinook salmon populations, there is typically less variability in size-at-age early in the life history (Jones 2002). Therefore, back-calculations of fish size during periods early in the life history, such as at the time of ocean entrance, will likely display less variability than later periods. Regional data on juvenile length (FL: mm) and TOW were compiled to assess the accuracy of Titus et al.'s equation (Eq. 1).

Eq. 1 $y = 0.07(TOW) – 1.39$, where TOW = total otolith width (μm)

Equation 1 was used to estimate juvenile fork length (FL) based on otolith TOW using juvenile Chinook (n = 63) collected from various locations, including outside of the Columbia River (1999, 2000, 2002, and 2003) and from the Trask, Rogue, and Umpqua Rivers in Oregon. The accuracy of the predicted lengths declined substantially for fish >155 mm FL. However, for fish ≤155 mm FL (n = 53), mean accuracy was within 3% ± 13% (1 SD) of the actual length with an $R^2 = 0.93$ (Figure 3). These data suggest that the use of Eq. 1 to estimate size-at-ocean entrance for fish ≤155 mm has a high likelihood of producing robust estimations within the range of 35 to 155 mm FL.

After otolith elemental data collection, images of polished otoliths were collected at 20 – 40x magnification with a Leica® image capture system. The location along the otolith transect at which a change in Sr:Ca, Ba:Ca, or both, occurred was measured. The total otolith width at the time of that transition was then determined by identifying the region, check mark, or growth increment associated with that transition and measuring the total otolith width at that point. The TOW at the transition, which is interpreted as brackish/ocean entrance, was used to estimate size-at-brackish/ocean entrance based on Eq. 1.

Size-at-ocean entrance was determined for 163 Chinook using Sr:Ca and Ba:Ca concentrations and Eq. 1. Length (FL: mm) ranged from <40 to >150 mm. Stock-specific size frequency histograms for five size classes (<45 mm, 46 to 75 mm, 76 to 95 mm, 96 to 149 mm, and >150 mm) were generated for Central Valley, South Puget Sound, Klamath/Trinity, Rogue, and Mid-Columbia Tule Chinook (Figure 4). Overall, there was fairly extensive variation in size-at-ocean entrance with substantial portions of smaller migrants (46 to 75 mm FL) in the Central Valley, Klamath, and mid-Columbia Tule stocks. The Klamath fish displayed to most variation in size-at-ocean entrance while the majority of the Puget Sound fish (>70%) migrated between 96 to 149 mm FL).

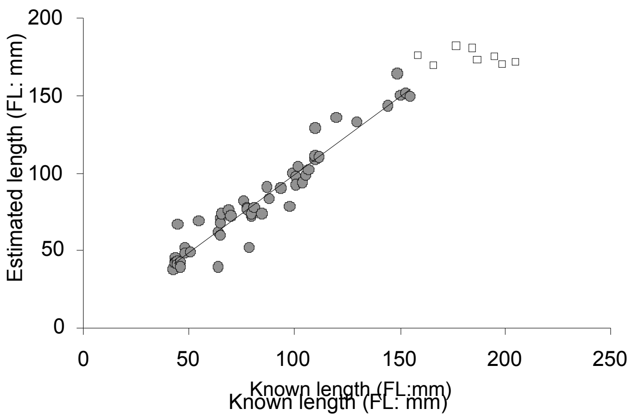


Figure 3. Known vs. estimated length for juvenile Chinook collected from the Columbia River, Washington to Central Valley California. Eq. 1 was used to estimate fork length (FL: mm) based on total otolith width.

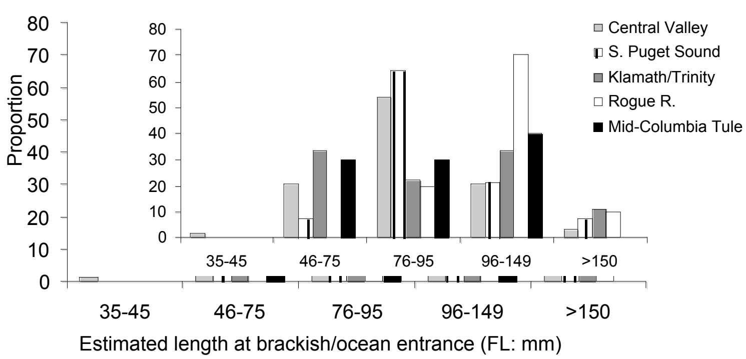


Figure 4. Frequency distribution for estimated size-at-ocean entrance for stocks with ≥10 individuals.

Adequate numbers of Central Valley Chinook were collected to examine variation in size-at-ocean entrance between two outmigrant years, 2003 and 2004 (Figure 5). Relatively small migrants, referred to as ‘fry migrants’ move downstream in many Central Valley river systems in late winter and early spring (Brandes and McLain 2001). It is not known how well these early migrants survive or if there is interannual variation in their survival due to environmental conditions. Our preliminary data indicate that there is substantial variation in the proportion of smaller migrants that contributed to each of the two outmigrant years examined here (2003 and 2004: Figure 5). Furthermore, it appears that, in certain years, greater proportions of the early migrants may contribute to the adult population. One potential mechanism that may regulate survival may be the river flow rate during late winter/early spring (Figure 5). River flow could influence both the absolute number of outmigrants as well as their relative survival. This observation is being further explored and may provide valuable information on the relative fitness associated with different juvenile migratory behaviors. The development of this methodology allows for more detailed exploration of the role of size-at-ocean entrance in early ocean survival, which may contribute to variation in year-class success within and among stocks.

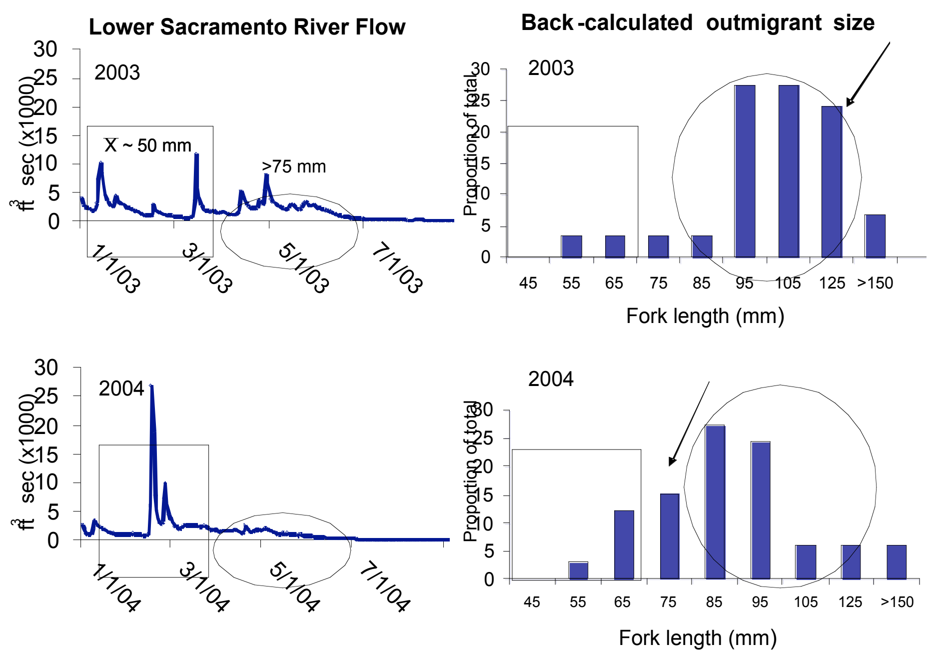


Figure 5. Size frequency distributions of back-calculated size-at-ocean entrance for Central Valley Chinook from the 2003 and 2004 outmigrant years (on right) and Sacramento River mean daily flow (on left). In the Central Valley, the smaller migrants (mean <50 mm FL) typically migrate downstream before April 1 (in box on left) whereas the larger migrants (mean >75 mm) typically migrate after April 1 (in oval on left). Note the increased proportion of larger migrants that contributed to the 2003 outmigrant population and the increased proportion of smaller migrants that contributed to the 2004 outmigrant population.

2007 Collections

As a result of poorer fishing conditions and less success acquiring otoliths from the 2007 ocean fishery, fewer than 100 otoliths were collected. The stock distribution was substantially different than 2006 with the Central Valley and Klamath River runs comprising the majority of the collections. Due to the limited stock distribution, fewer analytical options are available. Given the promising results associated with the $\delta^{18}O$ profiles and the limited sample sizes acquired in 2007, similar $\delta^{18}O$ analysis will be completed on a sub-set of the Klamath, Rogue, and Central Valley Chinook otoliths collected in 2007. Otolith carbonate extraction is currently underway and results should be available by Fall 2008.

References

Bacon, C.R., Weber, P.K., Larsen, K.A., Reisenbichler, R., Fitzpatrick, J.A., and Wooden, J.L. 2004. Migration and rearing histories of Chinook salmon (*Oncorhynchus tshawytscha*) determined by ion microprobe Sr isotope and Sr/Ca transects of otoliths. Can. J. Fish. Aquat. Sci. **61**(12): 2425-2439.

Brandes, P.L., and McLain, J.S. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento – San Joaquin Estuary. pp. 39-138, *In* Contributions to the Biology of Central Valley Salmonids, Vol. 2. *Edited by* R.L. Brown. California Department of Fish and Game.

Campana, S.E., and Thorrold, S.R. 2001. Otoliths, increments, and elements: keys to a comprehensive understanding of fish populations? Can. J. Fish. Aquat. Sci. **58**: 30-38.

Elsdon, T.S., and Gillanders, B.M. 2005. Alternative life-history patterns of estuarine fish: barium in otoliths elucidates freshwater residency. Can. J. Fish. Aquat. Sci. **62**(5): 1143-1152.

Hinke, J.T., Foley, D.G., Wilson, C., and Watters, G.M. 2005a. Persistent habitat use by Chinook salmon *Oncorhynchus tshawytscha* in the coastal ocean. Mar. Ecol. Prog. Ser. **304**: 207-220.

Hinke, J.T., Watters, G.M., Boehlert, G.W., and Zedonis, P. 2005b. Ocean habitat use in autumn by Chinook salmon in coastal waters of Oregon and California. Mar. Ecol. Prog. Ser. **285**: 181-192.

Jones, C. M. (2002) Age and growth, pp. 33-63 In Fuiman, L. A., and R. G. Werner [eds.] Fishery Science: the unique contributions of early life stages.

Kalish, J.M. 1991a. Carbon-13 and oxygen-18 isotopic disequilibria in fish otoliths metabolic and kinetic effects. Mar. Ecol. Prog. Ser. **75**(2-3): 191-203.

Kalish, J.M. 1991b. Oxygen and carbon stable isotopes in the otoliths of wild and laboratory-reared Australian salmon Arripis trutta. Mar. Biol. **110**(1): 37-48.

Kraus, R.T., and Secor, D.H. 2004. Incorporation of strontium into otoliths of an estuarine fish. J. Exp. Mar. Biol. Ecol. **302**(1): 85-106.

Murray, C.B. 1994. A method for preparing Chinook salmon otoliths for age determination, and evidence of its validity. Trans. Am. Fish. Soc. **123**(3): 358-367.

Radtke, R.L., Showers, W., Moksness, E., and Lenz, P. 1996. Environmental information stored in otoliths: insights from stable isotopes. Mar. Biol. **127**: 161-170.

Radtke, R.L., Showers, W., Moksness, E., and Lenz, P. 1998. Corrigendum: Environmental information stored in otoliths: insights from stable isotopes. Mar. Biol. **132**: 347-348.

Secor, D.H., Henderson-Arzapalo, A., and Piccoli, P.M. 1995. Can otolith microchemistry chart patterns of migration and habitat utilization in anadromous fishes? J. Exp. Mar. Biol. Ecol. **192**: 15-33.

Secor, D.H., Rooker, J.A., Zlokovitz, E., and Zdanowicz, V.S. 2001. Identification of riverine, estuarine, and coastal contingents of Hudson River striped bass based upon otolith elemental fingerprints. Mar. Ecol. Prog. Ser. **211**: 245-253.

Thorrold, S.R., Campana, S.E., Jones, C.M., and Swart, P.K. 1997. Factors determining delta C-13 and delta O-18 fractionation in aragonitic otoliths of marine fish. Geochim. Cosmochim. Acta **61**(14): 2909-2919.

Thresher, R.E. 1999. Elemental composition of otoliths as a stock delineator in fishes. Fish. Res. **43**: 165-204.

Titus, R.G., Volkoff, M.C., and Snider, W.M. 2004. Use of otolith microstructure to estimate growth rates of juvenile Chinook salmon from a Central Valley, California stock. Early life history of fishes in the San Francisco Estuary and watershed, Santa Cruz, California pp. 181-202.

Weber, P.K. 2002. Geochemical markers in the otoliths of Chinook salmon in the Sacramento-San Joaquin River system, California. Dissertation, Geography, University of California, Berkeley.

Zahn, R., Pedersen, T.F., Bornhold, B.D., and Mix, A.C. 1991. Water mass conversion in the glacial subarctic Pacific (54ºN, 148ºW): physical constraints and the benthic-planktonic stable isotope record. Paleooceanography **6**(5): 543-560.

Zimmerman, C.E. 2005. Relationship of otolith strontium-to-calcium ratios and salinity: experimental validation for juvenile salmonids. Can. J. Fish. Aquat. Sci. **62**: 88-97.

Section 5

Oceanography

OCEANOGRAPHY

Oceanographic analysis of data collected by Project CROOS is focused on two principle questions of interest. Is there an observed tendency for adult Chinook salmon (*Oncorhynchus tshawytscha*) to spatially aggregate by discreet population units and do average ocean conditions and short-term local events affect the local and coast-wide migration and ocean distribution of Oregon Chinook salmon. Consequent to its partnership with working fishermen and its ability to accurately identify distinct salmon stocks (Seeb et al., 2007), Project CROOS is uniquely positioned to address these questions.

While research activity investigating the ocean migration patterns of Pacific salmon has grown rapidly during the last two decades (Pearcy and McKinnell, 2007), at-sea migration remains a ripe area for research (Quinn, 2005). The strong homing affinity of salmon to their natal stream results in reproductively segregated populations whose unique genetics can be exploited by genetic stock identification (GSI) techniques. Just as local populations develop slight variations in run timing, freshwater holding periods, and downstream migration in response to the prevailing hydrological conditions of their home stream, genetic disposition is thought to be likewise reflected in ocean migration patterns of Chinook salmon (Brannon and Hershberger, 1984; Nicholas and Hankin, 1989).

Oceanographic investigation for Project CROOS examines characteristics of the at-sea distribution of salmon stocks for the 2006 and 2007 seasons. Due to 2006 area closures south of Florence, Oregon catch distributions for the two seasons differ markedly (Figures 1 and 2) limiting the ability to make year-by-year comparisons. Consequently, 2006 analysis generally focused on finer scale, local patterns while an additional broader examination of stock distribution by latitude was possible for the 2007 season. Figure 3 shows the latitudinal distribution for the 2007 Oregon Chinook catch for eight unique population units. Although stocks from the California Coast, Northern California/Southern Oregon Coastal unit, Mid Oregon Coast and North Oregon Coast are relatively widespread, each is more closely associated with their region of origin rather than uniformly and widely distributed regardless of stock. This suggests either a regional preference or a loosely defined upper limit to their range. The absence of fishing activity above latitude 45.8° N, however, constrains the value of this observation. Figure 3 also indicates that Chinook salmon from the Central Valley, Klamath River, and Rogue River, while they have similar ranges, do exhibit some general characteristics regarding their overall range. Large percentages of the Central Valley stock appear more disposed than their counterparts from the Rogue or Klamath rivers to travel long distances from their region of origin. More than 20 percent of the total Central Valley fall-run stock was harvested north of latitude 44° N in the Oregon fishery, compared to less than 5 percent of the Klamath stock, and just over 5 percent of the Rogue stock. In both 2006 and 2007, Central Valley Chinook made up the largest percentage of the total catch of all stocks in the area roughly offshore of Newport Oregon on the Heceta Bank, while the Klamath stock contributed only a small percentage. The Tule stock from the Middle Columbia River was indicative of other Columbia River stocks, which are taken by the fishery in larger percentages north of Coos Bay. A slightly greater percentage of the total catch of Columbia stocks from the Upper Columbia and Snake River, which coincidently make the longest downstream migrations, were caught far to the south compared to the percentages of the total catch of lower and mid Columbia River stocks.

The variability of travel distances between individual Chinook stocks is consistent with the findings of Weitkamp and Neely (2002) based on coded wire tag recoveries of coho salmon (*Oncorhychus kisutch*). Individual coho populations varied in distances traveled, some moved large distances, but most were captured in coastal regions broadly associated with their region of origin.

Capture distance from shore provides a complement to the latitudinal distribution of individual stocks. The Oregon Chinook fishery is not an open sea fishery. Offshore of California and Oregon, Chinook are found predominantly over the shallow water of the narrow shelf margins. Figure 4 and figure 5 examines the east to west extent of the range of individual Chinook stocks. Although mean capture distances from shore widely overlap for each distinct stock, some degree of separation is observed. The North Oregon Coast stock is notably consistent in its tendency, over both 2006 and 2007, to be caught much closer to shore than other stocks. Additionally, its average distance to shore remained nearly constant over both years despite the fact that much of the 2006 fishery was exercised on Heceta Bank – further from shore than the region of heavy fishing off the southern Oregon Coast in 2007 (See figure 1 and figure 2).

While these trends are possibly indicative of a genetic predisposition, they are not evidence that Chinook maintain population specific aggregations while at sea – the central topic of investigation and one which, if true, could offer greater flexibility in the management of the fishery. Nearest neighbor measurements for 2006 data calculates the average closest distance between individuals of the same stock. These distances are then compared to those obtained from 1,000 permutations where the recorded catch locations are held fixed, but fish are randomly assigned to one of the fixed locations. Reported p-values are equal to the fraction of permutations with nearest neighbor distances less than or equal to the observed values (Hennig and Hausdorf, 2004; McKinnell et al., 1997). Low p-values indicate greater probability of aggregation compared to a fully random distribution. There is no clear-cut p-value below which it can be asserted that a statistical significance exists (eg 0.05). This is mainly due to the fact the power of this nearest neighbor test (probability of detecting a false null hypothesis) is severely limited by the small sample size and by considering fish captured over several days (one week in this case). For these reasons, we consider the p-value more as a relative index of spatial aggregation (i.e., the lower the p-value the greater the aggregation) rather than an absolute test-statistic for hypothesis testing. Given that adult Chinook salmon are capable of moving substantial distances in a single day, nearest neighbor analysis requires a fine temporal scale – here the use of high-volume GSI catch data is superior to CWT data where limited tag recoveries precludes daily or weekly assessment. The nearest neighbor calculations depicted in the plots in figures 6 and 7 were performed on the total catch from two separate one-week periods in September 2006. While the movement of Chinook during this period can introduce a significant error, it is expected that inappropriately long time windows would obscure potential population aggregations rather than accentuate them. Nevertheless, with the exception of the Rogue River stock during the period from September 25-30, all stocks appear to be more closely associated than would be expected if they were randomly assigned to the observed 2006 capture locations. The most aggregated populations were noted for the Mid Oregon Coast stock and the Klamath River stock during the September 25-30 period (Figure 7).

The potential for population specific aggregations raises questions regarding the timing of their formation, their stability and duration. McKinnell et al. (1997) reported coincident at-sea recovery of hatchery-reared steelhead (*Oncorhynchus mykiss*) three years after their release from the same hatchery. They suggested that these same-aged individuals might have traveled together. The availability of age data from project CROOS allows an examination of age trends over the fishing season. If Chinook do, in fact, associate in population specific aggregations then these aggregations quite possibly begin early in life as noted for steelhead. Figure 8 plots the catch of Klamath River fish by age for each week of the 2006 season. The weekly catch of 4-year-old Klamath Chinook peaked in week 30 at 13 fish – during this same week only a single 3-year-old was caught. In week 38, again 13 4-year-olds were taken, while the harvest of 3-year-olds jumped to 40. The fishing effort during this period all occurred in the same general area offshore from Newport, thus, all fish were exposed to equal fishing pressure. This begs the question of whether an aggregation of 4-year-olds arrived early on the fishing grounds followed later by an aggregation of 3-year-olds. A less dramatic, yet similar, age-specific trend is noted for Mid Oregon Coast Chinook during week 38 and 39 (Figure 9). The weekly catch of 4-year-olds from the Mid Oregon Coast stock peaked and remained constant at 8 fish per week for both week 38 and 39. Six 3-year-olds were taken during week 38 then dropped off to 3 in week 39. This contrasted with an inverse pattern for 5-year olds with only 1 taken during week 38, but climbing to 6 during week 39. Of note, the Mid Oregon Coast stock tended to include more 5- and 6-year-old fish than most other stocks.

Catch numbers are likely too low to draw firm conclusions regarding age-specific stock aggregation, but long-term age and catch data from Project CROOS, combined with multiple avenues of investigation, has the potential to add considerably to our understanding of the ocean migration patterns and behavior of Chinook salmon.

The effect of short-duration variations in ocean conditions on Chinook distribution is another focus of oceanographic analysis irrespective of whether Chinook form population specific aggregations at-sea. Fisher et al. (2007) found that sub-yearling Chinook are strongly associated with near-shore shallow depths, but found no evidence of a temperature or salinity preference. Yearling Chinook, in contrast, while still found at shallower depths regardless of salinity, tended to be distributed in slightly cooler water than the average conditions recorded during the sampling period. Hinke et al. (2005), utilizing temperature/depth archival tags, found that adult Chinook salmon off the California and Oregon Coast favor a narrow temperature range of 8°C to 12°C and modify their depth in response near-surface conditions to maintain this temperature preference. Chinook capture data from Project CROOS combined with satellite sea surface temperature (SST) data suggest horizontal patterns of spatial movement may be of equal importance when Chinook respond to upper-ocean temperature variations.

It is widely accepted that salmon are frequently found in association with temperature fronts generated by summer upwelling of cold nutrient-rich water along the Oregon Coast. Catch data from both 2006 and 2007 confirm this tendency by observing changes in catch distribution in response to changes in sea surface temperatures. During the 3-day period from September 17-19 (top, figure 10) Chinook were caught well offshore along the mixing boundary between a tongue of cold water originating inshore and warmer offshore water. One week later, during the 3-day period between September 25-27 (bottom, figure 10), surface conditions were much warmer –

likely due to a shift in wind strength or velocity that weakened the cycle of upwelling. The change in surface conditions brought about a marked decrease of catch in the offshore area while it substantially increased in a narrow band of cooler water restricted to the near vicinity of the shoreline. The Chinook catch appears to likewise modulate horizontally during a similar change in surface conditions off of Coos Bay during the 2007 season. The 3-day period from July 27-29 (Figure 11) shows an area offshore from Coos Bay with a large catch of salmon somewhat close to shore near the boundary of cool upwelled water. By mid August (Figure 12), the region of cooler inshore water expanded offshore with the majority of the Chinook catch following.

The sparsity of physical data severely limits oceanographic analysis. Frequent cloud cover is a common condition along the Oregon Coast that restricts the availability of satellite SST data. Remote sensing also cannot measure temperatures at depth. Nevertheless, physical data obtained by satellite is an important source for oceanographic data and will be broadened to investigate the use of remotely sensed wind vector data and ocean color. Temperature loggers attached to fishing gear is another promising source of temperature/depth data from the 2007 season yet to be analyzed.

References

Brannon, E.L., and Hershberger W.K. 1984. Elwha River fall Chinook salmon. Pages 169-172. In Quinn T.P. The ecology and behavior of Pacific salmon and trout. American Fisheries Society, Bethesda Maryland and University of Washington Press, Seattle.

Fisher J., Trudel M., Ammann A., Orsi J.A., Piccolo J., Bucher C., Casillas E., Harding J.A., MacFarlane R.B., Brodeur R.D., Morris J.F.T., Welch D.W. 2007. Comaprisons of the coastal distribution and abundances of juvenile Pacfic salmon from Central California to the Northern Gulf of Alaska. America Fisheries Society Symposium. 57:31-80,2007

Hinke J.T., Foley D.G. Wilson C., Watters G.M. 2005. Persistent habitat use by Chinook salmon Oncorhynchus tshawytscha in the coastal ocean. Marine Ecol Prog Ser. Vol 304:207-220

Hinnig C, and Hausdork B. 2003. Distance-based parametric bootstrap tests for clustering of species ranges. Computational Statistics & Data Analysis. 45:875-895.

McKinnell S., Pella J.J., Dahlberg M.L. 1997. Population-specifc aggregations of steelhead trout (*Oncorhynchus mykiss*) in the North Pacific. Can J. of Fish. Aquat. Sci. 54:2368-2376

Nicholas J.W. and Hankin D.G. 1989. Chinook salmon populations in Oregon’s coastal river basins. In Quinn T.P. The ecology and behavior of Pacific salmon and trout. American Fisheries Society, Bethesda Maryland and University of Washington Press, Seattle.

Pearcy W.G. and Mckinnell S.M. 2007. The ocean ecology of salmon in the Northwest Pacific Ocean – an abridged history. American Fisheries Society Symposium 57:7-30

Quinn, T.P., 2005. The behavior and ecology of Pacific salmon and trout. American Fisheries Society, Bethesda, Maryland and University of Washington Press, Seattle.

Seeb L.W., Antonovich A., Banks M.A., Beacham T.D., Bellinger M.R., Blackenship S.M., Campbell M.R., Decovich N.A., Garza J.C., Guthrie III C.M., Lundrigan T.A., Moran P., Narum S.R., Stephenson J.J., Supernault K.J., Teel D.J., Templin W.D., Wneburg J.K., Young S.F., Smith C.T. 2007. Development of a standardized DNA database for Chinook salmon. Fisheries Vol 32 No. 11 November 2007 pp 540-532

Weitkamp L.A. and Neely K. 2002. Coho salmon (Oncorhynchus kisutch) ocean migration patterns: insight from marine coded-wire tag recoveries. Can J. Fish. Aquat. Sci. 59:1100-1115

Figure 1. 2006 Season Chinook catch locations

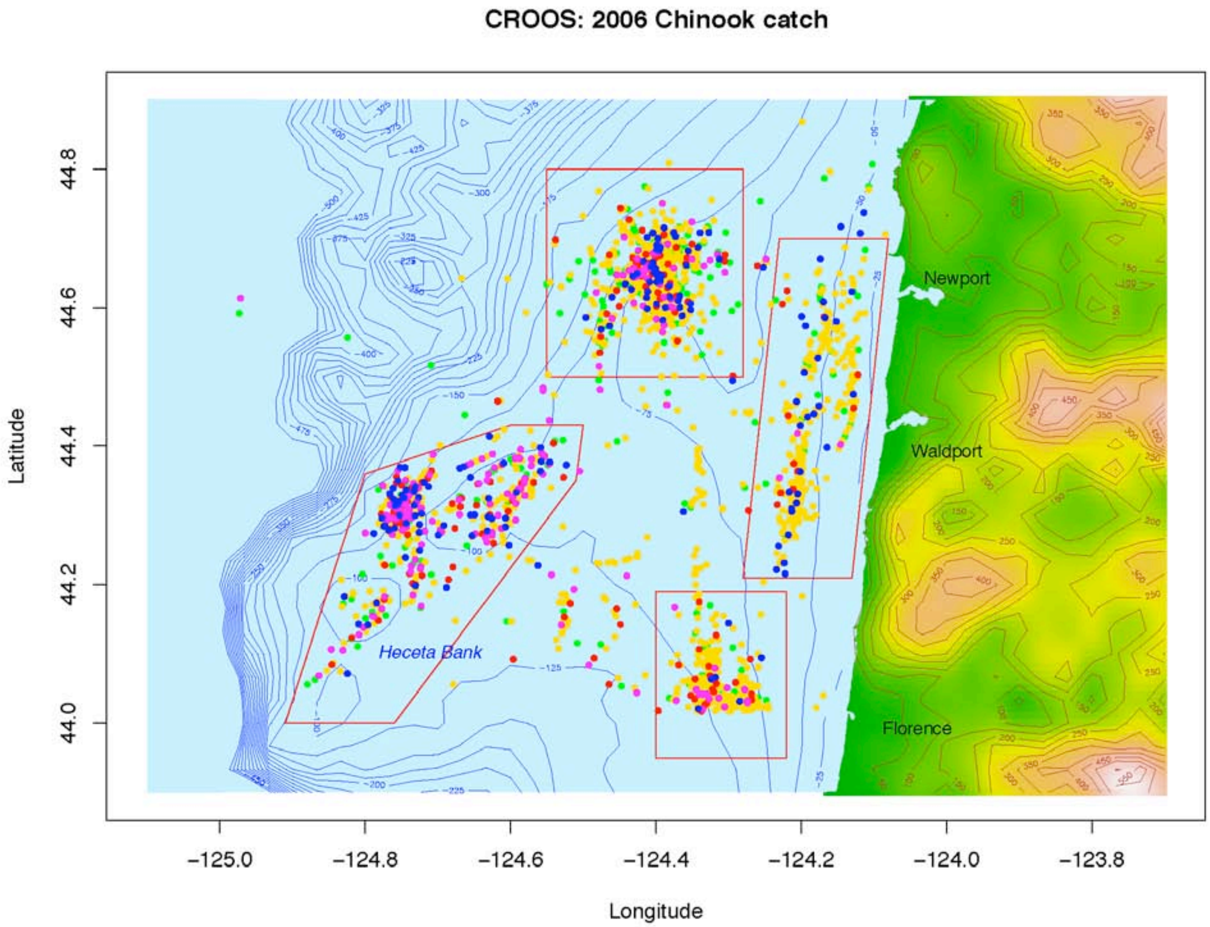


Figure 2. 2007 Season Chinook catch locations

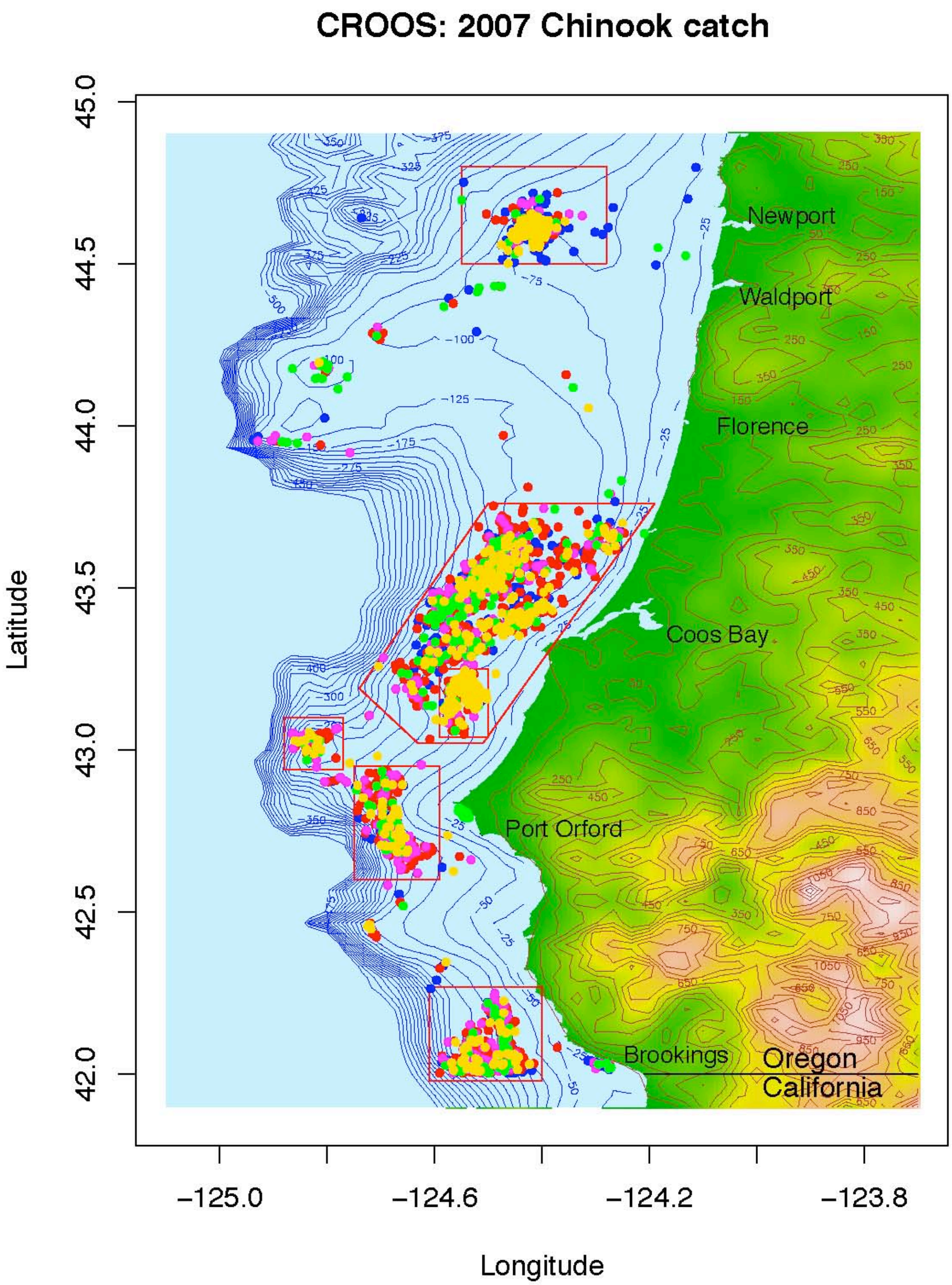


Figure 3. Catch distribution by latitude – total catch is in brackets []

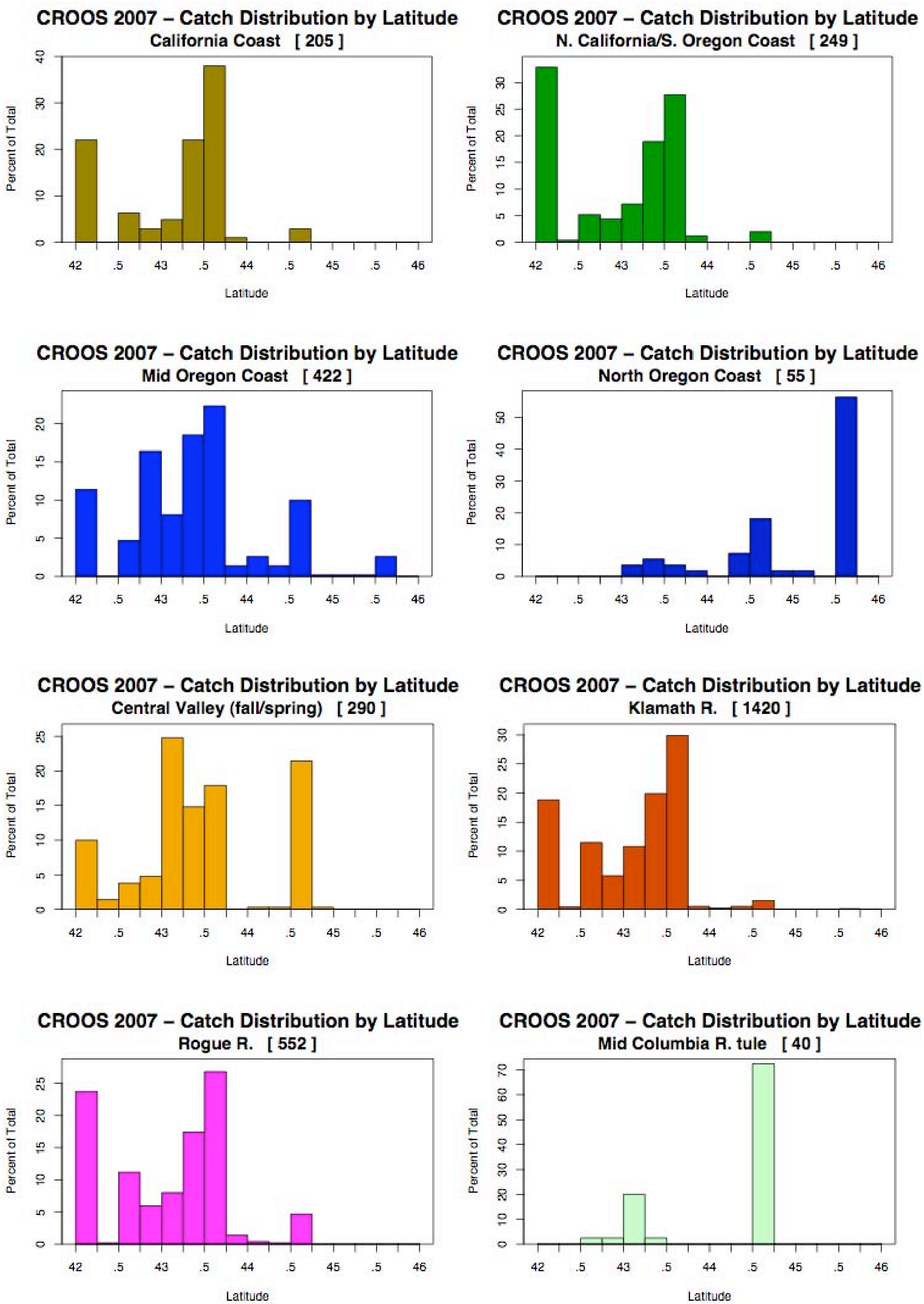


Figure 4. 2006 Chinook catch distance from shore

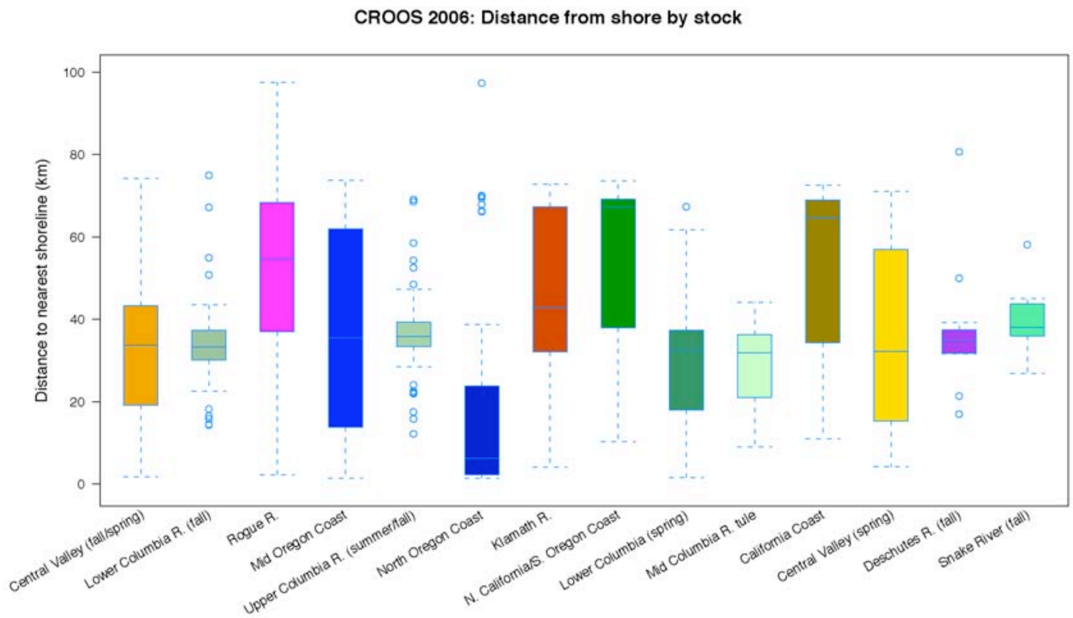


Figure 5. 2007 Chinook catch distance from shore

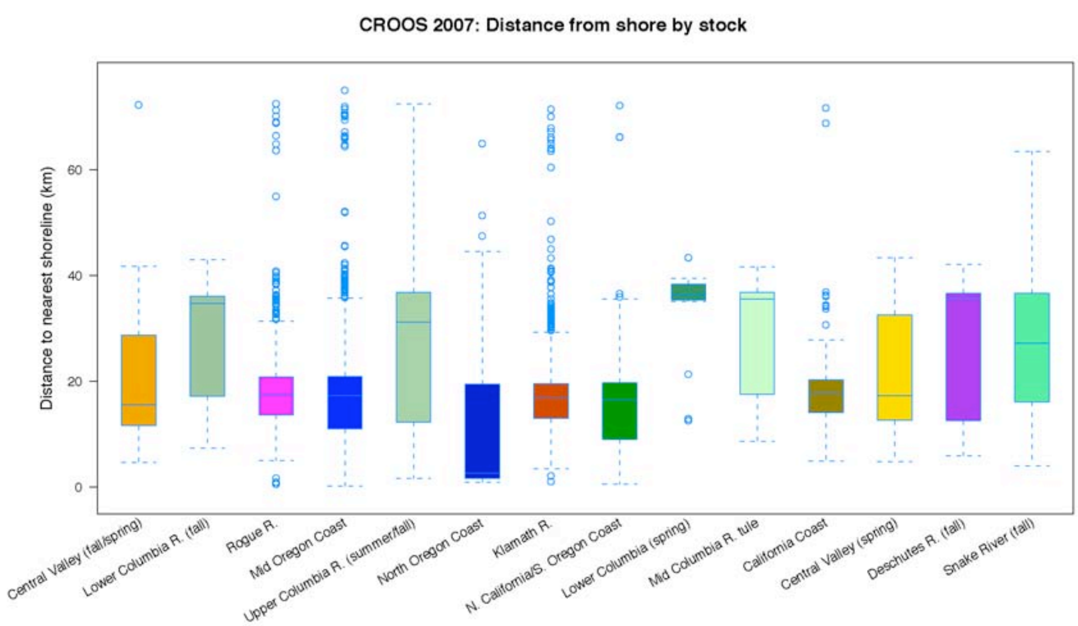


Figure 6. Chinook catch September 17-24, 2006

Observed nearest neighbor and distribution from random permutation at fixed catch location. Vertical bar on random permutation in column two represent actual mean nearest neighbor from column 1.

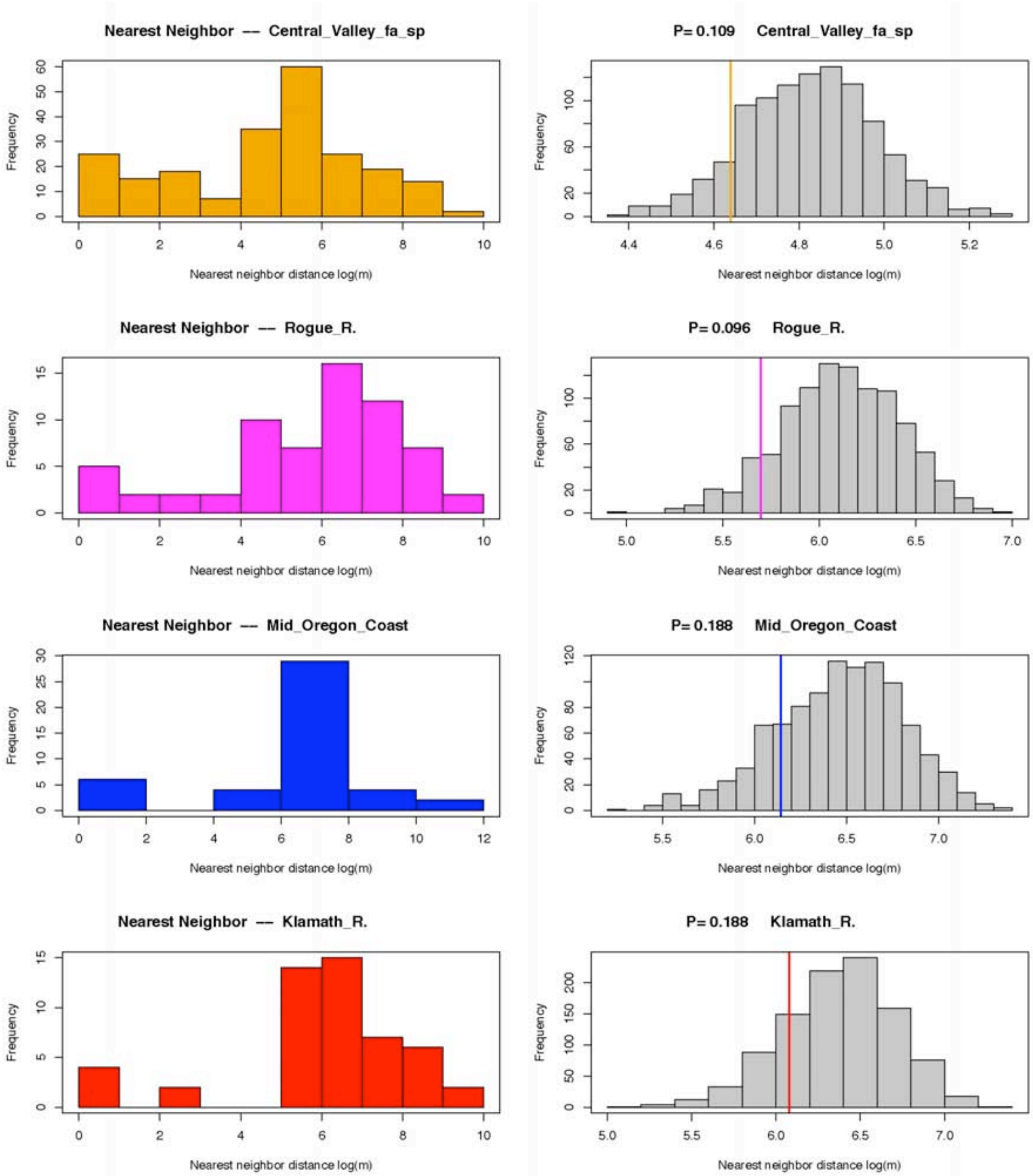


Figure 7. Chinook catch September 25-30, 2006

Observed nearest neighbor and distribution from random permutation at fixed catch location. Vertical bar on random permutation in column two represent actual mean nearest neighbor from column one. The value of P is the probability of the observed proximity, given the permutation distribution.

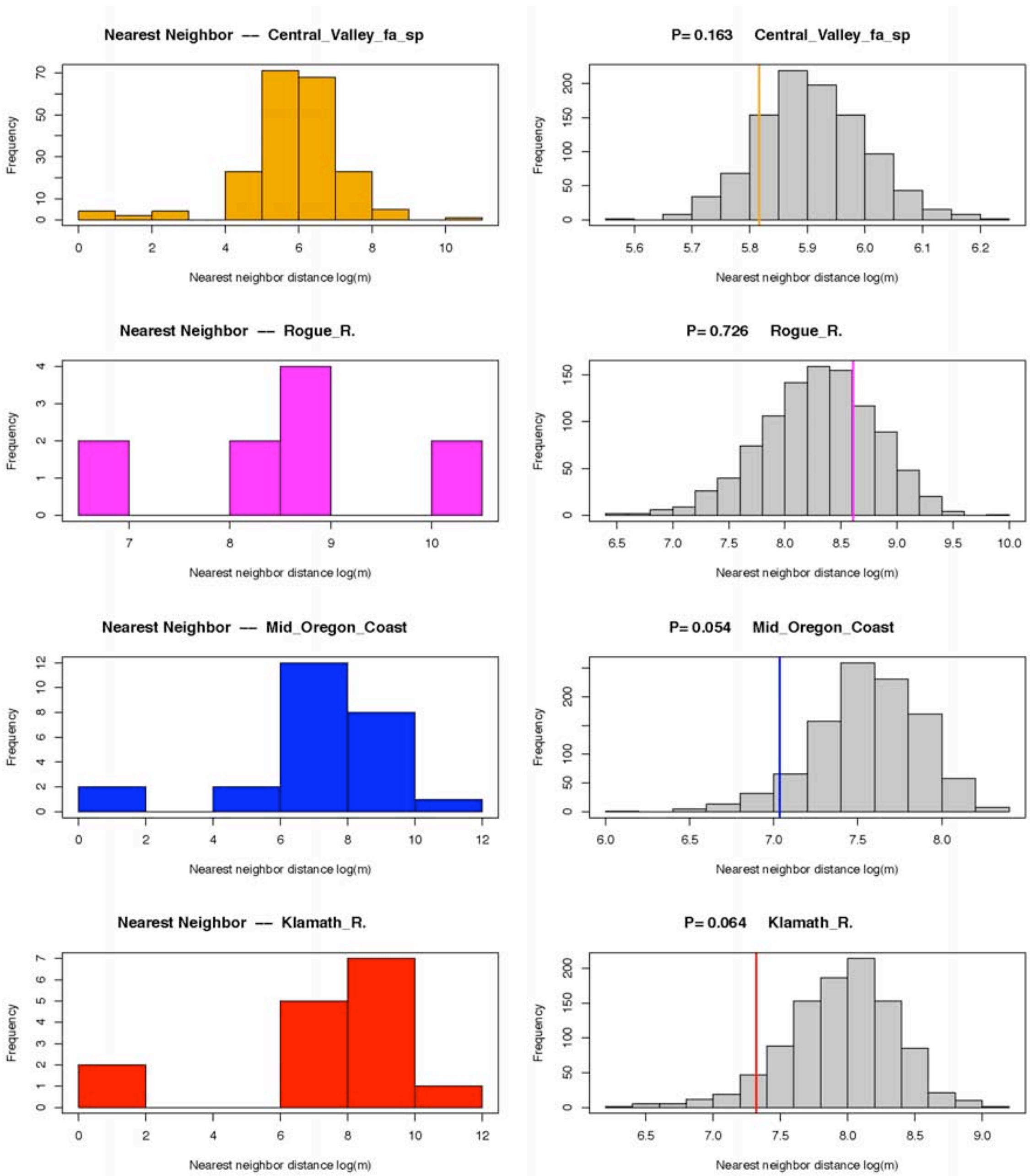


Figure 8. 2006 weekly catch by age

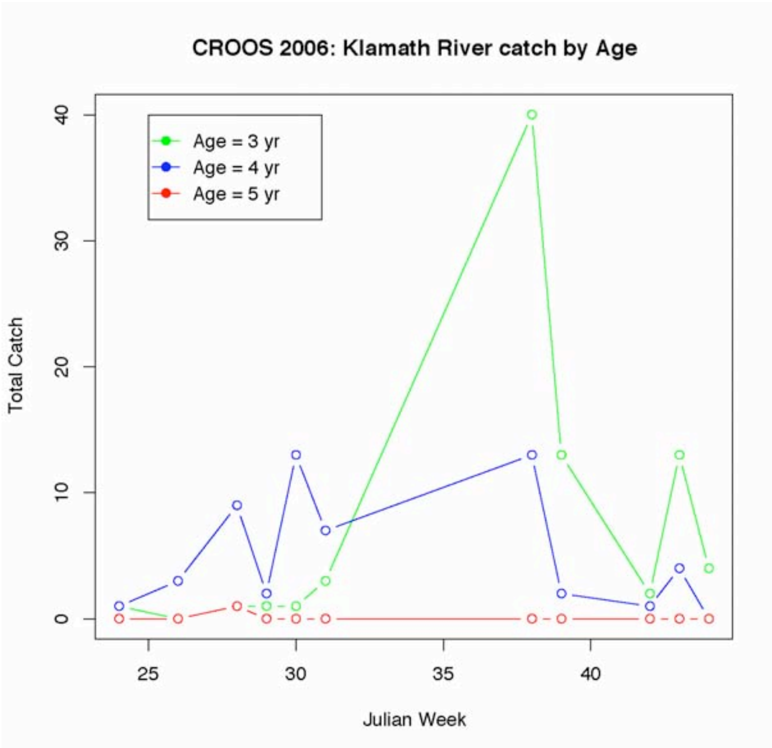


Figure 9. 2006 weekly catch by age

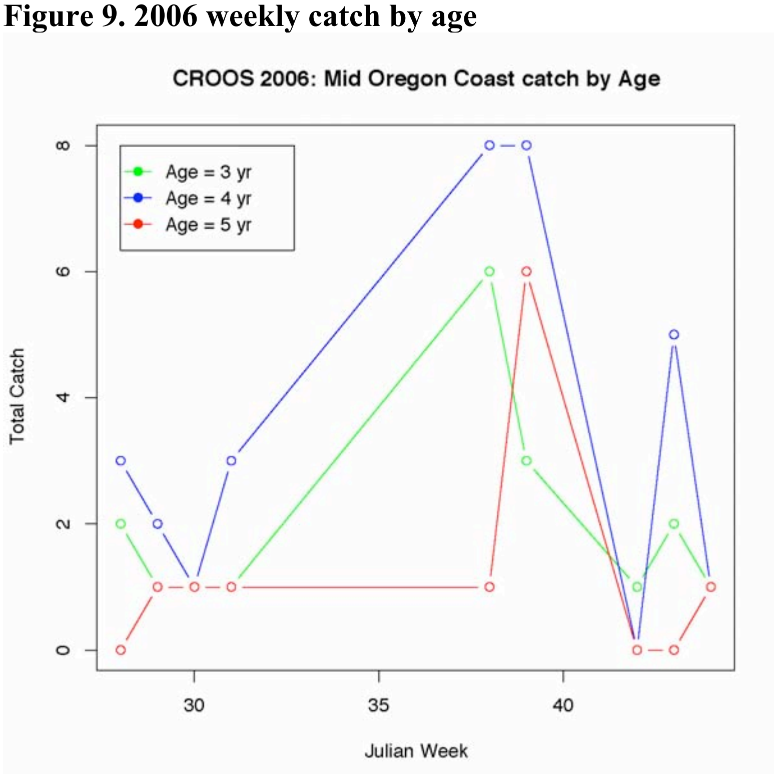
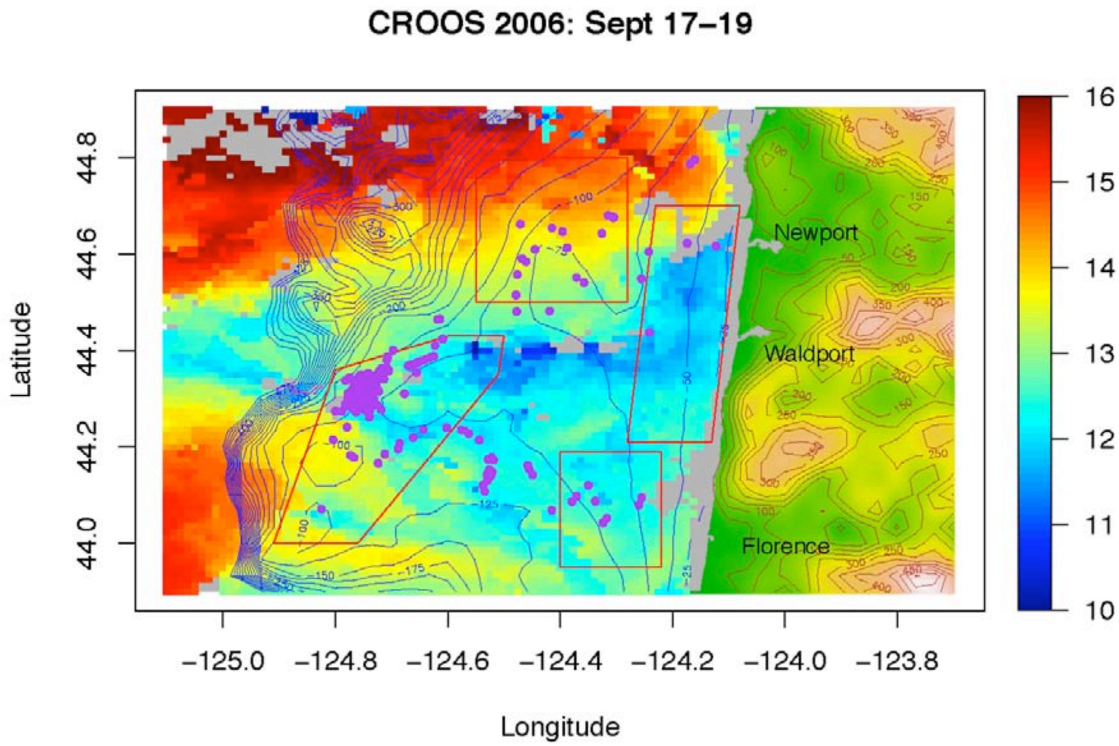


Figure 10. Distribution shift in response to SST changes



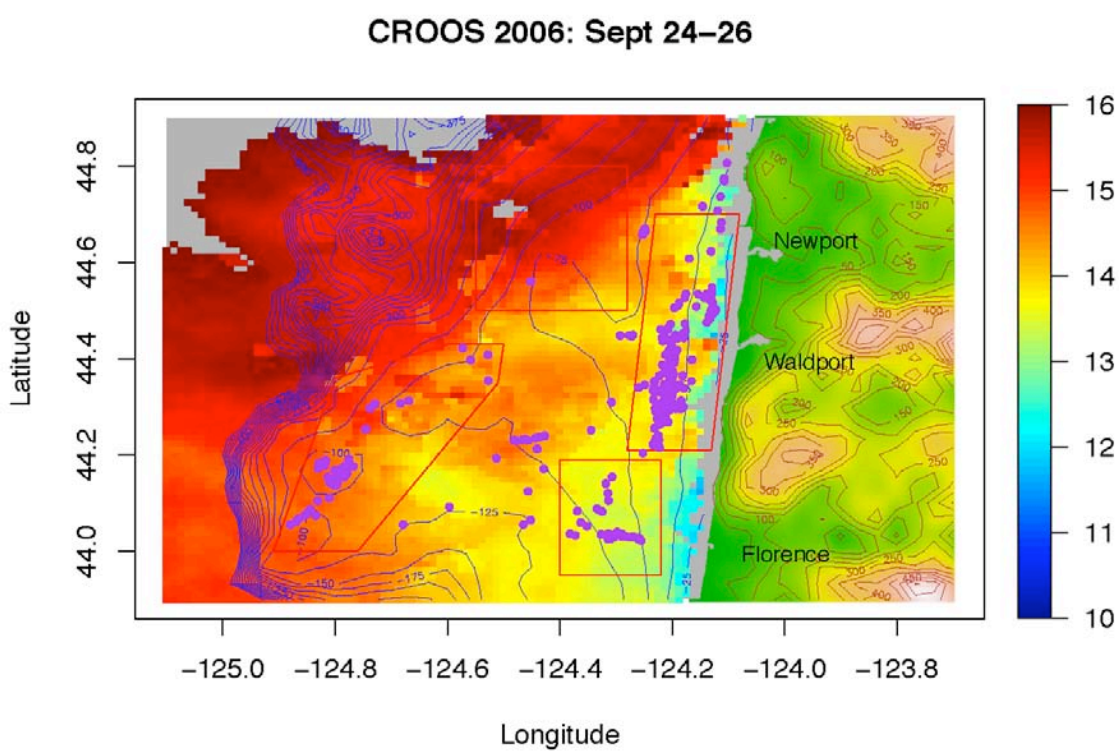


Figure 11. Chinook catch distribution

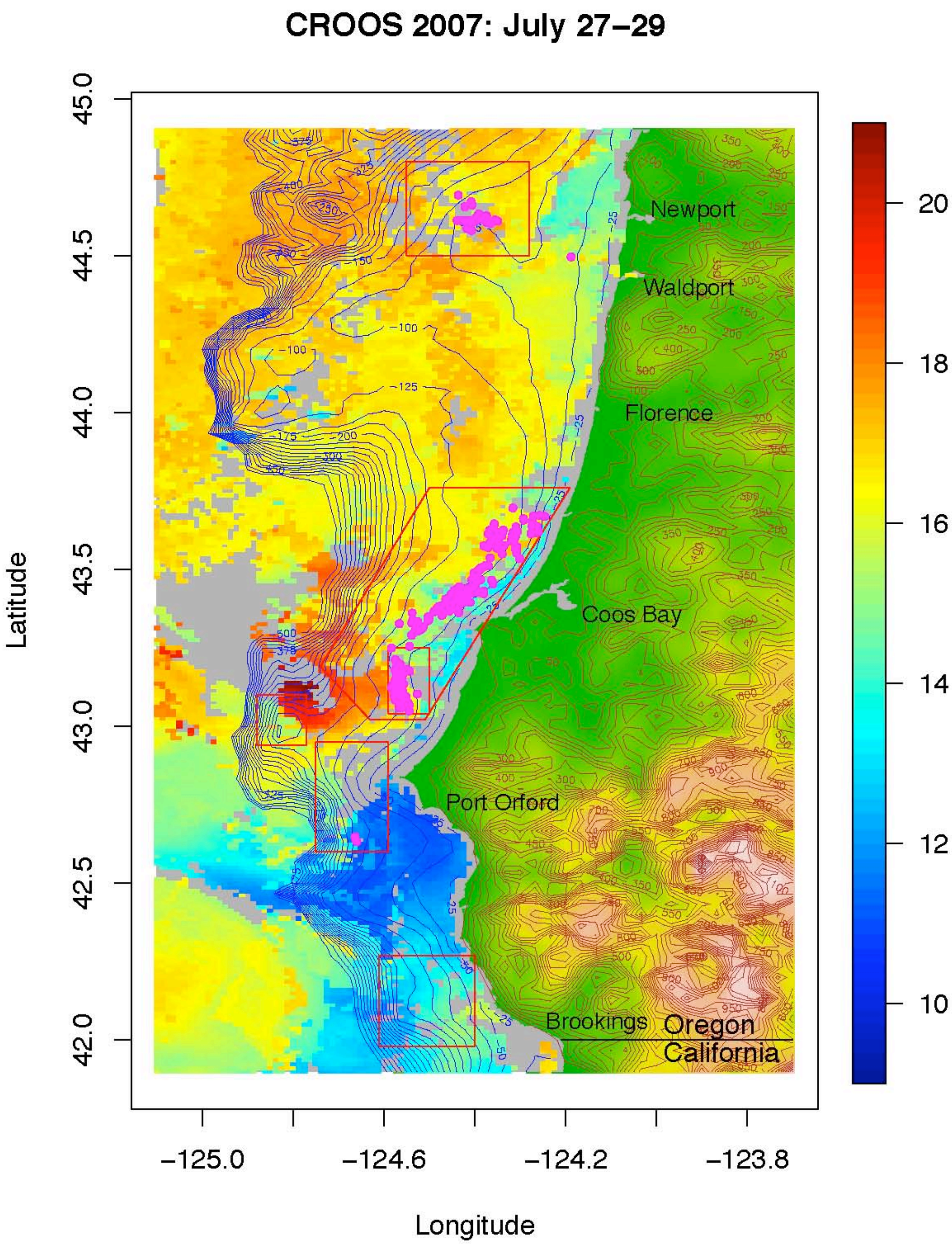
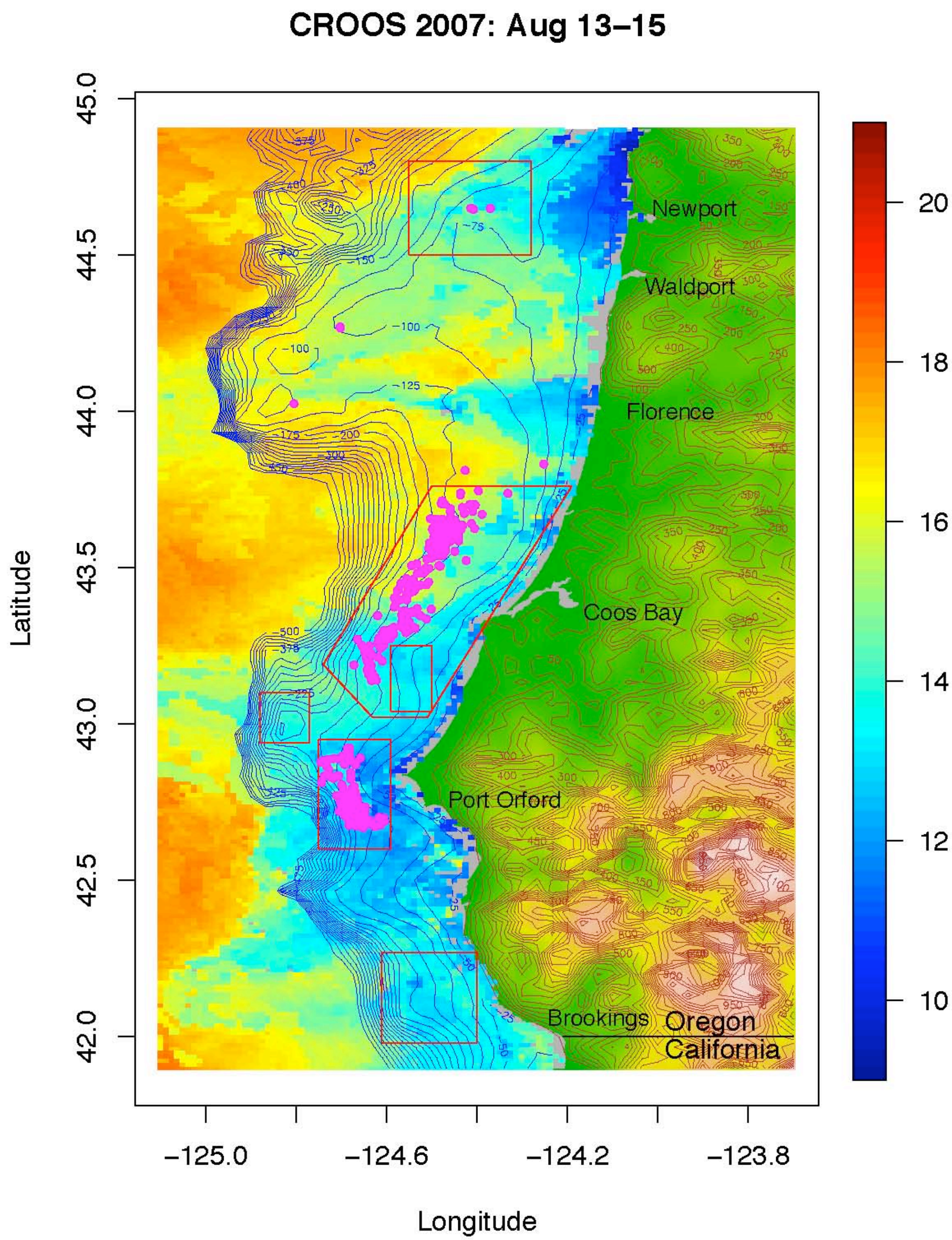


Figure 12. Chinook catch distribution



Section 6

Website Development

WEBSITE DEVELOPMENT PHASE II

One of Project CROOS's primary objectives is to develop a comprehensive website to serve multiple audiences and functions. The site is programmed to be the first of its kind in fisheries research, and is intended to serve as a template for development of other fisheries-related websites. It will house all of CROOS's data and results, as well as facilitate data sharing and collaborative research among multiple user groups. The site will also serve as the primary communication tool for parties participating in the project in order to support interdisciplinary and comprehensive research. It is designed to 1) meet the needs of multiple audiences, 2) provide easy access "portals" for each audience, and 3) and to allow each user to understand their relation to the "local" fishery seafood science, management, and marketing community. The website will be built on a platform capable of expanding to service future research needs occurring in multiple west coast geographies and fisheries.

This comprehensive website design is planned to meet seven key objectives and serve six primary audiences. The objectives are:

1) Deliver educative marketing to consumers, retailers and industry in new dynamic ways founded on traceable, direct, and "local" marketing principles.

2) Promote the unique aspects of the community, fishery, and fish stock (e.g. locale, wild caught, vessel and skipper, harvest location).

3) Provide near "real time" information to fisheries managers and scientists.

4) Inform audiences about distribution of salmon in ways that provide meaning and understanding.

5) Provide information that helps identify stock distribution patterns and how they connect to oceanographic variables.

6) Provide information that helps fishermen plan successful trips, while protecting individual privacy.

7) Present collaborative projects in a way that engages a community of supporters.

The audiences include:

1. Consumers and General Public
2. Retailers (Grocery and Food Service)
3. Seafood Distributors and Processors
4. Fishermen
5. Managers
6. Scientists

The permanent website will be capable of providing all potential user groups access to data and information in formats that best satisfy their specific interests, preferences, and needs. It will incorporate key elements of the initial prototype website *ProjectCROOS.org* which was developed during the first phase of Project CROOS. That website consisted of a front and back end designed to test the feasibility of the project's web-related objectives. The front end was designed to provide the general public with a description of the project and the significance of Project CROOS research. The back end was geared primarily toward data display. It utilized GIS web mapping software (ESRIs ArcIMS and Arc GIS) to display the full range of data collected in the project and allow for manipulation and interpretation by different user groups, specifically fishermen, scientists, and consumers. The development of this site was critical for demonstrating the feasibility of providing multi-user access to near "real time" data. Given the success of these early prototypes, Project CROOS pursued development of a permanent website.

The permanent website design plan includes a robust front end with layered security access points for each audience and a back end database with programmed query services for easy manipulation and user-friendly displays to serve each audience.

Development Approach

A subset of the Project CROOS participants formed an advisory committee to oversee the development of the comprehensive site. This committee includes:

Nancy Fitzpatrick, Oregon Salmon Commission
Gil Sylvia, Coastal Oregon Marine Experiment Station, Oregon State University
Pete Lawson, National Oceanic and Atmospheric Administration
Jeff Feldner, Oregon Sea Grant Agent
Renee Bellinger, Coastal Oregon Marine Experiment Station, Oregon State University

The committee engaged Diane Moody, the director of the Community Seafood Initiative and Chris Pugmire, a recent graduate of the Oregon State University Marine Resource Management Program to manage the development process.

Two web development professionals were contracted to build the site. The first is *Sparkplug*, a design and brand consultancy firm based in Portland Oregon. The firm is responsible for designing the front end of the website. The second is Bill Howe, OHSU, CMOP department who is responsible for developing the back end database and programmed query services.

The advisory and management teams chose a market-based approach for developing the site. This involved a comprehensive three-step research process. The first step was to conduct a literature review of existing websites with similar objectives and audiences as Project CROOS (Appendix 7). The second step was to conduct interviews, focus groups, and round table discussions with representatives of each target audience to understand their perceptions, needs, and potential website uses (Appendix 8 and 9). The third step was to synthesize and analyze responses to determine design elements for each specific audience.

The interviews were conducted by Sparkplug. Their staff conducted 10 to 20 one-on-one interviews with representatives from each of the target audiences. Oregon State University conducted three focus group sessions with consumers at the Food Innovation Center in Portland, Oregon. Each focus group consisted of an average of 10 participants who were prescreened for high seafood interest and shopping choices dominated by natural foods and gourmet grocery stores. Two round table discussions were held for a group of fishermen, scientists and managers and a group of processors, distributors and retailers. The first discussion group consisted of approximately 30 participants and was held at the Hatfield Marine Science Center in Newport, Oregon and the second group consisted of 15 participants and was held at the Oregon State University Food Innovation Center.

Outcome

The research results demonstrated that the front end design must, in particular, meet the *wants and needs* of consumers and the general public. These target groups are the least familiar with Project CROOS and have limited understanding of the community involved in fisheries production, science, and management. These groups would primarily intersect with the broader "fisheries community" through their seafood purchasing, eating, and cooking activities. Based on research results, it was decided that would include a major section, *Fish Tags,* and a complementary section *Nutrition and Recipes* dedicated to showcasing fish harvested by fishermen involved in the CROOS project. The majority of the target group would learn about the website through their seafood shopping experience in retail stores. Fish available in the grocery store and harvested by a Project CROOS fisherman would include a barcode linking information about the fish, fisherman, and fishery. Seafood retailers and processors would also use the site to support marketing and contractual needs to meet the needs of their consumers.

The website name brand and layout would also need to resonate with the broadest user groups. It would need to represent the long-range objectives of serving multiple geographies and fisheries. The website name and logo selected to achieve these goals is *PacificFishTrax*:

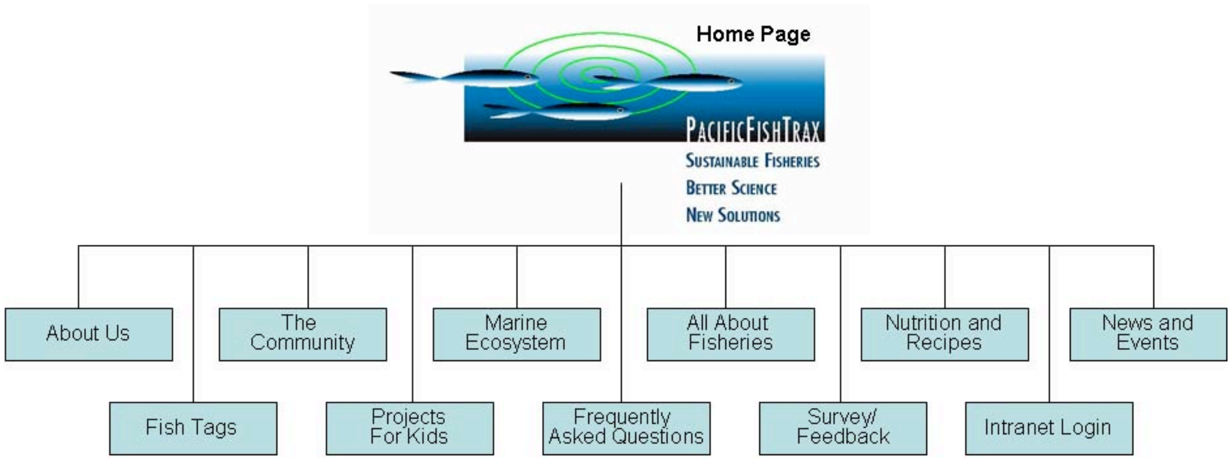
PACIFICFISHTRAX

SUSTAINABLE FISHERIES
BETTER SCIENCE
NEW SOLUTIONS

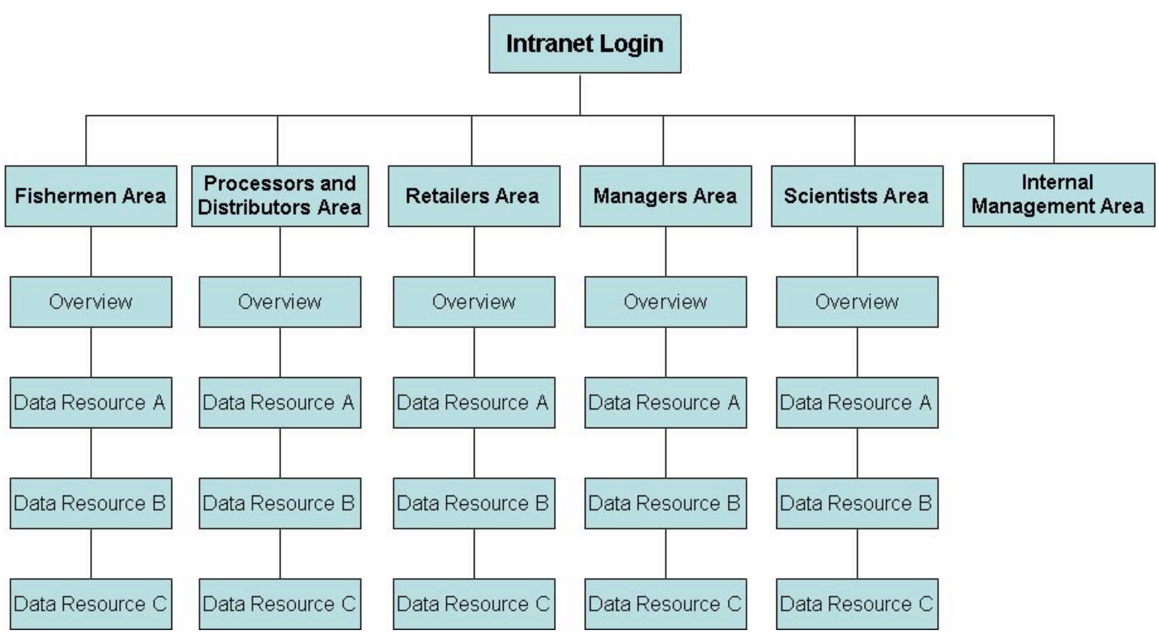
The fishermen, managers and scientist will interact with *PacificFishTrax* primarily to input and extract from the database and use the programmed query services. These groups will be able to access different layers of data through a password-protected portal. The data information stored in the database includes, but is not limited to, individual fishermen and aggregate catch data, fish DNA sample data, and track log data. The query services will allow users to pull multiple data points into different visual frames and maps to observe patterns, trends and plot future probabilities. These user groups will also submit news, events, and research findings to the site for use by other audiences.

With the completion of the market-based research, the *PacificFishTrax* site has been mapped and preliminary development and design has begun.

Navigational Site Map Overview



Intranet Site Map



Next Steps

The phase 1 website front and back end design work will be completed over the next six months. The site will be beta tested by representatives of each user group from during 2009. Fishermen, scientists and managers will be reviewing the entire website and testing the programmed query services. The *Fish Tag* segment and sales of barcoded seafood caught by Project CROOS fisherman will also be tested by consumers and retailers in 2009.

Upon completion of the beta tests, the website will be revised to reflect the feedback from each of the groups.

A management plan is also being written for *PacificFishTrax* that covers the operations, mechanics and costs of managing the site. The plan will also establish protocols that define the governing and managing relationships of existing Project CROOS partners and future partners and clients. This management plan will be completed by the end of 2008.

Section 7

Management

MANAGEMENT

A central goal of the CROOS project is to help improve fishery management through improving access to abundant stocks while avoiding weak stocks. 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 augment 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 immediate relevance to management is stock identification and specific catch locations. In 2006 we demonstrated that commercial fishermen can collect data that enable us to map the precise locations of catch by stock. In 2006 and 2007 we have shown that stock distributions differ by area and time, and that we can quantify these differences in near “real time”.

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 low rates to fisheries. This ability can be used to improve the base-year data used in fishery harvest models, thereby improving the pre-season 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.

An important international effort to explore incorporation of GSI in fisheries management was coordinated by the Pacific Salmon Commission, Committee on Scientific Cooperation. Two workshops were held in 2007 and attended by two principles of Project CROOS (Banks, Lawson). The overall objective of the workshops was to develop recommendations for integration of GSI information into a coordinated coast-wide management system to improve the ability of ocean fisheries to access abundant stocks within impact constraints established for other specific stocks and, to the extent possible, to identify and quantify the costs, implementation steps and time frames to incorporate these recommendations. The first workshop was help in Portland, Oregon on May 17-18. The second was in Vancouver, BC on September 11-13. Four workgroups were formed; Genetics, Management, Modeling/Sampling, and Logistics. Each workgroup provided a report to the workshop steering committee following the second workshop. The final report, "Recommendations for Application of Genetic Stock Identification (GSI) Methods to Management of Ocean Salmon Fisheries. Special report of the GSI Steering Committee and the Pacific Salmon Commission's Committee on Scientific Cooperation. Pacific Salmon Commission Technical Report No. 23" was released in January 2008. The report can be downloaded from http://www.psc.org/info_genetic_stock_id.htm. The report consisted of 14 recommendations of which several are active areas of interest for Project CROOS. The most important are:

Recommendation 2: Genetic and CWT technologies can and should be integrated to improve the scientific basis for management of Pacific salmon. These technologies can be applied separately, or in combination, as appropriate, where potential benefits of derived information are sufficient to justify costs.

> Stock composition estimates from Project CROOS sampling are being used to validate existing CWT estimates. We have shown the ability to determine stock compositions at space and time scales not feasible using CWTs alone. GSI does not, however, allow aging of samples, which must be done through scale analysis. Scale-based ages are not as precise as those from CWTs, and implications for cohort reconstruction are under investigation.

Recommendation 5: The PSC should support research into the development of protocols for GSI fishery analysis, including sample size criteria, statistical methods, guidelines for the interpretation of results, and characterization of uncertainty of results.

> In 2007 Project CROOS refined and extended protocols for sample collection and analysis developed in 2006. Analytical techniques for fishery management depend on the statistical properties of the sample data, which we are just beginning to understand, and the management intent, which has yet to be identified.

Recommendation 8: The potential for application of small area estimation in analysis of ocean salmon fishery data should be explored. This method may be used to characterize the consistency of stock distribution patterns and has potential to reduce sample size requirements for stocks which comprise small proportions of the total exploited population.

> Small area estimation is the focus of Project CROOS, with our fine-scale sampling protocols. While the Pacific Salmon Commission generally focuses on broader-scale distributions they recognize the value of understanding salmon fishery dynamics at a variety of scales.

Recommendation 13: GSI should be employed to selectively validate stock composition assumptions that are incorporated in existing PSC Chinook and Coho FRAM models, to produce estimates of stock compositions of landed and non-landed (sublegal) ocean catches, and to identify stocks that are currently not represented in models.

Data from Project CROOS in 2006 and 2007, along with samples collected in other studies and in other years, will be used to help validate the performance of the FRAM models. The most useful data will come from years when we can sample extensively over all segments of the fishery.

Reports from the individual workgroups contain considerably more detail and are available at http://www.psc.org/info_genetic_stock_id.htm#REPORTS.

In 2007 we had the opportunity to sample, for the first time, the area south of Florence South Jetty to the Oregon/California border. Although catch rates were low, this provided us with an initial look at stock distributions along the southern Oregon Coast. In the Newport area contribution rates of Central Valley Chinook in 2007 were much lower than in 2006 but Klamath Chinook contribution rates were only marginally lower (5.6% in 2006 to 3% in 2007). To the south, Central Valley rates fell while Klamath contribution rates were much higher. These results are consistent with a Klamath stock that has a relatively local ocean distribution mixed with Central Valley stocks that have wider distributions but were much less abundant in 2007 than in 2006. More detailed descriptions of stock distributions are provided in the Genetics section of this report.

In 2007 we had planned a management simulation, where samples would be analyzed within 48 hours and results provided to managers who would then discuss possible management actions as if they were going to implement in-season management actions based on GSI data. An adequate sample size of fish from a given region is necessary to perform genetic stock identification with acceptable levels of accuracy. Due to low catch rates precluding ideal sampling design for management decision, we were unable to conduct a full “real time” management simulation. As a surrogate the laboratory performed rapid-turnaround GSI analysis, from receiving fin-clips in the mail to mapping stock of origin, for 200 genetic samples in 48 hours. This information would have been available for fisheries managers to make a decision based on GSI results if the samples collection had been adequate. In this case the 200 fish were collected across the entire western coast of Oregon and were not sufficient in numbers to perform mixed stock analysis with high levels of accuracy for a given region.

In 2008 we will be unable to conduct at-sea sampling because of extremely low predicted returns for Central Valley stocks. We will, however, be analyzing data from 2006 and 2007 for patterns in distribution that may be useful for management. We will also be developing datalogging technologies to improve oceanographic data collection, enable rapid information flow from boat to shore and increase data accuracy.

Section 8

Summary: Key Findings and Recommendations

SUMMARY: KEY FINDINGS AND RECOMMENDATIONS

Project CROOS had a successful year in 2007 even though sampling was limited due to low stock abundance. The project remains an ambitious undertaking with a diverse set of partners and objectives. CROOS managers have combined 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. Project CROOS accomplishments were the result of hard work by a large and dedicated team including fishermen, scientists, managers, and educators from both the private and public sectors. The CROOS group is proud of its accomplishments and believes that the project builds a strong foundation for future success. 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 continued to improve the protocols developed in 2006, providing "proof" of concepts for science and management, and laying the groundwork for future GSI-based salmon research and management. Key to project success were four guiding principles:

- Authentic collaborative research 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

- <u>Fleet Participation</u> The project provided financial assistance to almost a quarter of the fleet which participated in the Oregon salmon troll fishery in 2007. More than 140 vessels signed up to participate including fishermen from Benton, Clackamas, Coos, Curry, Douglas, Lane, Lincoln, Linn, Marion, Tillamook, and Yamhill counties. A total of 93 vessels actually participated (93 operators, 63 crew members) for a total of 853 days fished which produced 3,913 fish samples. More than $182,000 was distributed to vessel owners, operators, and crew. This was the second year of the project and the fishing fleet was generally more receptive toward the project than in 2006. As the project progressed, there appeared to be an increase in enthusiasm about the goals and probability of success of the project.

- <u>Protocols, Fleet Management, Project Coordination</u> The roles of the six port liaisons were modified in 2007 as specific communication and logistical needs were better defined. Liaison functions were best met using week-by-week contracts for individuals who were chosen to best fit fleet participation and distribution. Project managers continued to develop and improve 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 Six digital datalogging devices designed for fishing vessels proved to be successful in 2006 and 2007 but recommendations were made to improve electronic data collection and datalogging. Most fishermen testing these units believed the equipment is easier to use than "manual" sampling protocols but that equipment needs to be improved in order to make it simple and relatively "foolproof". Proposals were written in 2007 to fund comprehensive R&D on developing dataloggers for use on small fishing vessels for collecting scientific and fishery information. Comprehensive testing is planned for 2008-2009.

- Genetic Stock Identification (GSI) Over 3,900 tissue samples were delivered to the genetics laboratories from May through October 2007 including 800 to NMFS's Northwest Science genetics Lab. 3,826 samples were accompanied by all required sampling data compared to only 3,112 samples in 2006. Other data collected included digital logs with time/harvest location, troll tracks, fish length, harvest depth, and for a subset of samples, water temperature. Approximately 3,360 samples amplified to 7 or more loci which were used to estimate stock mixture proportions and individual assignment to baseline populations. Probability values of stock assignment ranged from 28% - 100%.

- Analysis of Stock Mixture Proportions California Central Valley Fall and Feather River Spring contributed the greatest percent (monthly average across all zones) ranging from 26% in the North Oregon Coast (NOC) to 6% in the Klamath Zone. The 2007 average of 26% in the NOC was less than half the total in 2006 indicating the lower relative abundance of Central Valley fish in 2007. While Klamath averaged only 3% in the NOC it averaged greater than 31% and 48% in the South Oregon Coast (SOC) and Klamath Zone (KMZ) respectively. Rogue River fish averaged 6%, 17%, and 19% respectively in the three Zones (NOC, SOC, KMZ). Other relatively major stocks ranged from 1-13% depending on the specific stock and zone.

- Stock Proportions Across Time Proportional stock composition showed significant variation across months and per zone. For example, California Central Valley and Feather River Spring averaged almost 40% of the catch in SOC in early summer but decreased to less than 7% by late summer. Columbia River summer and fall chinook averaged 8% in late spring/early summer in the SOC but averaged less than 2% by late summer and fall.

- Assignment of Coded Wire Tag (CWT) Fish One hundred and ten of the 3,900 samples contained coded wire tags and of these 91 fish amplified to 7 or more loci. Genetic stock of origin was correct for 94% when individual assignments were compared to hatchery fish reared and released in the same place as their stock of origin.

- Catch per Unit Effort Daily CPUE was generally higher in 2006 (5.95 fish per vessel-day) than 2007 (4.2). In 2007, daily CPUE during the months of June – October was greatest in the KMZ (7.49), followed by the SOC (5.21) and the NOC (1.65).

- Near "Real Time" Analysis Similar to 2006, near "real time" genetic analysis was tested for only a few weeks (September 2007) in order to understand technical and logistical issues. Near "real time" analysis including managing and inventorying data can be conducted within 24-48 hours after samples are received. Cost estimates for conducting near "real time" analysis range from $40-$50 per sample or approximately 60-80% higher costs than traditional GSI data analysis. Results demonstrate potential for using GSI analysis for near "real time" management on weekly time scales.

- Monitoring Wild Salmon Stocks in Near "Real Time" This project continues to demonstrate that stock composition of wild, as well as hatchery salmon stocks captured in commercial fisheries, can 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 continued to be 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 are accessible at www.ProjectCROOS.com and maps will be available on the newly developed *PacificFishTrax* website by March 2009.

- Website Development "Real time" analysis based on GSI information requires a sophisticated website. Project CROOS designed a working "prototype" capable of describing the project and reporting information to multiple audiences using a variety of tools, maps and statistical analysis. Based on comprehensive market research and experience with the working prototype, a new website, *PacificFishTrax* was designed. The new site can serve the "real time" needs of different audiences while meeting all project objectives including serving the needs of multiple West coast fisheries. The front and back ends of the site will be "beta" tested during the winter of 2009 by representatives of each user group. A website management and financial plan will be completed by the end of 2008. Test marketing and evaluation of traceability using the "fishtags" portion of the site will be conducted in 2009.

- Scale Analysis and Age of Capture A total of 2,835 scales were mounted and ages were determined within 90% confidence for 2,456 fish. Scale readers correctly aged 95% of coded wire tagged fish. The age composition was 0.4% age-2, 54.0% age-3, 36.0% age-4, 8.2% age-5, and 0.6% age-6. Four year old fish dominated in the NOC fishery and three year old fish in the other zones. Except for the NOC region which is dominated by older and more northern stocks, there was a large change in the percentage of age-3 and age-4 fish between July/August to September with age-3 fish increasing from 20-60% of the catch and age-4 fish decreasing from 60% to 30% of the catch.

- Otolith Analysis The otoliths of a subset of Chinook salmon collected during 2005, 2006, and 2007 were examined in detail. It was found that: 1) Chinook salmon from different stocks reside in ocean waters with different chemical characteristics, 2) the temperature history and information on migration patterns of individual Chinook salmon can be determined from oxygen isotopes in otoliths, 3) 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 can be determined by evaluating otoliths size and chemical composition. Results showed considerable variation across stocks for size at ocean entrance. Results also indicated lower size of out-migrant Sacramento River fish in 2004 compared to 2003 due possibly to larger Sacramento River flows in the winter of 2004.

- Oceanographic Research Oceanographic research examined characteristics of the at-sea distribution of salmon stocks for the 2006 and 2007 seasons. Although stocks from the California Coast, Northern California/Southern Oregon Coastal unit, Mid Oregon Coast and North Oregon Coast were relatively widespread, each was more closely associated with their region of origin than other areas. Large percentages of the Central Valley stock appear more disposed than Rogue or Klamath stocks to travel long distances from their region of origin. Although mean capture distances from shore widely overlap for each distinct stock, some degree of separation is observed. The North Oregon Coast stock was caught much closer to shore than other stocks. Nearest neighbor measurements for 2006 data indicated more associations within stocks than between stocks. Although age specific harvest patterns were apparent, catch numbers were too low to draw firm conclusions. Catch data from both 2006 and 2007 confirm the tendency of salmon to be aggregated in association with temperature fronts generated by summer upwelling of cold nutrient-rich water.

- Fishery Management A central goal of Project CROOS is to help improve fishery management through improving access to abundant stocks while avoiding weak stocks. In 2007 CROOS continued to develop a database similar to the CWT contribution rate database but with fewer assumptions and with potential to improve the pre-season modeling of fishery impacts and perhaps allow for finer-scale shaping of fisheries. In 2007 CROOS scientists participated in Pacific Salmon Commission committees and contributed to major recommendations for improving management of Pacific salmon using GSI and Project CROOS developed techniques and protocols. In 2007 CROOS planned a management simulation, where samples would be analyzed within 48 hours and results provided to managers who would then discuss possible actions in a near "real time" management simulation. Due to low catch rates we were unable to conduct a full "real time" management simulation but as a surrogate the laboratory performed rapid-turnaround GSI analysis, from receiving fin-clips in the mail to mapping stock of origin, for 200 genetic samples in 48 hours.

- Development of a Coordinated West Coast Project The success of Project CROOS, together with success of similar projects in California and Washington research led to the organization of a West Coast GSI project. The West Coast team is working together to develop a long term strategic plan including developing experimental fishing permits, applying for grants and contracts, and develop standard protocols for research methods, data sharing, and communication. The plan will be completed and implemented by the Spring of 2009.

Recommendations

- Adjusting and Improving Project Protocols Although a wide range of protocols have been developed and tested, they will need continual adjustments and improvement in response to 1) fishery sampling outside of normal operating areas, 2) a continuous West Coast season versus shorter openings, 3) improved catch rates, 4) new technologies, 5) and coordination of fleet management over the entire West Coast. Project CROOS members will continue to 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.). The newly established West Coast GSI team will need to coordinate research activities to provide data and analysis to address these questions.

- 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 Project CROOS 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. Research must be conducted to evaluate alternative designs. Other projects should include a national workshop to examine common needs across fisheries and potential partnerships with private manufactures.

- Designing a Multiuse "Real time" Website The prototype GIS-based website constructed during the CROOS pilot project now serves as a foundation for a fully developed website named *PacificFishTrax*. Full evaluation and beta testing for the site will continue through phased development during the next three years as sophistication of application continues. Partnerships with other real time data sites will be evaluated. Continued testing will focus on security, privacy, reliability, and accommodating multiple user needs. Research should continue to evaluate the "real time" needs of different audiences including scientists, managers, fishermen, seafood markets, consumers, and the public.

- Using Barcodes, Traceability, and the Website to Improve Salmon Marketing Test marketing should be conducted using Project CROOS technologies and data that 1) "link" individual harvest information with producers and consumers, 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.

- Long term funding Project CROOS is a comprehensive and ambitious project evaluating new integrated approaches for improving the science, management, and economic development of the West Coast Chinook salmon fisheries. Along with other West Coast partners, successful evaluation will require five years of testing with data representing relatively complete spatial and temporal coverage. A one or two year project with limited data will be inadequate to evaluate the use of GSI. It will be critical to develop funding from multiple sources to support the full testing and evaluation of this promising approach.

Conclusion

Project CROOS is an effort to implement state-of-the-art genetic, oceanographic, and fishery information for estimating stock distribution and behavior of fish in the ocean and improve fishery science, management, and marketing. 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 comprehensive database – and creative tools to support the use of this database – in order to meet the needs of multiple audiences and 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, conserve salmon stocks, and maximize economic, social, and environmental benefits from wise use of salmon resources along the entire West Coast of North America.

Appendix 1

List of Regions and Populations in GAPS (Genetic Analysis of Pacific Salmonids) Baseline

Appendix 1. List of regions and populations in GAPS (Genetic Analysis of Pacific Salmonids) baseline v 2.1. Run time, hatchery (H) or wild (W) origin, life stage, collection data, and analysis laboratory are given (from Seeb et al. 2007 and Banks et all, in prep.).

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
		Cole Rivers Hatchery (b)	Sp	H	Adult	2004	OSU

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
8	Mid Oregon Coast	Coquille (a)	Fa	W	Adult	2000	OSU
		Siuslaw (b)	Fa	W	Adult	2001	OSU
		North Umpqua (c)	Sp	W	Adult	2004	OSU
		Coos[3]	Fa	H/W	Adult	2000, 2005	OSU
		Millicoma[3]	Fa	H/W	Adult	2000, 2005	OSU
		Sixes[3]	Fa	W	Adult	2005	OSU
		Elk[3]	Fa	H	Adult	2004	OSU
		South Umpqua[3]	Fa	H/W	Adult	2002	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
		Salmon[3]	Fa	W	Adult	2003	OSU

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Yaquina[3]	Fa	W	Adult	2005	OSU
		Necanicum[3]	Fa	W	Adult	2005	OSU
		Trask[3]	Fa	W	Adult	2005	OSU
		Wilson[3]	Fa	W	Adult	2005	OSU
		Kilchis[3]	Fa	W	Adult	2005	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
		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

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		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, 2004	OSU
		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

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
15	Deschutes River fall	Lower Deschutes R.	Fa	W		1999, 2001, 2002	CRITFC
		Upper Deschutes R.[3]	Su/Fa	W	Juvenile		
16	Upper Columbia R. summer/fall	Hanford Reach CR (a)	Su/Fa	W		1999, 2000	CRITFC
		Methow R. summer (b)	Su/Fa	W		1992, 1993, 1994	CRITFC
		Wells Dam (c)	Su/Fa	H		1993,1993	CRITFC
		Wenatchee	Su	W	Adult	1993	WDFW
17	Snake River fall	Lyons Ferry	Fa	W	Adult	2002, 2003	WDFW
18	Snake River spring/summer	Imnaha R. (a)	Sp/Su	W		1998, 2002, 2003	CRITFC

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		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	WDFW
		Newsome Creek[3]	Sp/Su	W	Adult	2001, 2002	
		WF Yankee Fork[3]		W		2005	IDFG
19	Washington Coast	Queets (a)	Fa	W	Adult	1996, 1997	WDFW
		Quillayute/ Bogachiel (b)	Fa	W	Adult	1995, 1996	WDFW
		Sol Duc (c)	Sp	H	Adult	2003	WDFW
		Forks Creek Hatchery[3]	Fa	H	Adult	2005	WDFW

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Hoh River[3]	Fa	W	Adult	2004, 2005	WDFW
		Humtulips[3]	Fa	H	Adult	1990	WDFW
		Makah[3]	Fa	H	Adult	2003	WDFW
		Quinalt[3]	Fa	H	Adult	2006	USFWS
20	South Puget Sound	Soos Creek (a)	Fa	H	Adult	1998, 2004	WDFW
		White River (b)	Sp	H	Adult	1998, 2002	WDFW
		Clear Creek (Nisqually) [3]	Fa	H	Adult	2005	WDFW
		Voights Creek[3]	Fa	H	Adult	1998	WDFW
		Hupp Springs Hatchery[3]	Sp	H	Adult	2002	WDFW
		South Prairie Creek[3]	Fa	W	Adult	1998, 1999, 2002	WDFW
21	North Puget Sound	NF Nooksack (a)	Sp	H/W	Juvenile Adult	1998 1999	WDFW

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		NF Stilliguamish (b)	Su	H/W	Adult	1996, 2001	WDFW
		Skagit summer (c)	Su	W	Adult	1994, 1995	WDFW
		Suiattle (Skagit) (d)	Sp	W	Adult	1989, 1998, 1999	WDFW
		Lower Sauk[3]	Su	W		1998	NWFSC
		Snoqualmie[3]		W		2005	NWFSC
		Marblemount[3]	Sp	H		1997	NWFSC
		Marblemount[3]	Su	H		1997	NWFSC
		Wallace[3]	Su	H		2004, 2005	NWFSC
		Skykomish[3]		W		2004	NWFSC
		Upper Skagit[3]	Su	W		1998	NWFSC
		Upper Cascade[3]	Sp	W		1998	NWFSC
		Upper Sauk[3]	Sp	W		1998	NWFSC

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Samish[3]	Fa	H	Adult	1998	NWFSC
22	Lower Fraser River	Birkenhead River (a)	Sp	H	Adult	1996, 1997, 1999, 2001 - 2003	SWFSC
		W Chilliwack (b)	Fa	H	Adult	1998, 1999	DFO
		Maria Slough[3]	Su	W	Adult	1999, 2000	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
25	North Thompson River	Clearwater (a)	Fa	W	Adult	1997	DFO

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Louis River (b)	Fa	W	Adult	2001	DFO
		Raft[3]	Su	W	Adult	2002	DFO
		Deadman[3]	Sp	H	Adult	1998,1999	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
		Chilcotin[3]	Fa	H	Adult	2001	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

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
28	East Vancouver Island	Big Qualicum (a)	Fa	H	Adult	1996	DFO
		Quinsam (b)	Fa	H	Adult	1996, 1998	DFO
		Cowichan[3]	Fa	H	Adult	1999, 2000	DFO
		Nanaimo[3]	Fa	H	Adult	1998, 2002	DFO
		Puntledge[3]	Fa	H	Adult	2000, 2001	DFO
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
		Tahsis[3]	Fa	W	Adult	1996, 2002, 2003	DFO

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		Tranquil[3]	Fa	W	Adult	1996, 1999	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
		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

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		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
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

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
		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
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

Region #	Region	Population	Run time[1]	Origin	Life Stage	Collection Date	Analysis Laboratory[2]
43	Hood Canal[3]	George Adams Hatchery[3]	Fa	H	Adult	2005	WDFW
		Hamma Hamma River[3]	Fa	W	Adult	1999 - 2001	
44	Juan de Fuca[3]	Dungeness River[3]	[5]	W	Adult	2004	WDFW
		Elwha Hatchery[3]	Fa	H/W	Mixed	1996, 2004	

[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.

[3] Not shown on map, Figure 1.

[4] Undefined

Appendix 2

Genetic Stock Mixture Compositions for the North Oregon Coast Commercial Chinook Salmon Troll Fishery from June – October 2006

Appendix 2. Genetic stock mixture compositions for the North Oregon Coast zone commercial Chinook salmon troll fishery (Cape Falcon to Florence South Jetty), from June-October, 2006, estimated with GAPS microsatellite baseline v2.1 and program ONCOR (Kalinowski et al. 2007).

	June			July			August			September			October			Average over all months		
	% Stock	% Stock Low CI	% Stock High CI	% Stock	Stock Low CI	Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	Ave. % Stock	CI Range Low	CI Range high
CA Coast	0.5	(0.0,	1.5)	1.1	(0.3,	1.7)	2.4	(0.4,	5.1)	3.7	(2.6,	4.9)	2.5	(1.1,	3.9)	2.0	(0.0,	5.1)
Central BC Coast	0.0	(0.0,	0.0)	0.0	(0.0,	0.7)	0.3	(0.0,	1.3)	0.0	(0.0,	0.0)	0.0	(0.0,	0.2)	0.1	(0.0,	1.3)
Central Valley fa	57.4	(49.0,	63.3)	61.4	(57.5,	63.9)	70.0	(61.9,	73.6)	58.4	(55.3,	60.7)	51.4	(45.2,	55.9)	59.7	(45.2,	73.6)
Central Valley sp	1.7	(0.0,	4.7)	1.1	(0.2,	2.0)	2.0	(0.4,	4.1)	1.7	(0.6,	2.7)	1.9	(0.4,	3.9)	1.7	(0.0,	4.7)
Deschutes R. fa	1.0	(0.0,	4.1)	1.4	(0.3,	2.7)	0.6	(0.0,	2.5)	0.0	(0.0,	0.6)	0.0	(0.0,	1.9)	0.6	(0.0,	4.1)
E Vancouver Is.	0.0	(0.0,	0.0)	0.2	(0.0,	0.7)	0.0	(0.0,	1.1)	0.0	(0.0,	0.2)	0.0	(0.0,	0.4)	0.0	(0.0,	1.1)
Hood Canal	0.3	(0.0,	1.7)	2.1	(0.6,	3.1)	0.9	(0.0,	1.9)	0.0	(0.0,	0.1)	0.0	(0.0,	0.3)	0.6	(0.0,	1.9)
Juan de Fuca	0.0	(0.0,	0.0)	0.0	(0.0,	0.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)	0.0	(0.0,	0.8)
Klamath R.	4.4	(1.7,	9.0)	4.9	(3.6,	5.8)	5.0	(1.8,	7.6)	8.4	(6.2,	9.7)	8.2	(4.9,	10.5)	6.2	(1.7,	10.5)
L Columbia R. fa	2.2	(0.0,	4.0)	3.5	(1.5,	4.2)	2.4	(0.0,	4.2)	0.3	(0.0,	1.0)	0.0	(0.0,	0.7)	1.7	(0.0,	4.2)
L Columbia R. sp	0.7	(0.0,	3.8)	0.9	(0.5,	3.2)	0.0	(0.0,	0.9)	0.3	(0.0,	1.0)	1.2	(0.0,	2.8)	0.6	(0.0,	3.8)
L Fraser R.	1.1	(0.0,	2.7)	1.7	(0.5,	2.4)	1.3	(0.0,	3.1)	0.0	(0.0,	0.3)	1.3	(0.0,	2.1)	1.1	(0.0,	3.1)
L Skeena R.	0.0	(0.0,	0.5)	0.0	(0.0,	0.4)	0.0	(0.0,	0.0)	0.1	(0.0,	0.2)	0.0	(0.0,	0.0)	0.0	(0.0,	0.5)
L Thompson R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)
Mid/Up. Columbia R. sp	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)
Mid Columbia R. tule	2.9	(1.0,	5.0)	1.6	(0.7,	2.5)	2.1	(0.4,	4.1)	0.1	(0.0,	0.3)	0.0	(0.0,	0.0)	1.3	(0.0,	5.0)
Mid Fraser R.	1.3	(0.0,	3.1)	0.2	(0.0,	0.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.2)	0.4	(0.0,	1.1)	0.4	(0.0,	3.1)
Mid OR Coast	1.5	(0.0,	5.4)	5.0	(2.7,	7.0)	4.0	(1.1,	7.5)	9.2	(6.7,	11.9)	8.7	(5.9,	14.1)	5.7	(0.0,	14.1)
N CA / S OR Coast	0.5	(0.0,	1.6)	1.0	(0.1,	1.6)	1.6	(0.0,	3.8)	4.1	(2.3,	5.0)	2.0	(0.7,	3.9)	1.8	(0.0,	5.0)
N Gulf Coast; Alsek R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.1	(0.0,	0.2)	0.0	(0.0,	0.0)	0.0	(0.0,	0.2)

	June			July			August			September			October			Average over all months		
	% Stock	% Stock Low CI	% Stock High CI	% Stock	Stock Low CI	Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	Ave. % Stock	CI Range Low	CI Range high
N OR Coast	0.7	(0.0,	3.0)	0.1	(0.0,	0.7)	0.0	(0.0,	1.8)	3.0	(2.2,	4.5)	3.4	(1.6,	6.8)	1.4	(0.0,	6.8)
N Puget Sound	1.3	(0.0,	3.8)	0.8	(0.3,	2.5)	1.2	(0.0,	3.2)	0.3	(0.0,	0.7)	0.0	(0.0,	1.5)	0.7	(0.0,	3.8)
N Thompson R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.2)	0.0	(0.0,	0.0)	0.1	(0.0,	0.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.4)
Nass R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.3)	0.0	(0.0,	0.3)
NSE AK; Chilkat R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.3)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.3)
Rogue R.	4.1	(0.2,	6.5)	3.0	(1.5,	4.5)	1.4	(0.0,	4.1)	9.6	(7.0,	12.1)	16.6	(10.4,	18.9)	6.9	(0.0,	18.9)
S Puget Sound	3.9	(1.1,	6.8)	3.3	(2.1,	5.1)	0.0	(0.0,	2.0)	0.2	(0.0,	0.5)	0.3	(0.0,	0.9)	1.5	(0.0,	6.8)
S Thompson R.	0.3	(0.0,	1.5)	1.3	(0.4,	1.9)	0.0	(0.0,	0.0)	0.0	(0.0,	0.4)	0.0	(0.0,	0.3)	0.3	(0.0,	1.9)
Snake R. fa	2.2	(0.0,	5.0)	0.8	(0.0,	2.0)	0.3	(0.0,	2.5)	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)	0.6	(0.0,	5.0)
Snake R. sp/su	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)	0.0	(0.0,	0.3)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.3)
SSE AK	0.0	(0.0,	1.5)	0.2	(0.0,	0.5)	0.5	(0.0,	1.6)	0.0	(0.0,	0.4)	0.2	(0.0,	0.8)	0.2	(0.0,	1.6)
SSE AK; Stikine R.	0.0	(0.0,	0.5)	0.0	(0.0,	0.1)	0.0	(0.0,	0.8)	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)	0.0	(0.0,	0.8)
Taku R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.2)	0.0	(0.0,	1.3)	0.0	(0.0,	0.3)	0.0	(0.0,	0.0)	0.0	(0.0,	1.3)
U Columbia R. su/fa	10.7	(6.8,	16.1)	4.3	(2.8,	6.3)	4.2	(1.0,	8.8)	0.2	(0.1,	1.4)	0.5	(0.0,	2.2)	4.0	(0.0,	16.1)
U Fraser R.	0.0	(0.0,	0.4)	0.1	(0.0,	0.5)	0.0	(0.0,	0.0)	0.1	(0.0,	0.3)	0.0	(0.0,	0.1)	0.0	(0.0,	0.5)
U Skeena R.	0.8	(0.0,	1.1)	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.2	(0.0,	1.1)
U Stikine R.	0.0	(0.0,	1.0)	0.0	(0.0,	0.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.2)	0.0	(0.0,	0.2)	0.0	(0.0,	1.0)
W Vancouver Is.	0.0	(0.0,	0.0)	0.2	(0.0,	0.6)	0.0	(0.0,	0.8)	0.0	(0.0,	0.2)	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)
WA Coast	0.0	(0.0,	0.0)	0.0	(0.0,	0.4)	0.0	(0.0,	1.0)	0.2	(0.0,	0.9)	1.2	(0.0,	2.4)	0.3	(0.0,	1.0)
Willamette R.	0.5	(0.0,	1.5)	0.2	(0.0,	0.8)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.3	(0.0,	0.8)	0.2	(0.0,	1.5)

AK = Alaska;, CA = California; CACV fa/fsp = California Central Valley fall and Feather River spring; CI = Confidence Interval; fa = fall; E = east; N = north; OR = Oregon; R = River; S = south; sp = spring; su = summer; U = Upper

Appendix 3

Genetic Stock Mixture Compositions for the North Oregon Coast Commercial Chinook Salmon Troll Fishery from June & July 2007

Appendix 3. Genetic stock mixture compositions for the North Oregon Coast commercial Chinook salmon troll fishery (Cape Falcon to Florence South Jetty), during the months of June and July, 2007, estimated with GAPS microsatellite baseline v2.1 and program ONCOR (Kalinowski et al. 2007).

	June			July			Average Over all Months		
	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	Ave. % Stock	CI Range Low	CI Range High
California Coast	0.0	(0.0,	0.0)	2.1	(0.5,	4.3)	1.1	(0.0,	4.3)
Central BC Coast	0.0	(0.0,	0.0)	0.5	(0.0,	1.6)	0.3	(0.0,	1.6)
Central Valley fa	31.8	(23.5,	37.2)	19.5	(13.1,	21.9)	25.7	(13.1,	37.2)
Central Valley sp	0.2	(0.0,	1.0)	0.6	(0.0,	3.1)	0.4	(0.0,	3.1)
Deschutes R. fa	2.3	(0.0,	5.0)	4.2	(0.2,	7.3)	3.2	(0.0,	7.3)
E Vancouver Is.	0.0	(0.0,	0.2)	0.0	(0.0,	1.1)	0.0	(0.0,	1.1)
Hood Canal	2.4	(0.0,	5.2)	1.0	(0.0,	4.1)	1.7	(0.0,	5.2)
Juan de Fuca	0.2	(0.0,	1.9)	0.0	(0.0,	0.7)	0.1	(0.0,	1.9)
Klamath R.	2.7	(0.5,	5.0)	3.4	(0.2,	5.6)	3.0	(0.2,	5.6)
L Columbia R. fa	4.5	(1.7,	8.5)	7.4	(2.0,	12.1)	6.0	(1.7,	12.1)
L Columbia R. sp	3.7	(0.3,	8.6)	3.3	(0.4,	6.8)	3.5	(0.3,	8.6)
L Fraser R.	2.2	(0.0,	4.9)	0.0	(0.0,	0.6)	1.1	(0.0,	4.9)
L Skeena R.	1.1	(0.0,	2.4)	0.0	(0.0,	0.0)	0.6	(0.0,	2.4)
Mid/Upper Columbia R. sp	0.0	(0.0,	1.0)	0.0	(0.0,	0.0)	0.0	(0.0,	1.0)
Mid Columbia R. tule	5.1	(1.9,	8.1)	9.9	(6.3,	13.8)	7.5	(1.9,	13.8)
Mid Fraser R.	1.8	(0.0,	3.8)	1.5	(0.0,	3.2)	1.7	(0.0,	3.8)
Mid Oregon Coast	11.7	(6.7,	16.0)	7.1	(5.4,	13.4)	9.4	(5.4,	16.0)
N California / S Oregon Coast	0.0	(0.0,	1.1)	1.9	(0.0,	4.3)	1.0	(0.0,	4.3)
N Oregon Coast	1.0	(0.0,	3.2)	1.1	(0.0,	3.1)	1.0	(0.0,	3.2)
N Puget Sound	1.8	(0.0,	4.1)	2.9	(0.0,	6.3)	2.4	(0.0,	6.3)
N Thompson R.	0.0	(0.0,	0.1)	0.5	(0.0,	1.1)	0.2	(0.0,	1.1)
Nass R.	0.0	(0.0,	0.5)	0.0	(0.0,	1.0)	0.0	(0.0,	1.0)
NSE Alaska; Chilkat R.	0.0	(0.0,	0.5)	0.0	(0.0,	0.0)	0.0	(0.0,	0.5)
Rogue R.	5.4	(1.8,	9.2)	6.8	(2.1,	10.5)	6.1	(1.8,	10.5)
SBC Mainland	0.0	(0.0,	0.9)	0.0	(0.0,	0.0)	0.0	(0.0,	0.9)
S Puget Sound	6.9	(2.4,	10.2)	4.2	(0.3,	7.6)	5.6	(0.3,	10.2)
S Thompson R.	0.9	(0.0,	2.8)	2.3	(0.0,	4.2)	1.6	(0.0,	4.2)
Snake R. fa	1.7	(0.0,	4.7)	3.7	(1.2,	8.3)	2.7	(0.0,	8.3)
SSE Alaska	0.0	(0.0,	2.0)	0.0	(0.0,	1.5)	0.0	(0.0,	2.0)
SSE Alaska; Stikine R.	0.7	(0.0,	2.6)	0.3	(0.0,	1.5)	0.5	(0.0,	2.6)
Taku R.	0.0	(0.0,	1.5)	0.0	(0.0,	0.0)	0.0	(0.0,	1.5)
U Columbia R. su/fa	11.3	(6.1,	16.7)	14.2	(7.9,	21.7)	12.8	(6.1,	21.7)
U Fraser R.	0.0	(0.0,	0.0)	0.5	(0.0,	1.1)	0.3	(0.0,	1.1)
U Skeena R.	0.0	(0.0,	0.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.4)
U Stikine R.	0.0	(0.0,	0.4)	0.5	(0.0,	1.6)	0.3	(0.0,	1.6)
W Vancouver Is.	0.0	(0.0,	1.0)	0.0	(0.0,	1.1)	0.0	(0.0,	1.1)
Washington Coast	0.5	(0.0,	1.7)	0.5	(0.0,	2.7)	0.5	(0.0,	2.7)
Willamette R.	0.0	(0.0,	0.3)	0.0	(0.0,	1.6)	0.0	(0.0,	1.6)

AK = Alaska;, CA = California; CACV fa/fsp = California Central Valley fall and Feather River spring; CI = Confidence Interval; fa = fall; E = east; N = north; OR = Oregon;
R = River; S = south; sp = spring; su = summer; U = Upper

Appendix 4

Genetic Stock Mixture Compositions for the South Oregon Coast Commercial Chinook Salmon Troll Fishery from May - October 2007

Appendix 4. Genetic stock mixture compositions for the South Oregon Coast commercial Chinook salmon troll fishery (Florence South Jetty to Humbug Mountain), from May-October, 2007, estimated with GAPS microsatellite baseline v2.1 and program ONCOR (Kalinowski et al. 2007).

	May			June			July			August			September			October			Average over all months		
	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	Stock Low CI	Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	Ave. % Stock	CI Range Low	CI Range high
CA Coast	2.0	(0.4,	3.6)	1.9	(0.0,	5.7)	5.1	(3.0,	7.9)	7.3	(5.7,	8.3)	5.8	(2.2,	10.3)	6.3	(0.0,	12.8)	4.7	(0.0,	12.8)
Central BC Coast	0.4	(0.0,	1.2)	0.0	(0.0,	0.0)	0.2	(0.0,	0.8)	0.0	(0.0,	0.2)	0.0	(0.0,	1.6)	0.0	(0.0,	0.0)	0.1	(0.0,	1.6)
Central Valley fa	35.8	(28.3,	39.3)	41.4	(29.2,	51.4)	17.8	(14.3,	21.1)	7.2	(6.0,	8.3)	2.4	(0.0,	4.9)	1.6	(0.0,	5.0)	17.7	(0.0,	39.3)
Central Valley sp	0.5	(0.0,	2.5)	0.0	(0.0,	4.0)	0.3	(0.0,	1.1)	0.0	(0.0,	0.1)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.1	(0.0,	4.0)
Deschutes R. fa	1.3	(0.0,	4.0)	4.3	(0.0,	10.3)	1.0	(0.0,	2.2)	0.2	(0.0,	0.7)	0.0	(0.0,	3.4)	0.0	(0.0,	2.4)	1.1	(0.0,	10.3)
E Vancouver Is.	0.0	(0.0,	0.6)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.6)
Hood Canal	1.0	(0.0,	2.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.1	(0.0,	0.3)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.2	(0.0,	2.4)
Klamath R.	23.7	(16.3,	27.7)	5.7	(1.9,	13.4)	47.1	(38.3,	49.0)	48.9	(43.2,	50.0)	43.5	(33.6,	52.0)	17.3	(8.1,	27.8)	31.0	(1.9,	52.0)
L Columbia R. fa	1.2	(0.0,	3.0)	2.0	(0.0,	7.7)	0.8	(0.0,	1.8)	0.2	(0.0,	0.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.7	(0.0,	7.7)
L Columbia R. sp	0.9	(0.0,	3.1)	0.0	(0.0,	3.8)	0.0	(0.0,	1.0)	0.1	(0.0,	0.6)	0.0	(0.0,	0.0)	0.0	(0.0,	3.3)	0.2	(0.0,	3.8)
L Fraser R.	0.4	(0.0,	1.2)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.1	(0.0,	1.2)
L Skeena R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.5)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.5)
Mid Columbia R. tule	2.7	(0.5,	4.8)	3.7	(0.0,	9.3)	0.5	(0.0,	1.5)	0.0	(0.0,	0.2)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	1.1	(0.0,	9.3)
Mid Fraser R.	0.0	(0.0,	1.2)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	1.2)
Mid OR Coast	8.1	(4.1,	12.6)	5.6	(0.0,	13.0)	8.2	(5.1,	12.5)	10.9	(9.1,	14.4)	16.1	(7.0,	24.5)	19.2	(8.1,	33.3)	11.3	(0.0,	33.3)
N CA / S OR Coast	2.2	(0.3,	4.1)	6.0	(0.0,	13.1)	4.8	(2.4,	6.9)	6.8	(5.1,	8.0)	12.9	(5.0,	18.0)	14.0	(5.7,	23.4)	7.8	(0.0,	23.4)
N OR Coast	1.2	(0.0,	2.5)	1.8	(0.0,	5.5)	0.0	(0.0,	0.2)	0.2	(0.0,	0.7)	0.0	(0.0,	3.3)	1.5	(0.0,	5.5)	0.8	(0.0,	5.5)
N Puget Sound	0.9	(0.0,	3.2)	0.0	(0.0,	3.5)	0.6	(0.0,	2.0)	0.0	(0.0,	0.5)	0.0	(0.0,	2.4)	0.0	(0.0,	3.0)	0.3	(0.0,	3.5)
Nass R.	0.0	(0.0,	0.8)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)
Rogue R.	5.6	(2.1,	10.5)	15.8	(1.9,	23.0)	11.8	(7.5,	18.1)	17.5	(14.9,	21.8)	15.1	(7.4,	21.8)	36.8	(20.1,	50.0)	17.1	(1.9,	50.0)
SBC Mainland	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)
S Puget Sound	1.9	(0.0,	3.7)	0.0	(0.0,	0.0)	0.0	(0.0,	0.7)	0.1	(0.0,	0.3)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.3	(0.0,	3.7)
S Thompson R.	0.4	(0.0,	1.8)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.2	(0.0,	0.6)	0.0	(0.0,	0.1)	0.0	(0.0,	1.4)	0.1	(0.0,	1.8)
Snake R. fa	0.0	(0.0,	1.6)	4.8	(0.0,	8.4)	0.0	(0.0,	1.1)	0.3	(0.0,	0.5)	0.0	(0.0,	1.3)	0.0	(0.0,	0.0)	0.9	(0.0,	1.6)
SSE AK	0.0	(0.0,	0.1)	0.0	(0.0,	1.2)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.8	(0.0,	2.4)	0.0	(0.0,	0.0)	0.1	(0.0,	2.4)
SSE AK; Stikine R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.7)	0.0	(0.0,	0.1)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.7)
Taku R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)	0.7	(0.0,	3.4)	0.0	(0.0,	0.0)	0.1	(0.0,	3.4)
U Columbia R. su/fa	8.8	(5.1,	13.0)	7.1	(0.0,	19.5)	1.6	(0.5,	3.4)	0.3	(0.1,	1.2)	2.0	(0.0,	4.8)	1.7	(0.0,	6.9)	3.6	(0.0,	19.5)

	May			June			July			August			September			October			Average over all months		
	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	Stock Low CI	Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	Ave. % Stock	CI Range Low	CI Range high
U Fraser R.	0.8	(0.0,	1.6)	0.0	(0.0,	0.0)	0.0	(0.0,	0.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.1	(0.0,	1.6)
U Stikine R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.1	(0.0,	0.2)	0.3	(0.0,	2.4)	0.0	(0.0,	0.0)	0.1	(0.0,	2.4)
W Vancouver Is.	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.3	(0.0,	0.8)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)
WA Coast	0.0	(0.0,	1.2)	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)	0.0	(0.0,	0.6)	0.6	(0.0,	2.8)	1.6	(0.0,	4.9)	0.4	(0.0,	4.9)
Willamette R.	0.4	(0.0,	1.5)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.1	(0.0,	1.5)

AK = Alaska;, CA = California; CACV fa/fsp = California Central Valley fall and Feather River spring; CI = Confidence Interval; fa = fall; E = east; N = north; OR = Oregon; R = River; S = south; sp = spring; su = summer; U = Upper

Appendix 5

Genetic Stock Mixture Compositions for the Klamath Zone Commercial Chinook Salmon Troll Fishery from July - September 2007

Appendix 5. Genetic stock mixture compositions for the Klamath zone commercial Chinook salmon troll fishery (Humbug Mountain to the Oregon/California border), from July-September, 2007, estimated with GAPS microsatellite baseline v2.1 and program ONCOR (Kalinowski et al. 2007).

	July			August			September			Average over all months		
	% Stock	Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	% Stock	% Stock Low CI	% Stock High CI	Ave. % Stock	CI Range Low	CI Range high
CA Coast	6.2	(3.3,	8.3)	8.6	(4.8,	12.4)	9.0	(2.6,	15.3)	7.9	(2.6,	15.3)
Central BC Coast	0.2	(0.0,	1.4)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.1	(0.0,	1.4)
Central Valley fa	11.8	(6.9,	15.6)	4.5	(1.5,	7.3)	2.6	(0.0,	6.4)	6.3	(0.0,	15.6)
Central Valley sp	0.6	(0.0,	1.5)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.2	(0.0,	1.5)
Deschutes R. fa	0.0	(0.0,	0.9)	0.9	(0.0,	2.5)	0.0	(0.0,	2.6)	0.3	(0.0,	2.6)
E Vancouver Is.	0.0	(0.0,	0.7)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.7)
Juan de Fuca	0.0	(0.0,	0.3)	0.0	(0.0,	0.8)	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)
Klamath R.	45.8	(38.0,	50.4)	44.2	(36.0,	49.1)	53.4	(37.4,	61.6)	47.8	(36.0,	61.6)
L Columbia R. fa	0.6	(0.0,	1.3)	0.0	(0.0,	1.0)	0.0	(0.0,	0.0)	0.2	(0.0,	1.3)
L Columbia R. sp	0.0	(0.0,	1.2)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	1.2)
Mid Fraser R.	0.0	(0.0,	0.6)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.6)
Mid OR Coast	6.9	(4.0,	12.0)	10.6	(5.5,	18.0)	9.5	(2.9,	20.4)	9.0	(2.9,	20.4)
N CA / S OR Coast	4.2	(1.6,	7.2)	7.1	(3.7,	11.4)	11.7	(3.5,	18.4)	7.7	(1.6,	18.4)
N OR Coast	0.0	(0.0,	1.7)	0.0	(0.0,	0.6)	0.0	(0.0,	0.0)	0.0	(0.0,	1.7)
N Puget Sound	0.0	(0.0,	1.5)	0.0	(0.0,	2.2)	0.7	(0.0,	4.8)	0.2	(0.0,	4.8)
N Thompson R.	0.0	(0.0,	0.9)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.9)
Rogue R.	21.8	(14.2,	27.5)	23.1	(15.1,	30.5)	12.1	(2.8,	22.6)	19.0	(2.8,	27.5)
SBC Mainland	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)
S Puget Sound	0.4	(0.0,	1.2)	0.0	(0.0,	0.4)	0.0	(0.0,	0.0)	0.1	(0.0,	1.2)
S Thompson R.	0.0	(0.0,	0.0)	0.0	(0.0,	0.8)	0.0	(0.0,	2.5)	0.0	(0.0,	2.5)
Snake R. fa	0.0	(0.0,	1.2)	0.0	(0.0,	0.5)	0.0	(0.0,	0.0)	0.0	(0.0,	1.2)
SSE AK	0.0	(0.0,	0.1)	0.0	(0.0,	0.0)	0.0	(0.0,	0.0)	0.0	(0.0,	0.1)
U Columbia R. su/fa	1.3	(0.0,	2.9)	0.9	(0.0,	3.3)	0.0	(0.0,	2.7)	0.7	(0.0,	3.3)
U Fraser R.	0.0	(0.0,	0.3)	0.0	(0.0,	0.6)	0.0	(0.0,	0.0)	0.0	(0.0,	0.3)
WA Coast	0.4	(0.0,	1.1)	0.0	(0.0,	2.0)	1.0	(0.0,	4.2)	0.5	(0.0,	4.2)

AK = Alaska;, CA = California; CACV fa/fsp = California Central Valley fall and Feather River spring; CI = Confidence Interval; fa = fall; E = east; N = north; OR = Oregon; R = River; S = south; sp = spring; su = summer; U = Upper

Appendix 6

Individual Fish Coded Wire Tag and Genetic Assignments

Barcode	Year	SNOUT ID	run	HATCHERY	STOCK	RELEASE SITE	Correct	Notes	Estimated Stock using Genetics	Probability
3235	2007	07J3709	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	0.98
910	2006	06J6503	1	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
19477	2007	07J0859	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
6175	2006	06J5416	3	FEATHER R HATCHERY	FEATHER RIVER	WEST SACRAMENTO	yes		CentralValleyfaFeasp	1.00
7454	2006	06J3393	3	ELK R HATCHERY	ELK R (ELK R HT)	ELK R	yes		MidOregonCoast	0.99
7772	2006	06J6500	7	COLEMAN NFH	COLEMAN NFH	COLEMAN NFH	yes			
19452	2007	07J0858	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
19459	2007	07J0852	3	IRON GATE HATCHERY	KLAMATH RIVER	IRON GATE HATCHERY	yes		KlamathR.	1.00
3781	2006	06J2497	3	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
6409	2006	06J3387	3	IRON GATE HATCHERY	KLAMATH RIVER	IRON GATE HATCHERY	yes		KlamathR.	1.00
7704	2006	06J3368	1	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
7748	2006	06J3364	7	COLEMAN NFH	COLEMAN NFH	COLEMAN NFH	yes		CentralValleyfaFeasp	1.00
848	2006	06J2804	3	ELK R HATCHERY	CHETCO R	CHETCO R	yes		NCalifornia/SOregonCoast	1.00
6357	2006	06J3358	3	H-CHEHALIS R	S-HARRISON R	R-CHEHALIS R	yes		LFraserR.	0.99
6426	2006	06J3357	1	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
7706	2006	06J3367	3	FEATHER R HATCHERY	FEATHER RIVER	WEST SACRAMENTO	yes		CentralValleyfaFeasp	1.00
9018	2006	06J3381	3	COLEMAN NFH	COLEMAN NFH	CLARKSBURG	yes		CentralValleyfaFeasp	1.00
544	2007	07J0815	3	KLASKANINE S FK POND	COLE RIVERS HATCHERY	KLASKANINE R S FK	yes	Rogue hatchery stock maintained on Columbia	RogueR.	0.99
7055	2007	07J3717	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
8657	2007	07J3778	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
9983	2007	07J3766	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	0.99
19485	2007	07J0856	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
19487	2007	07J0857	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
29406	2007	07J3036	1	COLE RIVERS HATCHERY	COLE RIVERS HATCHERY	ROGUE R 4	yes		RogueR.	1.00
3185	2006	06J6401	3	COLEMAN NFH	COLEMAN NFH	BATTLE CREEK	yes		CentralValleyfaFeasp	1.00
6424	2006	06J3386	7	COLEMAN NFH	COLEMAN NFH	COLEMAN NFH	yes		CentralValleyfaFeasp	1.00
7488	2006	06J3396	1	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
7730	2006	06J3366	7	COLEMAN NFH	COLEMAN NFH	BENICIA	yes		CentralValleyfaFeasp	1.00
9009	2006	06J3380	1	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
9991805	2006	06J3353	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
5861	2007	07J1938	1	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00

7031	2007	07J0521	2		WELLS HATCHERY	COLUMBIA R - GENERAL	yes		UColumbiaR.su/fa	1.00
7032	2007	07J0520	3	NISQUALLY HATCHERY	CLEAR CR 11.0013C	CLEAR CR 11.0013C	yes		SPugetSound	1.00
7054	2007	07J3718	3	ELK R HATCHERY	ELK R (ELK R HT)	ELK R	yes		MidOregonCoast	1.00
7263	2007	07J3622	1	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
7363	2007	07J3679	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
7524	2007	07J3014	3		LEWIS R -NF 27.0168	LEWIS R -NF 27.0168	yes		LColumbiaR.fa	1.00
8768	2007	07J0523	3	BIG CR HATCHERY	COLE RIVERS HATCHERY	KLASKANINE R N FK	yes	Rogue hatchery stock maintained on Columbia	KlamathR.	0.97
9691	2007	07J0524	2	DRYDEN POND	WENATCHEE R 45.0030	WENATCHEE R 45.0030	yes		UColumbiaR.su/fa	1.00
9920	2007	07J3667	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
14778	2007	07J0622	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
15857	2007	07J0621	3	IRON GATE HATCHERY	KLAMATH RIVER	IRON GATE HATCHERY	yes		KlamathR.	0.99
18025	2007	07J3704	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
18037	2007	07J3702	3	ROCK CR HATCHERY	UMPQUA R(ROCK CR HT)	ROCK CR (N UMPQUA R)	yes		MidOregonCoast	0.96
18061	2007	07J3714	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
19067	2007	07J0803	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
19492	2007	07J0853	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
19588	2007	07J3713	3	INDIAN CR PD (STEP)	ROGUE R LWR	INDIAN CR (ROGUE R)	yes		RogueR.	1.00
25096	2007	07J0787	3	ELK R HATCHERY	ELK R (ELK R HT)	ELK R	yes		MidOregonCoast	1.00
25171	2007	07J0788	3	ELK R HATCHERY	ELK R (ELK R HT)	ELK R	yes		MidOregonCoast	1.00
25172	2007	07J0789	3	ELK R HATCHERY	ELK R (ELK R HT)	ELK R	yes		MidOregonCoast	1.00
30453	2007	07J3765	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
30456	2007	07J3767	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
904	2006	06J6405	3	ELK R HATCHERY	ELK R (ELK R HT)	ELK R	yes		MidOregonCoast	1.00
913	2006	06J6513	1	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
919	2006	06J6512	1	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	0.99
1016	2006	06J3348	3	FEATHER R HATCHERY	FEATHER RIVER	PORT CHICAGO	yes		CentralValleyfaFeasp	1.00
1823	2006	06J2806	2	CARLTON REARING POND	METHOW & OKANOGAN	METHOW R 48.0002	yes		UColumbiaR.su/fa	1.00
3341	2006	06J3399	3	FEATHER R HATCHERY	FEATHER RIVER	PORT CHICAGO	yes		CentralValleyfaFeasp	1.00
3731	2006	06J3363	1	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	0.98
3747	2006	06J3359	3	COLE RIVERS HATCHERY	COOS R - PUBLIC	MORGAN CR (COOS R)	yes		MidOregonCoast	1.00
4403	2006	06J2816	1	COLE RIVERS HATCHERY	COLE RIVERS HATCHERY	ROGUE R 4	yes		RogueR.	0.99
4859	2006	06J6510	7	COLEMAN NFH	COLEMAN NFH	COLEMAN NFH	yes		CentralValleyfaFeasp	1.00
4924	2006	06J3378	1	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00

6152	2006	06J5415	3	BANDON HATCHERY	COOS R - PUBLIC	MORGAN CR (COOS R)	yes		MidOregonCoast	0.99
6246	2006	06J6403	1	COLE RIVERS HATCHERY	COLE RIVERS HATCHERY	ROGUE R 4	yes		RogueR.	0.97
6432	2006	06J3385	3	MATTOLE SAL. GP. HAT	MATTOLE RIVER	MATTOLE SAL. GP. HAT	yes		CaliforniaCoast	1.00
7465	2006	06J3395	3	COLEMAN NFH	COLEMAN NFH	BATTLE CREEK	yes		CentralValleyfaFeasp	1.00
7469	2006	06J3394	1	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
7471	2006	06J3392	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	yes		KlamathR.	1.00
7487	2006	06J3397	1	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
7703	2006	06J3369	3	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
8170	2006	06J3379	3	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
9717	2006	06J6509	1	FEATHER R HATCHERY	FEATHER RIVER	SAN PABLO BAY	yes		CentralValleyfaFeasp	1.00
9720	2006	06J6508	1	COWLITZ SALMON HATCH	COWLITZ R 26.0002	COWLITZ R 26.0002	yes		LColumbiaR.sp	1.00
5268	2007	07J3666	7	COLEMAN NFH	COLEMAN NFH	COLEMAN NFH	yes**	assigned correctly in weekly mixture by management zone, but not monthly mixture	CentalValleyfaFeasp	1.00
8651	2007	07J3779	3	BANDON HATCHERY	COQUILLE R	SEVENMILE CR (COQUIL	no		SThompsonR.	0.95
9921	2007	07J3665	3	CEDC YOUNGS BAY NET	COLE RIVERS HATCHERY	YOUNGS R & BAY	no	Rogue hatchery stock maintained on Columbia	KlamathR.	1.00
6232	2006	06J6402	3	ELK RIVER	ELK R (ELK R HT)	ELK R	no	Chetco broodstock maintained on Elk River	NCalifornia/SOregonCoast	1.00
19062	2007	07J0806	1	FEATHER R HATCHERY	FEATHER RIVER	LIVE OAK	no		KlamathR.	1.00
19489	2007	07J0854	3	KLASKANINE HATCHERY	COLE RIVERS HATCHERY	KLASKANINE R N FK	no	Rogue hatchery stock maintained on Columbia	MidOregonCoast	0.97
921	2006	06J6514	3	SIUSLAW NATURAL PRODUCTION TAG	SIUSLAW R	SIUSLAW R	no		NOregonCoast	0.98
1031	2006	06J2495	1	KALAMA FALLS HATCHRY	KALAMA R 27.0002	GOBAR CR 27.0073	no		MidOregonCoast	0.97
3331	2006	06J6400	1	COWLITZ SALMON HATCH	COWLITZ R 26.0002	COWLITZ R 26.0002	no	right basin, wrong run-time	LColumbiaR.fa	0.99
18227	2007	07J3653	3	CEDC YOUNGS BAY NET	COLE RIVERS HATCHERY	YOUNGS R & BAY	n/a (yes)	Rogue hatchery stock maintained on Columbia	RogueR.	0.75
19780	2007	07J3700	8	LYONS FERRY HATCHERY	SNAKE R-LOWR 33.0002	LYONS FERRY REL.SITE	n/a (yes)		SnakeR.fa	0.62

30401	2007	07J3037	1	COLE RIVERS HATCHERY	COLE RIVERS HATCHERY	ROGUE R 4	n/a (yes)		RogueR.	0.81
7746	2006	06J3365	1	ROCK CREEK	UMPQUA R (ROCK CR HT)	ROCK CR (N UMPQUA R)	n/a (yes)		MidOregonCoast	0.51
1024	2006	06J2496	3	ELK R HATCHERY	ELK R (ELK R HT)	ELK R	n/a (no)		SSEAlaska	0.86
1516	2006	06J3321	3	GROVERS CR HATCHERY	GROVERS CR 15.0299	GROVERS CR HATCHERY	n/a (no)		HoodCanal	0.83
9015	2006	06J3382	1	COLE RIVERS HATCHERY	COLE RIVERS HATCHERY	ROGUE R 4	n/a (no)		MidOregonCoast	0.56
19618	2007	07J3712	3	INDIAN CR PD (STEP)	ROGUE R LWR	ROGUE R 1	failed amplification			
9374	2006	06J2814	1	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	failed amplification			
6829	2007	07J3654	3	ELK R HATCHERY	ELK R (ELK R HT)	ELK R	failed amplification			
19454	2007	07J0855	3	TRINITY R HATCHERY	TRINITY RIVER	TRINITY R HATCHERY	failed amplification			
5856	2007	07J1939	2	DRYDEN POND	WENATCHEE R 45.0030	WENATCHEE R 45.0030	failed amplification			
4360	2006	06J3388	0	NO TAG			no tag			
6827	2007	07J3652	0	NO TAG			no tag			
7988	2007	07J0610	0	NO TAG			no tag		KlamathR.	1.00
3197	2006	06J3398	0	NO TAG			no tag		CentralValleyfaFeasp	1.00
4373	2006	06J3389	0	NO TAG			no tag		CentralValleyfaFeasp	0.98
9446	2006	06j3390	0	NO TAG			no tag		CentralValleyfaFeasp	1.00
7026	2007	07J0519	0	NO TAG			no tag		CentralValleyfafeasp	0.71
7395	2007	07J3678	0	TAG LOST			no tag		KlamathR.	0.88
7990	2007	07J0611	0	NO TAG			no tag		RogueR.	1.00
9447	2006	06J3391	0	TAG READ WRONG - was COHO			no tag		RogueR.	0.97
8762	2007	07J0522	0	TAG LOST			no tag		KlamathR.	0.88
19607	2007	07J3711	0	TAG LOST			no tag		KlamathR.	0.83
846	2006	06J2805					no tag		UColumbiaR.su/fa	0.94
4605	2007	07J3650					no tag			

Appendix 7

Development of the Project CROOS Website: Laying the Groundwork for the Future of Fisheries Research

(This section is excerpted from pages 13-36 of Christopher M. Pugmire's final paper for the degree of Master of Science in Marine Resource Management presented on September 20, 2007 Titled: Development of the Project CROOS Website: Laying the Groundwork for the Future of Fisheries Research)

Literature Review

Once consensus was reached concerning expectations for the website, the next development issue that was addressed involved the site's design. Creating a website without a well-conceived design, regardless of the information or services being provided, often results in an ineffective site. The design is what draws users in, maintains their interest, and encourages them to return. It's what shapes a website into an attractive, functional, and easy to use resource. Without a proper design, a website's valuable content is vulnerable to being overlooked, underappreciated and unused.

In an effort to help create an effective website for Project CROOS, an extensive review of web-design literature was conducted. The objective was to identify key elements associated with quality website design. The results of the review revealed that despite numerous opinions and conflicting viewpoints, several design commonalities do exist among highly rated websites. These design aspects generally fall into the following categories: content, page layout, navigation, interactivity, responsiveness, and credibility.

Content. According to most web design literature, there is a trend toward simplicity when it comes to content [6,7]. "Revolving wingdings, flashing banner ads, grotesque background colors and textures, and meaningless multimedia effects that require endless plug-ins are headed towards extinction. Users no longer want glitter—they want content and service, and they want it fast" [7]. To meet this growing demand for simplistic quality, the literature offers several recommendations.

Beginning with the actual information and services provided by the website, Leavitt and Shneiderman [8] recommend limiting content to material that is engaging, relevant and appropriate to the targeted audiences. They further suggest presenting that material in the most useful and usable format possible. This would imply that the entire website's content be displayed in the user's language and converted or summarized into its most concise, understandable, and salient form [9, 10]. For content designed with inexperienced and/or first time users in mind, this may require the assistance of an FAQ (Frequently Asked Questions) or a help link [8]. Similarly, in scenarios where multiple users are involved, there may also be a need to provide content in multiple formats and at different levels of detail [8, 10].

Regarding website text, the consensus among the literature is that less is more. Well-designed websites tend to use clear and concise text, paying close attention to spelling and grammar [11]. Text that is characterized as promoting effective communication generally uses only a few familiar fonts that are at least 9-points in size, dark, and placed on plain, high-contrast backgrounds containing colors that are subtle and few in numbers [8, 9, 10, 12, 13]. The text is usually restricted to brief sentences, bulleted lists, highlighted keywords, colorful and descriptive paragraph headings, and any other format capable of promoting scanning [8, 10, 11]. When paragraphs are necessary, they are kept small, containing one major idea with the most important point included in the first sentence [8, 11].

Similar to website text, the literature also recommends a minimalist approach when it comes to graphics, images, and multimedia. The idea is that this type of content, when used excessively and inappropriately, hinders efficiency by reducing loading speeds [8, 10, 12]. To avoid efficiency issues, Bevan [10] recommends using graphics sparingly, as well as using small images, interlaced images, and repeat images whenever possible. Similarly, Ivory and Megraw [12] suggest not only minimizing the number of images, but also avoiding certain types, such as images that contain text (content graphics), images that are used for navigation, and images that are animated. They further discourage the use of applets, controls, scripts, video, sound, and plug-ins. Leavitt and Shneiderman [8] argue that video, animation, and audio only be used when the anticipated benefits greatly outweigh the potential risks of distracting the user or slowing download times. They also recommend using background images sparingly, as well as providing users with thumbnail images when the viewing of full-sized images is not critical.

Page layout. Quality websites are structured and organized to facilitate both ease of comprehension and use [8]. To achieve this objective, several design strategies are often implemented. Among the many strategies, one of the most commonly cited is consistency. Many web experts advocate for the consistent use of design elements (e.g., the size and spacing of characters; the colors used for labels, fonts, and backgrounds; and the locations of labels, text, and pictures) throughout the site [8, 9, 12]. This approach is believed to improve user performance by eliminating the mental strain associated with constantly reinterpreting numerous page layouts within a single website [9].

In addition to consistency, the use of page space is also an important component of a website's layout. According to the literature, well-designed web pages tend to occupy space in a manner that is neither cluttered nor empty [8, 9]. Instead they reflect a healthy balance of both content and white space that allows users to locate desired information, without being overwhelmed by visual and functional paraphernalia [9].

The organization of website content is another important area of page layout. In the literature, many web experts agree that content should be organized to both facilitate usability and avoid timely distractions. To achieve this objective, several recommendations exist. Leavitt and Shneiderman [8] recommend visually aligning page elements, either vertically or horizontally, to avoid the confusion that is sometimes associated with random design. They also suggest organizing content to avoid scrolling both horizontally and through numerous screenfuls of information. Other web experts, recommend arranging content in an order that reflects its relative importance, meaning the most relevant material is placed toward the top and center of the page [14]. They also suggest improving the users' scanning capability by grouping related elements, using descriptive headings generously, and highlighting important items that require user attention [8, 9, 10].

Navigation. Incorporating efficient and user-friendly navigability within a website is one of the most critical elements of successful web design. Without the ability to move freely and accurately throughout the website, users are likely to get confused, lost, or frustrated and eventually leave the site [11]. To avoid such navigation breakdowns, there are several guidelines that need to be considered.

The ability to effectively navigate a website requires that users be aware of their location and their destination options within a site's information architecture [9, 10, 12]. To achieve this objective, web experts recommend the use of site maps and effective location feedback [8, 10, 12, 14]. A simple, but popular, feedback method is to apply distinct, visible page titles throughout the website that are capable of signaling the users' whereabouts [12]. Another recommendation for improving navigation is to differentiate navigational elements (e.g., buttons, bars, tabs, etc.) by grouping and placing them in consistent and easy to find places on each page [8, 9, 14]. This allows users to increase their performance efficiency by reducing the amount of time spent searching the website for navigation aids.

The effective use of links is another way to enhance a website's navigation capacity. Links have the ability to transport users quickly and efficiently throughout a website. However, when utilized incorrectly, they can very easily lose a user in hyperspace. To ensure that links are used appropriately, web experts recommend using descriptive, text-based links, which are easy to view and accurate [8, 11, 14]. They also suggest providing links to the local contents and home on every page; using multiple links to access significant information; avoiding links that open up new browsers or pop-up ads; highlighting important links; and differentiating between links that are used, unused, internal, and/or external [10, 11, 14]. In larger websites, where links and other traditional navigation aids are not sufficient, search engines with clearly defined scopes are also recommended [8, 10, 11, 14].

Interactivity. To be considered interactive, a website must facilitate exchanges with its users [15]. These exchanges are intended to engage the site's visitors and enable them to complete whatever process or experience is offered by the site [16]. To conduct these interactions, users usually require the use of screen-based controls, sometimes known as widgets [8]. Web experts recommend using only familiar screen-based controls in a conventional or commonly used-manner [8]. They also suggest making them easily identifiable to the users by placing them on the site in a manner that clearly distinguishes them from other web features [9]. The most commonly used screen-based controls include pushbuttons, radio buttons, check boxes, drop-down lists and entry fields [8]. The literature provides several pointers on using each of these 'widgets' to maximize a website's interactive capabilities.

Beginning with pushbuttons, Leavitt and Shneiderman [8] recommend using only those that are clearly labeled and easily identifiable. They also suggest prioritizing them using location and highlighting to facilitate their proper use. In addition to pushbuttons, Leavitt and Shneiderman [8] also advocate using radio buttons when selecting from among two or more mutually exclusive selections, check boxes when binary choices are required (e.g. yes or no), and drop down lists when selecting one item from among many.

Entry fields are another interactive option recommended by Leavitt and Shneiderman [8], especially in scenarios where website users are required to complete forms and enter text into search boxes. According to web experts, well designed entry fields share the following user-friendly characteristics: they are clearly and consistently labeled, they are easy to use, they distinguish between required and optional data, they show default values when appropriate, and they minimize the amount of information entered by users [8, 9].

Responsiveness. The general consensus among web-experts is that users are impatient. They don't like wading through busy, overstuffed websites and they certainly don't tolerate slow page-loading speeds [14]. Recent studies suggest that users begin to lose patience within seconds [14]. Consequently, websites must be designed to respond rapidly in order to ensure user satisfaction.

To achieve rapid responsiveness, web experts agree that designers must determine appropriate bandwidth, connection speed, and server requirements for their site's content and users [14]. They also suggest trading off fancy graphics, applets, audio and video clips, and other slow-loading elements for quicker download times [11, 14]. Their viewpoint is that content should be kept simple, meaningful, and immediately accessible. However, the literature does recognize that some circumstances call for the use of more advanced and often less responsive design elements. In such scenarios, process indicators capable of informing users of download progress are recommended as a means for improving a website's usability [8, 14].

Credibility. Given the lack of standards regarding internet content, numerous websites have surfaced containing incorrect and misleading information [17]. This trend has forced web users to become more skeptical of the information they find online. As a result, web designers now face increasing pressure to enhance the credibility of their sites [17]. Fortunately, the literature provides numerous design strategies for improving web credibility.

Fogg et al. [17] recommend incorporating design elements that convey the real world aspect of a website. This can mean displaying a logo, listing a physical address and phone number, and/or showing employee photographs [8, 11, 17]. Including these features is recommended because it increases user-confidence by communicating the legitimacy and accessibility of the organization behind the website [17].

Website Review

In addition to reviewing web design literature, another important step in developing a quality website involves learning from the existing sites themselves. This process of reviewing websites allows designers to visualize both the strengths and weaknesses that make up the competition. By learning from their mistakes and building upon their successes, web designers can utilize the efforts of others to enhance their own chances of creating an attractive, usable, and useful website.

In an effort to develop such a website for Project CROOS, an extensive website review was conducted. The review process involved identifying and analyzing both websites and web pages from three distinct categories, which were selected based on their relevance to the goals and objectives of the CROOS website. They included: multi-user sites with user-specific access portals, web pages featuring access to geographically displayed real time data, and web pages featuring traceability. The websites and web pages selected from these categories were identified using common search engines (e.g. Google, Yahoo, etc.) and then analyzed using the design criteria identified by the literature review. The analysis consisted of rating the web-material's content, page layout, navigation, interactivity, responsiveness, and credibility based on the presence or absence of certain design qualities. Websites and web pages found to possess the literature-derived qualities from each of these categories were awarded high ratings of 3, while those who did not were subject to lower ratings of 1-2. The objective behind this quantitative review process was to identify model web-examples capable of inspiring the development of the Project CROOS website. The results of the review are shown below.

Table 1. Website and web page ratings. Ratings based on the design qualities identified in the literature review. See website review notes in the Appendix for details on rating scores.

	Content	Page Layout	Navigation	Interactivity	Responsiveness	Credibility	Total
Multi-user websites with user-specific access portals							
http://www.cosi.org/ (AAWM gold award)	2	2	2	2	2	3	13
http://www.weeklyreader.com/ (AAWM 2005 site of the year)	1	2	1	3	3	1	11
http://www.smithsonianeducation.org/ (2007 People's Voice)	3	2	1	3	3	3	15
http://kidshealth.org/ (2005 Webby Award)	2	1	1	3	3	2	12
http://www.aqua.org/ (2005 People's Voice Winner)	2	3	2	3	3	2	15
http://www.stopwaste.org/home/index.asp?page=1 (2006 Webaward)	3	2	2	3	3	3	16
http://www.stormwaterauthority.org/default.aspx (2006 Webaward)	2	2	1	1	2	2	10
http://www.adelphi.edu/ (2006 Webaward)	3	2	1	3	3	2	14
http://www.bluecrossca.com/	2	2	1	3	3	3	14
http://www.wbmd.com/index.shtml	3	2	1	3	2	2	13
Web pages featuring geographically displayed real-time data							
http://las.pfeg.noaa.gov/TOPP_recent/index.html (2006 Webaward)	3	1	1	2	3	2	12
http://www.cefas.co.uk/data/wavenet.aspx	1	1	1	1	1	2	7
http://waterdata.usgs.gov/nwis/rt	2	1	1	1	3	2	10
http://nowcoast.noaa.gov/	1	1	1	1	1	2	7
http://www.gomoos.org/data/recent.html	1	1	1	3	2	3	11
http://www.cormp.org/indexreal.php	2	2	1	2	2	2	11
http://www.skio.peachnet.edu/research/sabsoon/tower.php	1	1	1	2	3	2	10
http://sdcoos.ucsd.edu/data/CurrentsObjList.cfm	1	1	2	1	3	2	10
http://www.glerl.noaa.gov/res/recon/	1	1	2	1	3	2	10
http://www.ndbc.noaa.gov/dart.shtml	1	1	1	1	1	3	8
Web pages featuring traceability							
http://www.jsorganic.co.uk/trace.asp	1	2	2	3	3	3	14
http://www.linecaught.org.uk/	2	3	2	3	3	3	16
http://www.wheresgeorge.com/	1	1	1	2	2	1	8
http://www.dmv.org/vehicle-history.php	2	1	2	2	3	1	11
http://www.carfax.com/	1	2	1	2	2	1	9

Multi-user sites with user-specific access portals. Among the web-categories that were reviewed, the multi-user sites with user-specific access portals were by far the most abundant. Their relatively high numbers were complemented by a greater selection of quality websites, which most likely contributed to their higher design ratings. The highest rated site from among this category was Stopwaste.org, an award winning website created to represent the collaborative waste management and resource conservation efforts of the Alameda County Waste Management Authority and the Alameda County Source Reduction and Recycling Board.

Figure 1. Stopwaste.org homepage. Highest rated website among the multi-user sites with user specific access portals.

As the highest rated website from the multi-user category, Stopwaste.org is a model site for inspiring the development of the Project CROOS website. Beginning with its content, the website provides user-centered material formatted to meet the needs of its targeted audiences: residents, business and industry, schools, and local government. It also features text that is adequately sized, easy to read, and formatted to facilitate scanning. The text is effectively complemented by graphics that are simple, meaningful, and relevant to the site's goals and purposes.

The layout of Stopwaste.org is almost equally impressive. Besides a slightly different presentation of design elements on the home page, all other pages are consistently designed to facilitate both ease of comprehension and use. The layout is also benefited by a well-balanced use of page space, which features a reasonable mix of highly organized content and visually appealing background colors. These design qualities along with the site's use of descriptive headings, highlighted text, and grouped elements result in a website that is both attractive and useable.

The ability to freely and accurately navigate Stopwaste.org is another key factor contributing to this site's superior design. This quality is largely attributed to the website's use of clearly labeled and consistently placed navigational aids, which are featured on both the top and the left-hand side of every single page. User-mobility is also supported by the inclusion of several descriptive and well-placed text-based links throughout the site. The website's effective use of both colors and page headings as location feedback devices also contribute to the excellent navigability of Stopwaste.org. Besides missing a site map, the only navigational flaws associated with this website include a lack of distinction between used and unused links, as well as the presence of a few non-descriptive, image-based links.

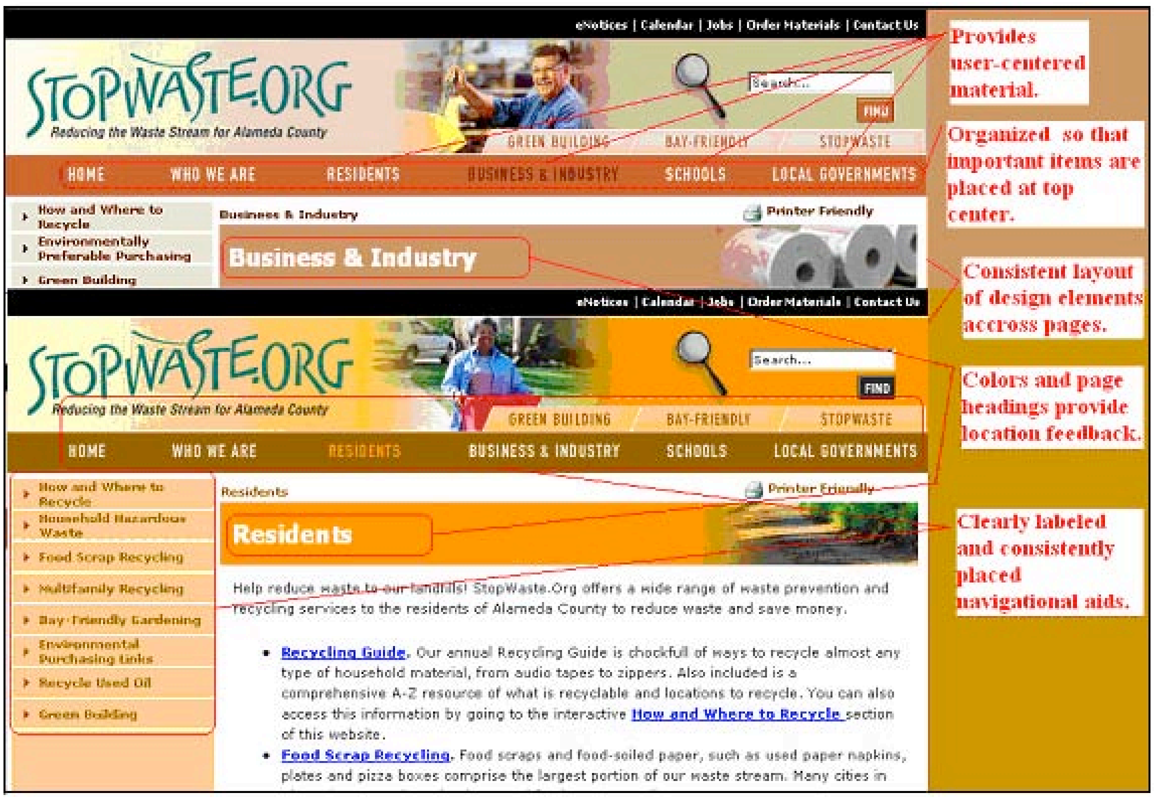


Figure 2. The Business & Industry and Residents pages of Stopwaste.org. Illustrates some of the content, page layout, and navigation design qualities featured on the website.

The interactivity of Stopwaste.org is one of the site's most highly rated design categories. Although limited to a few drop-down menus and entry fields, the site's interactive features are easy to use, they function correctly, and they are utilized in the appropriate circumstances. In addition to interactivity, the responsiveness of Stopewaste.org is also among the site's most highly rated design categories. Its superior responsiveness is the result of rapid page loading speeds.

A strong sense of credibility regarding the information and services provided by Stopwaste.org is the site's final exemplary design feature. This ability to trust in the website is facilitated by the presence of several important features. For example, Stopwaste.org displays photographs of its personnel and provides a physical address and phone number to communicate a tangible and real presence to the users. It also has a highly professional look, which stems from its accurate, up to date, and functional content. The website's credibility is also enhanced by including numerous articles, reports, and studies containing legitimate citations and references. A policy on content statement is the only significant confidence-building feature missing from the site to prevent it from receiving a perfect credibility rating.

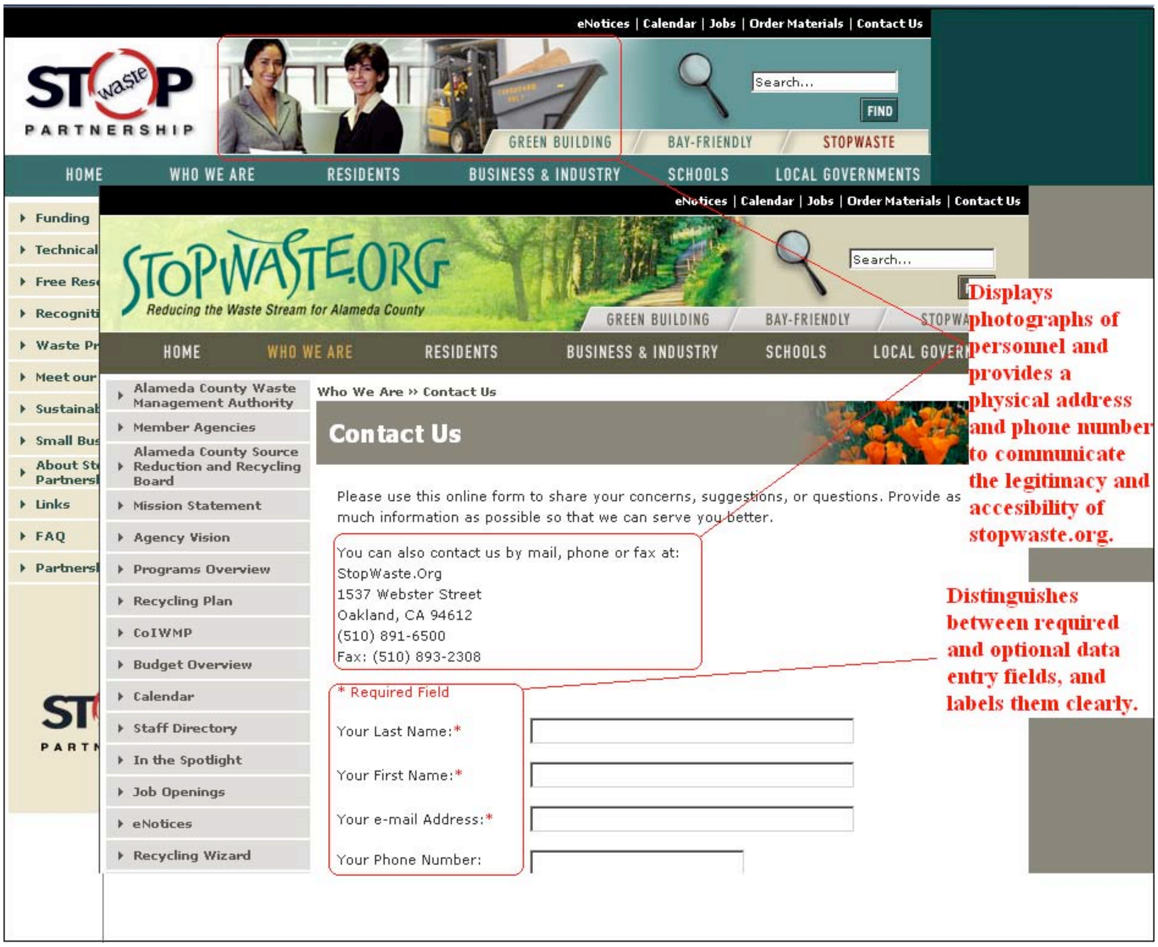


Figure 3. Two pages within stopwaste.org that show specific design qualities associated with the site's interactivity and credibility.

Web pages featuring geographically displayed "real time" data. The web-review category with the lowest design ratings was clearly the web pages featuring geographically displayed "real time" data. The majority of material reviewed from this particular genre was associated with extremely complex content and highly technical functionality, which made finding attractive, user-friendly web pages very difficult. Among the "real time" pages that were identified, the one with the highest design rating was that of the award winning TOPP (Tagging of Pacific Pelagics) website. TOPP is a NOAA (National Oceanographic and Atmospheric Administration) sponsored research project, which utilizes specialized tagging devices to collect data on the migration patterns of a select group of pelagic animals living in the Pacific Ocean. This data is housed within the Near Real Time Animal Tracks page of the TOPP website, where it can be accessed and viewed by the general public.

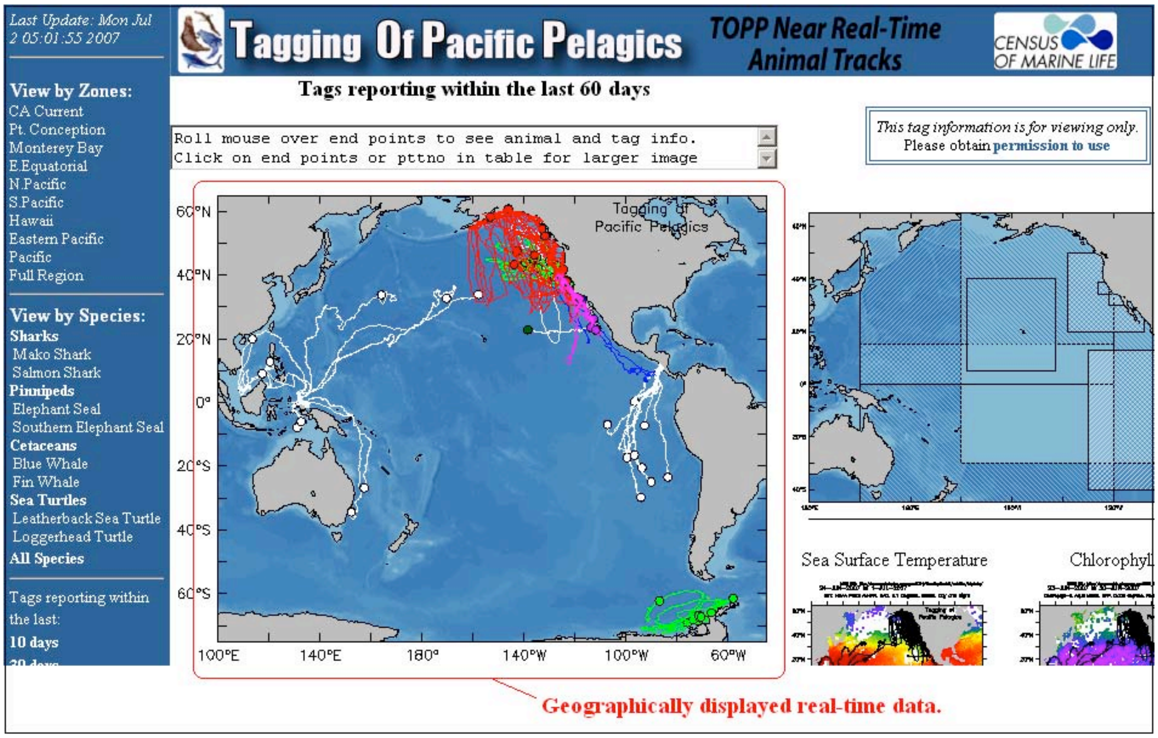


Figure 4. Near Real-Time Animal Tracks page of the Tagging of Pacific Pelagics (TOPP) website. Highest rated web page among those featuring geographically displayed real-time data.

Although clearly lacking in comparison to the model web-examples from the other review categories, the TOPP web page still features several qualities capable of inspiring the development of certain elements of the Project CROOS website. Among those qualities, is the page's content. Unlike most other "real time" web pages, TOPP's content is displayed in a format that is both easy to use and understand. The language is not overly technical and foreign, nor are the mapping functions heavily complicated. Instead, the data and information is presented in simple terms that are both meaningful and engaging to a wide spectrum of users.

The ability to interact with TOPP's "real time" data is another highly rated quality of the web page. This high rating is attributed to the advanced usability associated with TOPP's interactive features. In contrast to many other pages, TOPP's features are kept simple, so they are easy to operate and they don't break down. Users are not required to undergo extensive training to master complicated tools or confusing map layers. Instead, retrieving data for analysis is as easy as clicking on a geographic image or a descriptive link.

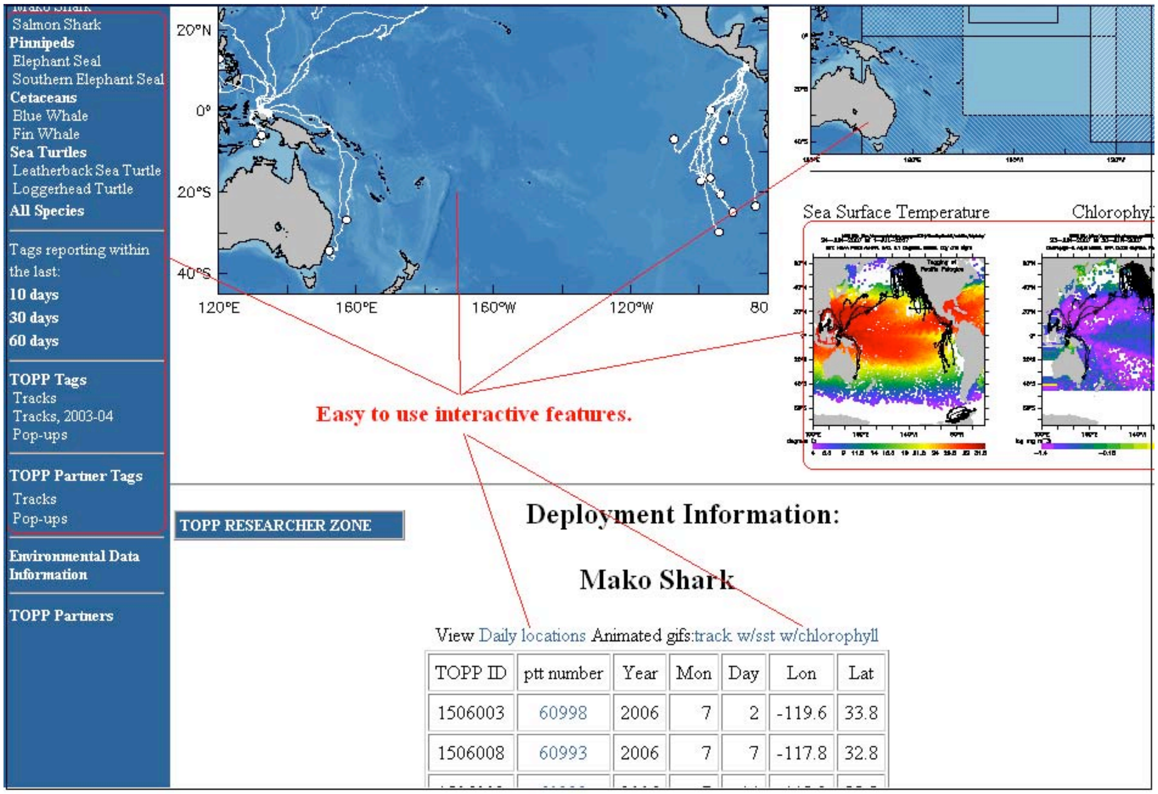


Figure 5. Interactive data retrieval elements featured on the Near Real-Time Animal Tracks web page.

The other two model-design areas associated with the TOPP web page are responsiveness and credibility. The page's highly rated responsiveness is the product of rapid page loading speeds, maps and images that download fast, and data plots that are made immediately accessible. TOPP's perceived credibility is attributed to the numerous scientists, universities, government agencies, and respected sponsors that are listed as being affiliated with the site and its corresponding research.

Despite being the highest rated page within the "real time" category, the TOPP web page is not free from design weaknesses. In fact, the page features several flaws that will need to be avoided when developing the Project CROOS website. One flaw involves the page's layout. Due to poor organization and structuring of content, the TOPP web page requires excessive amounts of scrolling both vertically and horizontally, which can obstruct users from viewing the entire page and make finding information extremely frustrating. It also displays design elements differently than other pages within the site, forcing users to make unnecessary mental adjustments when interpreting the page's content.

Another weakness of the TOPP web page involves its lack of navigational aids. Besides a poorly labeled link to the homepage, there are no other means for users to access other areas of the site. In fact the only other links on the page are for retrieving data, but even these hinder navigation by flooding the screen with unnecessary browser windows.

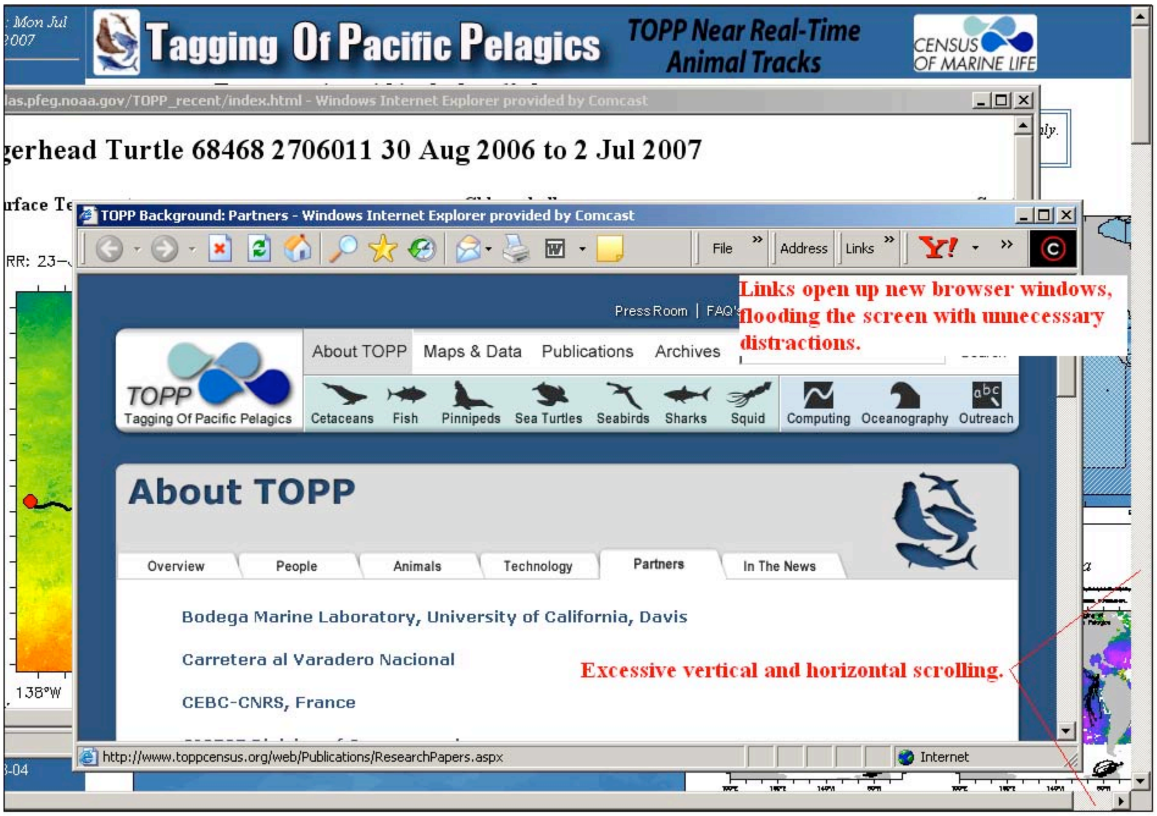


Figure 6. Design weaknesses of the Near Real-Time Animal Tracks web page.

Web pages featuring traceability. The final web-category reviewed was the web pages featuring traceability. This selection of web-material was the most difficult to review because of quantity limitations. Despite numerous hours of searching the internet, only a few examples of web pages featuring traceability were located. Fortunately, these pages were fairly well-designed and scored remarkably high ratings. The highest rated web page from among this category was linecaught.ork.uk, the homepage of the South West Handline Fishermen's association.

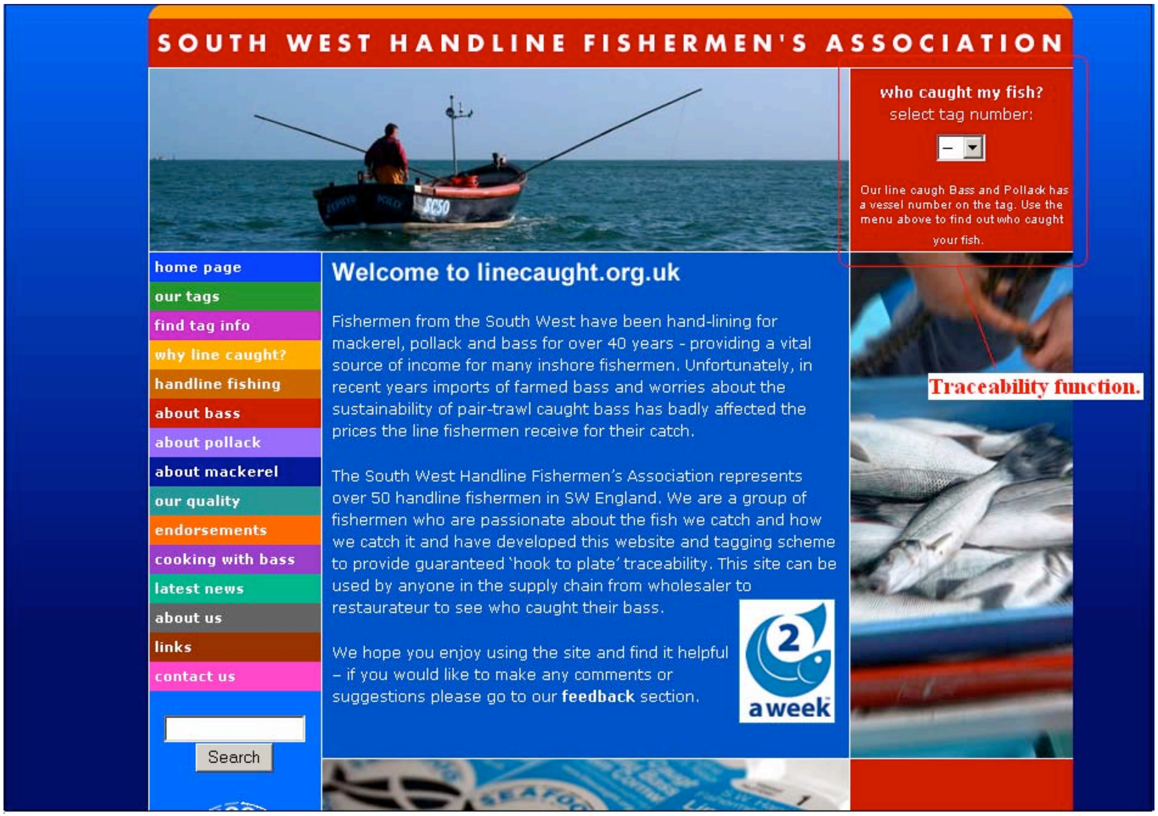


Figure 7. Homepage of the South West Handline Fishermen's association. Highest rated web page among those featuring traceability.

As a web page that allows seafood consumers to trace their purchases back to their origin of harvest, linecaught.org.uk serves as a model for the Project CROOS website. Besides possessing identical traceability objectives, the web page also features superior design qualities. One of its key qualities is its content. Similar to the model examples from the other web-review categories, linecaught.org.uk features material that is user-centered and formatted to facilitate ease of use and comprehension. It also provides text that is capable of facilitating scanning, and displays images that complement the site without creating distractions.

Another favorable design feature of linecaught.org.uk is its page layout. By utilizing a consistent, non-crowded, organized presentation of design elements, this web page provides users with an interface that is both visually appealing and user-friendly.

Interactivity is another strong design feature of linecaught.org.uk. Despite being limited to a search entry field and a traceability drop-down menu, the interactive elements of this web page are ideal because they are simple, easy to use, and operate without error. Similarly, the responsiveness of linecaught.org.uk is also a strong feature. This is primarily due to the rapid functionality of the page's interactive elements, as well as its exceedingly fast loading speeds.

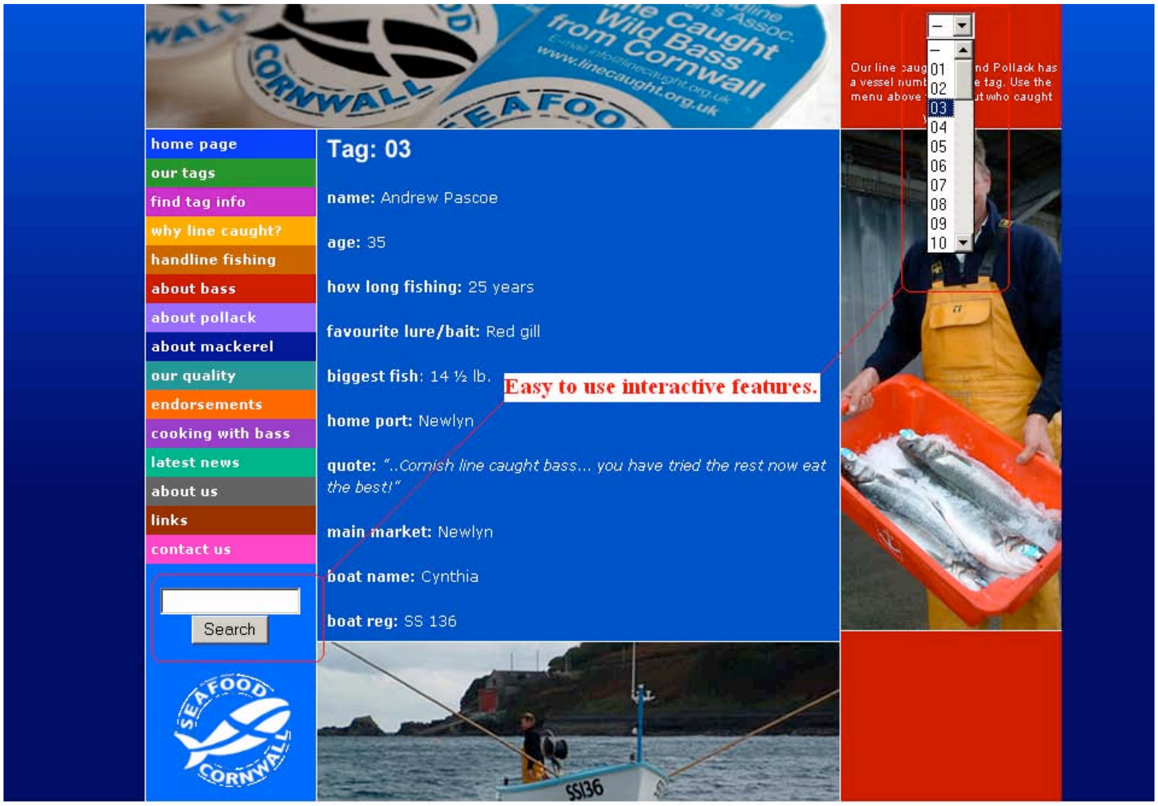


Figure 8. Interactive design elements featured on linecaught.org.uk.

Other desirable qualities of linecaught.org.uk are the various design features it uses to communicate the credibility of its content. Similar to the model examples from the other web-review categories, this web page utilizes several strategies to promote user-confidence regarding the information and services it provides. Some of these tactics include: displaying photographs and personal information of the individuals behind the web page, providing links to other credible sites, and maintaining a professional look by ensuring flawless functionality and up to date, accurate information.

The one area of concern regarding the design of linecaught.org.uk is its navigability. Although the web page does provide descriptive and easy to use navigational aids that are consistent with the rest of the site, it also contains several design elements that obstruct user-mobility. The page's misuse of links is probably the most significant obstruction. Unlike other navigation-friendly web page's, linecaught.org.uk does not adequately distinguish its links from ordinary text, nor does it provide a distinction between links that have been used and those that have not. In addition, some of the page's links also open up new browser windows, which can disorient users by filling the screen with needless distractions.

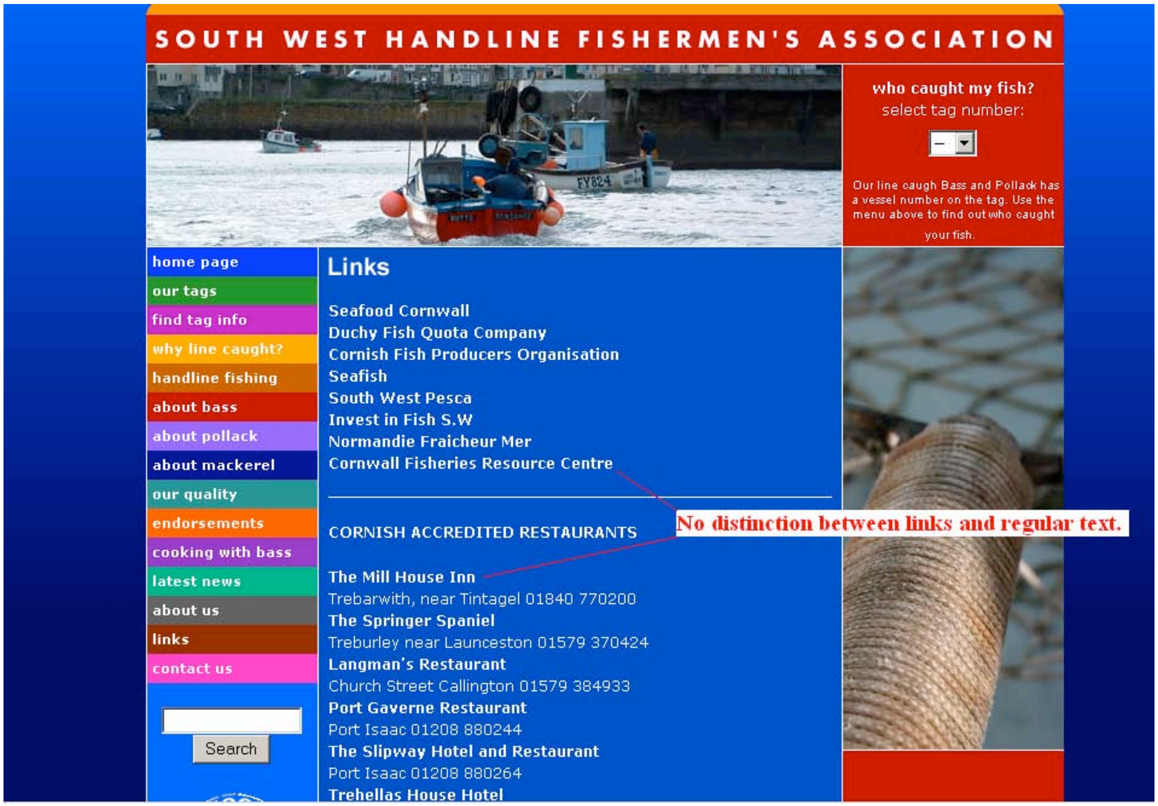


Figure 9. Design weakness of linecaught.org.uk.

REFERENCES

[1] Kouzes, R.T., Myers, J.D. and Wulf, W.A. (1996). Collaboratories: Doing science on the internet. *Computer*, 29(9), 40-46.

[2] Preece, J. and Maloney-Krichmar, D. (2003). Online communities: Focusing on sociability and usability. In Jacko, J. and Sears, A. (Eds.) *The Handbook of Human-Computer Interaction*. Mahwah, NJ: Lawrence-Erlbaum Associates Inc. Publishers.

[3] Shortliffe, E.H., Barnett, G.O., Cimino, J.J., Greenes, R.A., Huff, S.M. and Patel, V.L. (1996). Collaborative medical informatics research using the Internet and the World Wide Web. *Journal of Am Med Inform Assoc*, 3, 125-129.

[4] Ocean.US Website. (2006, October). What is IOOS? http://www.ocean.us/what_is_ioos

[5] Project CROOS Website. (2007). Project CROOS Final Report. http://projectcroos.com/news-media

[6] Rosen, D.E. and Purinton, E. (2004, July). Website design: Viewing the web as a cognitive landscape. *Journal of Business Research,* 57(7), 787-794.

[7] Turban, E. and Gehrke, D. (2000). Determinants of e-commerce website. *Human Systems Management,* 19, 111-120.

[8] Leavitt, M.O. and Shneiderman, B. (2006). *Research-Based Web Design and Usability Guidelines*. Washington, DC: Health and Human Services Department.

[9] Cato, J. (2001). *User-Centered Web Design.* Great Britain: Addison-Wesley Professional.

[10] Bevan, N. (1998). Usability issues in web site design. *Proceedings of UPA'98.* Washington, DC.

[11] Gehrke, D. and Turban, E. (1999). Determinants of successful website design: Relative importance and recommendations for effectiveness. *Proceedings of the 32nd Hawaii International Conference on System Science.*

[12] Ivory, M.Y. and Megraw, R. (2005, October). Evolution of Web Site Design Patterns. *ACM Transactions on Information Systems,* 23(4), 463-497.

[13] Ivory, M.Y. and Hearst, M.A. (2002, April). Statistical profiles of highly-rated web sites. *Proceedings of CHI 2002,* 1(1), 367-374.

[14] Palmer, J. (2002, July). Designing for web site usability. *Computer,* 35(7), 102-103.

[15] Song, J.H. and Zinkhan, G.M. (2003). Features of web site design, perceptions of web site quality, and patronage behavior. *ACME Proceedings,* 106-114.

[16] Fitzpatrick, R. (2000). Additional quality factors for the world wide web. *Proceedings of the Second World Congress for Software Quality, Yokohama, Japan, Union of Japanese Scientists and Engineers,* Tokyo, Japan.

[17] Fogg, B.J., Marshall, J., Laraki, O., Osipovich, A., Varma, C., Fang, N., Paul, J., Rangnekar, A., Shon, J., Swani, P. and Treinen, M. (2001, March-April). What makes web sites credible? A report on a large quantitative study. *Proceedings of CHI 2001,* 3(1), 61-68.

[18] Abras, C., Maloney-Krichmar, D. and Preece, J. (2004). User-centered design. In Bainbridge, W. (Ed.) *Encyclopedia of Human-Computer Interaction*. Thousand Oaks: Sage Publications.

[19] Nielsen, J. (1997). The use and misuse of focus groups. *IEEE Software*, 14(1), 94-95.

[20] Murray, G. and Costanzo, T. (1999) Usability and the Web: An Overview, *Network Notes #61*, Information Technology Services, National Library of Canada.

Appendix 8

CROOS Website User Groups Research Report


CROOS Website User Groups
Research Results
March 26, 2008


Research Methods
• 5 key user groups were identified and subjected to a series of individual interviews and round-table discussions:
1) Scientists
2) Managers
3) Fishermen
4) Industry (processors, retailers, etc.)
5) Consumers

Fishermen, Scientists, and Managers

- Research Objective:

  Identify user preferences and expectations concerning the key functions, data points, and uses of the website. This entailed identifying what information the users wanted to be collected and made available on the site, as well as how this information was intended to be used.

Key Findings: Fishermen

- Geographic visualization of real-time and historical CROOS harvest data
- All available oceanographic and weather data
- Tracking feature to allow fishermen to see where their fish is being sold
- A Place to tell their story

Key Findings: Scientists

- Historic and real-time CROOS harvest data
- Weather conditions, current speed and direction, sea surface temperature, and chlorophyll concentrations
- Age composition relative to stock composition
- Ability to access data in its raw form

Key Findings: Managers

- Again historic and real-time CROOS harvest data
- Visualizations that identify the major stocks caught within given geographic zones and time periods
- Display data aimed at improving their existing management models (effort, CPUE, Klamath fish contacts relative to units of effort, etc.)

Consumers

- Research Objectives:
  1) Determine what information consumers are interested in receiving when purchasing seafood
  2) Identify the venues/sources consumers would prefer to access this information
  3) Determine the value and utility of the website as a potential seafood information source

Most Valuable Seafood Information

- Discussion:

  -Questions Presented:

  1. What information do you value now?
  2. What additional information would you like to have available?

- Survey:

  -The groups were asked to rate the importance of several types of seafood information

Interview and Focus Group Discussion Results	
Information Desired By All 3 Groups	**Information Desired By 2/3 Groups**
Wild vs. Farmed*	Recipes
Product Origin*	Information On Who Caught the Seafood (photos and descriptions of the fishermen and the locations responsible for producing the seafood)
Price	
Fresh or Frozen* (what do these terms mean exactly?)	
Sustainability Related Information* (harvesting methods, bycatch info., ESA status, sustainability certifications, etc.)	
Safety Information (mercury content, presence of contaminants, chemicals and dyes used on farmed products, etc.)	
Nutritional Information (protein content, preservatives/additives, organic certifications, etc.)	
Date of harvest	
Tracking Information (where has it been and how has it been handled since harvest)	

Focus Group Survey Results		
Rank (most important to least)	Seafood Information	Combined Avg. Rating (very important=5, not important=1)
1	Date of harvest	4.9
2	ESA status of seafood	4.7
3	Thermal history of seafood	4.4
4	River basin/hatchery of origin (salmon)	4.4
5	Tracking information	4.3
6	Seafood handling/storage information	4.3
7	Information about the fishery	4.3
8	General harvest info. (e.g. catch region)	4.3
9	Nutritional Information	4.0
10	Information on seafood suppliers	4.0
11	Who caught the seafood?	3.8
12	Tips for identifying quality seafood	3.7
13	Specific harvest info. (e.g. exact location, time, etc)	3.4
14	Handling and storage instructions for home use	3.3
15	General "fish facts" (e.g. biological info, life history)	3.2
16	Recipes and cooking instructions	3.0
17	Specific "fish facts" (e.g. length, weight, age, etc.)	2.9
18	Info. on seafood news, publications, events, etc.	2.8

Preferred Sources For Seafood Information

- Sources:
  - -Label/packaging
  - -Sales display/brochure
  - -Salesperson
  - -Internet
- Primary: Point of Sale (e.g. label and sales display)
- Secondary: The internet *to verify information found at the point of sale and/or accessing more detailed information*

Website Function & Uses for Seafood Information

Survey Results (combined average ratings):

	Not Likely 1	2	Fairly Likely 3	4	Very Likely 5

1. Use the website described today **3.6**

2. Be more inclined to purchase seafood that has information available on this website, than seafood that has not **4.1**

3. Purchase seafood sourced from fisheries supported by the cooperative efforts of fishermen, scientists, and managers **4.2**


Consumers Intended Uses
• Enhance consumer confidence in seafood products
• Provide access to more product info
• Provide educational opportunities (kids science projects)
• Facilitate in-store purchasing decisions (Kiosk)
• Influence their future purchasing decisions

Industry (Processors, Retailers, etc.)

- Research Objectives:
  1) Determine what information the seafood industry would like to see made available to consumers
  2) Evaluate the utility of the website
  3) Determine what seafood industry specific content and features the website should include

Website's Utility

- "This is a great tool for allowing consumers the opportunity to make informed purchasing decisions"
- "If consumers are able to trust the site, it could act as an informal type of 3rd party certification"
- "The website's access to traceability info and genetic results could help combat fraudulent fish marketing"

Industry Specific Content

- About seafood industry (for public):
  - -Provide informative descriptions of the various links in the seafood supply chain (e.g. wholesalers, processors, retailers, restaurateurs, etc.)
  - -Provide users with a “virtual journey” that visually illustrates the tracking process.

Industry Specific Content

- For seafood industry:
  - -Provide industry with intranet login
  - -Info. on individual fish and printable labels
  - -A thermal history tracking option
  - -Information on where product was originally landed and when (e.g. ability to access the Oregon State Fishticket Database)
  - -An option that provides seafood education for staff
  - -Access to up to date seasonal information, industry news, meetings, events, etc.

Appendix 9

Project CROOS, Intensive Personal Interview (IPI) Report

Project CROOS

Intensive Personal Interview (IPI) Report

October 22, 2007

Methodology

Sample Composition

To date, one-on-one telephone interviews have been successfully conducted with nearly thirty individuals whose names and contact information were provided to us by the CROOS team. (And, to establish a benchmark, the average number of IPI's that are usually required to provide adequate direction for the Design Team is *seven*. But the scope of Project CROOS is so large that additional people will need to be added to the nearly thirty people contacted so far.) To date our interview contacts have been predominantly from three main groups: fishermen, scientists, and regulators.

The duration of the interviews ranged from about 25 minutes for the shortest interview, to just under two hours for the longest interview. Plus subsequent email exchanges have been conducted with numerous members of the contact group.

Privacy

Each individual was assured complete anonymity for his or her statements and opinions. (See note on page 3.) For those who were curious about the depth of that anonymity we explained that it is our policy that only the researcher who conducts the interview will ever know the name, phone number, or email address of a contact. Even other employees of Sparkplug will have no access to that information.

Interview Technique

An average interview begins with our researcher explaining our appointed task. Then the questioning itself began with an open-ended question that in this case would be similar to, "What do *you* think we need to know, to construct an ideal CROOS website…and what will *you* need, or want, to find on the website?"

From that point on, the interviewers are listening to answers, taking notes, and listening for the non-verbal clues that suggest there is more the person wants to say. This is where the trained counselors are invaluable, since skills in hearing the non-verbal cues allow them to take the conversation in any direction the subject want to go in…*even* if the individual is trying to please us with the "right" answers — a significant hazard in live-interview customer research. Interviews conclude when the subject is either out of time, or feels they have shared everything. In rare cases — but especially when a subject is both exceptionally knowledgeable and skillful at communicating — we ask for permission to contact them again, via email, with additional questions, as we did with individuals mentioned above.

Summary of General Findings

In this section will be found the assembled quotes of fisherman, scientists, and regulators & managers, in that order, that are related in some way to the question, "What would *you* like to see on this website?"

Here, for the first time, the collected wisdom of the three major (initial) groups is assembled, partially processed, and held up for review. Using this information the CROOS and Sparkplug teams can begin the dialog about what should be included in this website.

The organization of this section:

Each section begins – under the heading "**What the (Fishermen) Said**" – with all of the related quotes from this section's speakers.

Which is followed by – under the heading "**What the (Fishermen) Asked For**" – a more succinct and formal list of things that the speakers in the section felt were worth considering for inclusion in the new CROOS website; a list that has been translated out of all of the quotes that preceded the list, (and from the verbal and non-verbal cues that accompanied those statements during the interviews.)

What the Fishermen Said:
"I want to be able to track my catch – from catch to end-user – that's a big one. And I want to see if anyone else is tracking theirs too."

"Weather patterns and sea temps."

"Timeliness – sometimes the managers say, "The fisheries will open on March 15th!" And then it doesn't – and we've spent thousands of dollars getting our boats ready…sometimes for nothing." "But the managers say they can't get the fishery information in time. The CROOS info can be ready within 24 hours."

"We, the fishermen, have no organization – no lobby power – and we end up being the small people in this organization. But we don't want to be involved in all of that stuff either – we're fishermen!"

"I'd like the website to be one-stop shopping for oceanographic info." "It should have things like ocean currents, sea surface temp, chlorophyll blooms, current or short-term weather, "glider" info…and spatial information on historic catches."

"The current website has a Collaborator Info page – I'd like to see that expanded to include fishermen and their stories." (Telling Scott Boley's story was mentioned numerous times.)

"The website should talk about where funding comes from – lots of lottery and taxpayer dollars. It's also important that it have (or be) a marketing tool – show the genetics research as a market advantage – it's big."

"What fish are caught, and when and where. (But…I don't want my up-to-the minute info spread out to everyone. We need to let the info sit for a couple of weeks or so. But the scientists can have it right away.)"

"My main thing is that I want the managers to have in-season decision-making capability."

"One of our biggest goals is to try to stop a huge catch of Klamath fish – you want to leave them alone – or you'll impact next year's catch."

"Market it as, 'It's the healthiest, freshest, and best-tasting salmon in the world!' Calling it a 'rich man's' food is the wrong way to go."

"Do restrict raw data to managers only. I don't want a lot of my real-time data to be made publicly available while I'm still using it."

"I'd like to go in and look at my track logs, the values of my catch, and their (river) origins. If I could do that on a chronological log, and just punch in just my boat name to get access, and see all that, that would be great."

"Interesting to see where the fish are from – the people I sell to would like to know where they're from. It's good for customer education."

"Would like to see the boats involved, diagrams of how we catch [the fish], we trollers are a pretty small fishery."

"We'd like to be able to punch up each of the different kinds of fish and see where they're being caught. We'd like to be able to subdivide an area by types of fish. And maybe show the bottom contours, and see why the fish are there."

“We were told there could be a pass-code to get into the different [areas] on the website… But as for dreams…we’ve been working on this for a couple of years now. Some buyers *don’t* want the consumer to know how old that fish is. But I’d love to see some fish history, with photos of boat and crew made available to the public.”

“A lot of the fishermen are afraid of *too much* info getting out – some don’t want the IRS to be able to go through the data and find out how much they’re really catching. Or the processors – they’ll lower the price if they find out we’re catching lots of fish.”

“…make the site interactive, so people can ask questions on the site – what great marketing that would be.” Answering the question, “**Could CROOS coordinate the development of an ‘Answers Cooperative’ – where, fisherman, scientists et al – who would volunteer for the task – could answer these questions in person?**”

A salient point: “In the end all kinds of people make money from one fish – a single fish could be worth a thousand dollars or more in the end. Processors, wholesalers, restaurateurs, waiters (and do include their tips,) all add to the value of a salmon – plus all the people who study and manage them. (The salmon…not the waiters.)”

What The Fishermen Asked For:

- Catch tracking – from river or origin, through catch to consumer
- All available oceanographic, weather and catch data…
- As “real time” as possible…
- Preferably in graphic form…
- Endlessly filterable and/or combinable
- Current and historic…
- A larger, louder, more powerful, more organized “voice” in the industry
- For the website to be *the* sole source for all fishing industry-related information
- A place where they can tell their stories and show their photographs
- The website to be informational – showing and explaining *every* aspect of the industry
- It to be a major marketing tool
- Make *absolutely* sure it protects the information that makes them competitive. (But many said they would like to know their competitors up-to-the-minute information.)
- The fisheries managers to have in-season decision-making capability
- The ability to avoid endangered stocks
- An accessible archive of track logs, catch values and rivers of origin
- Be aware that some buyers want to *hide* a fish’s “catch to consumer” time
- Protection of too-specific and too-timely information from the IRS and fish processors
- A highly interactive site, especially with consumers and students in mind
- The tracking of a hypothetical fish’s continually additive value, as it moves from ocean to plate
- Six months of notice for when they are allowed to fish…and no more than an hour’s notice when they are required to stop fishing

Appendix 10

Budget

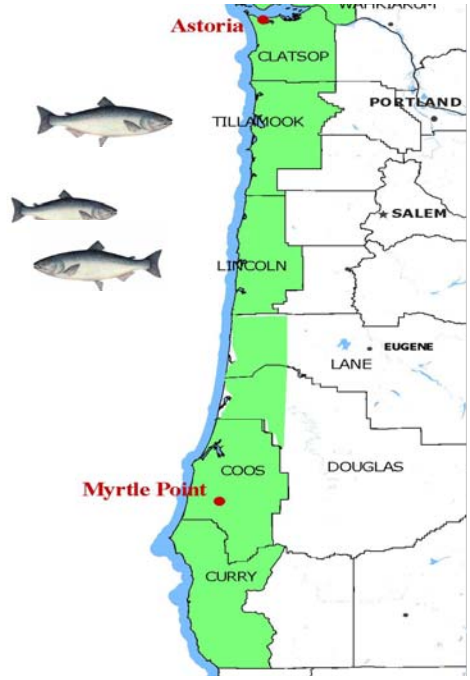
Collaborative Research on Oregon Ocean Salmon-May 2007-June 2008 Budget

RESEARCHER SALARIES	Monthly Salary	OPE %	FTE	MM	OWEB May-Sept	Disaster Relief Formerly NMFS Funding	OWEB Revised	TOTAL	PROJECT MATCH	PROJECT TOTAL
Position, Name										
Professor (Gil Sylvia)	$ 8,703	39.5%	1.00	2					$ 24,281	
Assistant Prof (Jessica Miller)	$ 5,250	42.9%	1.00	1					$ 7,502	
Assistant Prof (Michael Banks)	$ 8,394	40.3%	1.00	2					$ 23,554	
Professor (Michael Morrissey)	$ 7,942	40.5%	1.00	0.5					$ 5,579	
Professor (David Sampson)	$ 6,445	43.2%	1.00	0.5					$ 4,615	
Assistant Professor (Jeff Feldner)	$ 4,992	43.5%	1.00	4					$ 28,654	
Dr. Peter Lawson	$ 7,331	29.0%	1.00	2					$ 18,914	
Faculty Research Associate (Renee Bellinger)	$ 3,250	0.59	1	2					$ 6,500	
NMFS Genetic Researchers (NWFSC Laboratory)									$ 30,000	
Subtotal									**$ 149,599**	**$ 149,599**
Faculty Research Associate (Renee Bellinger)	$ 3,380	0.59	1	10	$ 16,123	$ 37,619				
Res. Asst:(Salary and OPE tech staff - genetics)	$ 2,500	0.65	1	5	$ 12,375	$ 8,250				
Res. Asst:(Salary and OPE tech staff - genetics real time)	$ 2,500	0.65	1	3	$ 12,375					
Res. Asst: (Salary for OPE tech staff - otoliths)	$ 2,500	0.65	1	3	$ 6,187					
Graduate Research Assistant-Management	$ 3,750	$437	1	5		$ 20,449				
Subtotal					**$ 47,060**	**$ 66,318**	**$ -**	**$ 113,378**		**$ 113,378**
EXPENDABLE SUPPLIES & EQUIPMENT										
Field Supplies					$ 13,865					
Laboratory Supplies					$ 45,475					
Laboratory Supplies - NMFS									$ 30,000	
Port Liaison Supplies					$ 3,600					
Subtotal					**$ 62,940**	**$ -**		**$ 62,940**	**$ 30,000**	**$ 92,940**
CAPITAL EQUIPMENT										
Port Liaison					$ 3,978					
Genetics Laboratory					$ 24,000					
Field equipment										
Subtotal					**$ 27,978**	**$ -**		**$ 27,978**		**$ 27,978**
CAPITAL PROJECTS										
Commercial Fishing Vessel Charter for Fish Sampling					$ 200,000	$ -	$ -		$ 40,000	
Recreational Fishing Vessel Charter for fish Sampling						$ -	$ -			
Subtotal					**$ 200,000**	**$ -**	**$ -**	**$ 200,000**	**$ 40,000**	**$ 240,000**
OTHER RESEARCH COSTS										
Port liasons					$ 20,250	$ 23,000	$ 500			
GIS and Website Design Contractors					$ 10,000		$ 37,500			
Fleet management					$ 3,000	$ 3,000	$ -			
ODFW scale aging (Lisa Borgerson)							$ 12,000			
Otolith spectroscopy analysis							$ 2,477			
Subtotal					**$ 33,250**	**$ 26,000**	**$ 52,477**	**$ 111,727**		**$ 111,727**
TRAVEL										
Travel OSU					$ 2,000	$ 4,000	$ 3,500			
Travel Salmon Commission					$ 1,000	$ 1,682	$ 3,818			
Subtotal					**$ 3,000**	**$ 5,682**	**$ 7,318**	**$ 16,000**		**$ 16,000**
ADMINISTRATIVE COSTS					$ 16,500		**$ 15,500**	**$ 32,000**		**$ 32,000**
GRAND TOTAL					**$ 390,728**	**$ 98,000**	**$ 75,295**	**$ 564,023**	**$ 219,599**	**$ 783,622**
SALMON COMMISSION PORTION					**$ 262,193**	**$ 27,682**	**$ 31,818**	**$ 321,693**	**$ 40,000**	**$ 361,693**
OSU PORTION					**$ 128,535**	**$ 70,318**	**$ 43,477**	**$ 242,330**	**$ 119,599**	**$ 361,929**
NMFS PORTION (MATCH)									**$ 60,000**	**$ 60,000**

Appendix 11

Vessel Protocols

PROJECT CROOS
Collaborative Research on Oregon Ocean Salmon



CROOS COLLABORATIVE RESEARCHER FIELD SAMPLING PROTOCOL

(draft June 8th, 2007)

Project Funded by:
Oregon Watershed Enhancement Board & NOAA National Marine Fisheries Service
To the Oregon Salmon Commission

GENERAL CROOS PROCEDURE

Attach one metal barcode tag to each of the first 20 fish harvested per day on days you are instructed to collect data. Use the GPS only on days you are collecting data.

- Turn GPS **on** when lines are in water and **off** when lines are pulled up (see GPS Units Procedure, page 6)
- Use the GPS to make one waypoint for each fish

For each fish sampled

1) When a fish is landed, press the **MARK** button to record a waypoint. If you land more than one fish, make a waypoint for each fish.
2) Check this waypoint number and time (to remember it), and press the **ENTR** button to store the waypoint number on your GPS
3) **Remove a barcode from an envelope**. You will use this envelope to record data for this fish.
4) Use a zip-tie to **attach metal barcode tag on the fish** (page 7)

Record data on Envelope. The barcode placed on the fish needs to match the number on the envelope. See Instructions: Filling out Envelope Data Procedure (page 8).

5) Write the GPS waypoint number on the envelope
6) Write the time the waypoint was recorded for time and the day's date
7) Write the depth the fish was caught at (in fathoms)
8) Measure Fork Length in Inches (page 9).
9) Check fish for hatchery markings (page 8)
10) Remove 8 - 10 scales from the "Key Area" and place in middle of paper (p. 10-11)
11) Fold paper once over the scales (pages 10 - 11)
12) Take genetic sample (page 12)
13) Fold last paper flap over tissue sample and place paper in envelope
14) Write your Vessel's name on the envelope

Use clean scissors and tweezers when taking samples!

Sample Storage at End of Day

Samples need to dry out as fast as possible. The longer they stay wet, the more the tissue breaks down. Place samples in the wheelhouse or somewhere dry after you have taken them. The envelopes need to be kept clean and dry. If fish blood soaks through, the samples will be contaminated.

Within 24 hours return from sea (see Fleet Communication Protocol, page 5)

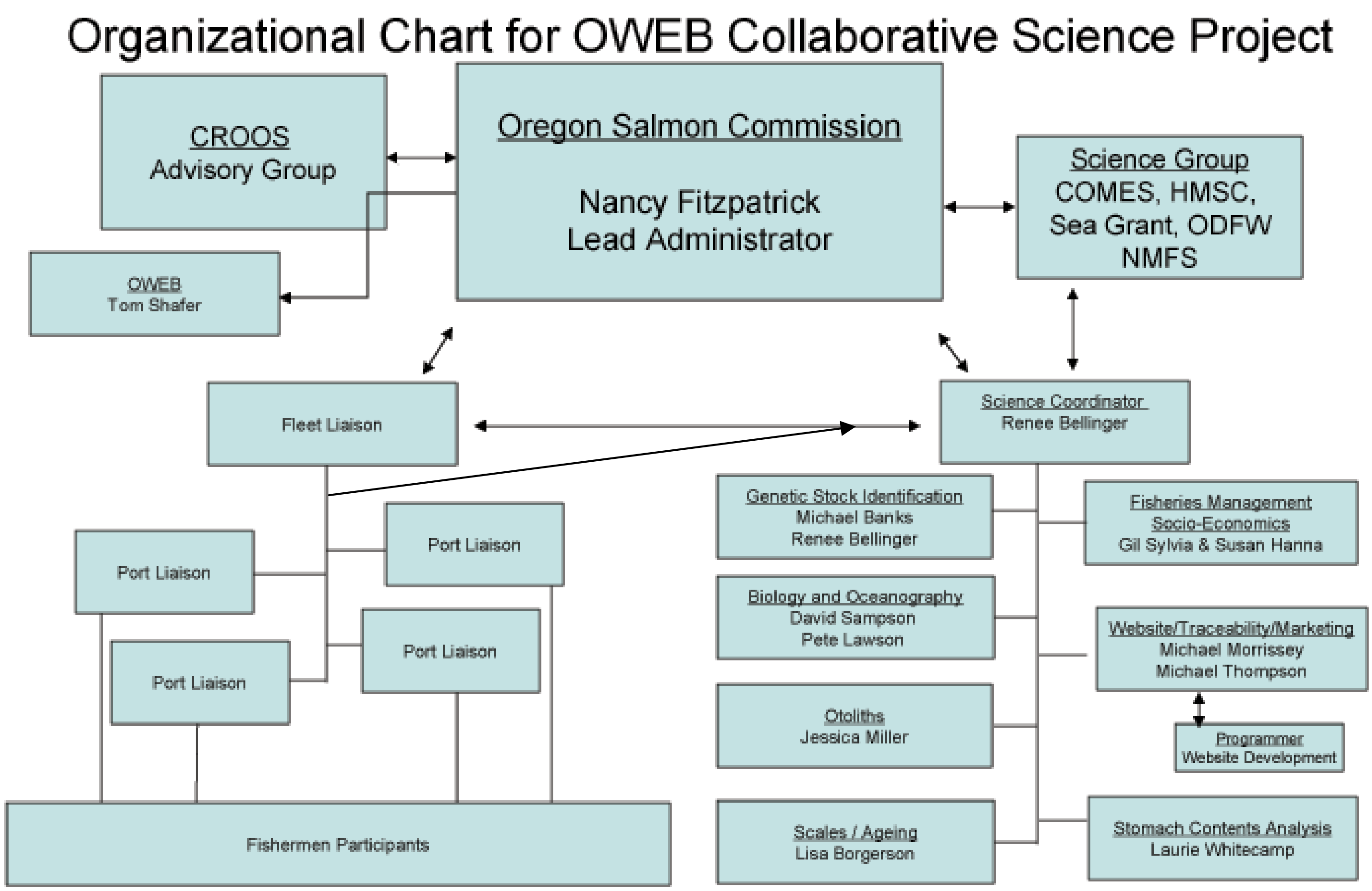
- Take samples, your protocol and the CROOS Toolkit (with all supplies, including the GPS) to the Port Liaison at the port you landed your fish (Liaison list on page 2)
- Contact your home-port Liaison so they know that your samples were received
- Port Liaison will fill out your invoice and submit it to the Oregon Salmon Commission for payment
- Port Liaison will download your GPS data, check your samples in, and either restock the CROOS kit and give it back to you, or will keep it to re-issue it if you are not going to be sampling again that week. The Port Liaison will give you any protocol updates.

Port Liaison Contact Information

Port	Port Liaison Contact Information	Hours
Garibaldi	**Val Folkema** c/o Garibaldi Marina	
Newport	**Jennifer Wimpress**	
Winchester Bay	**Carla Hedgepeth**	
Coos Bay / Charleston	**Dan Morris**	
Port Orford	**Julie Watson**	
Brookings	**Lynn Dairy**	

Other Contact Information for Project CROOS

Role	Name	
Fleet Liaison	**Paul Merz**	
OSC Administrator	**Nancy Fitzpatrick**	
OSC / Oregon Sea Grant	**Jeff Feldner**	



Fleet Communication Protocol

Overview

All communications with the fleet will happen through liaisons. Each fisherman will have an assigned liaison and must contact their liaison within 24 hours of returning from each sampling trip. If a boat comes in to a port other than their homeport it is their responsibility to contact their assigned liaison (to let them know where they are ported) AND the liaison in their port of call to turn in their data. Each liaison has an individual contact plan (see Liaison Contact and Instruction Sheet.)

Fishing Days Assignments

There are limits to how many boats can go out per week and how many samples may be taken. Fleet managers will assign fishing days and adjust assignments as needed. When assignments become available your liaison will let you know. It is your responsibility to confirm with your liaison whether or not you will be fishing those days.

Samples and Data

It is your responsibility to contact your liaison (if landing in a port other than your home, you must ALSO contact the liaison in that port) within 24 hours of returning from a sampling trip.

When You Come in to Port

You must **bring your kit and all data and samples and your protocol to the Liaison at that port**. You will wait while the liaison checks your samples and GPS data for completeness and consistency. Your kit may or may not be returned, depending on upcoming sampling day assignments. If your kit is returned to you, you and your liaison will restock your supplies (batteries, envelopes etc…) at that time.

Protocol Changes

Your liaison will inform you of changes in protocol as needed.

Invoicing

Invoices will be completed and turned in by your liaison. No payment will be allowed until samples are properly received.

GPS Units Procedure

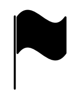
- Check GPS units throughout day to make sure the batteries haven't run out of power. You can change the batteries and will not lose the data stored in the GPS unit.
- When using GPS, keep it outside where it can get satellite reception (typically there is no reception in the wheelhouse)

Turn GPS **<u>ON</u>** when your gear is in water

Turn GPS **<u>OFF</u>** when your gear is not in water

Make one waypoint PER FISH. For example, if you land 3 fish, make 3 waypoints.

To record a waypoint when you land a fish



1. Press "**MARK**" button to record a waypoint
2. Read the waypoint number on the screen and remember the waypoint's time
3. Hit " **ENTR**" button to store the waypoint on the GPS unit
4. Write the **Waypoint number** on the envelope
5. Write the **Time and Date** of the waypoint on the envelope.

To check waypoints that you have already made

1. Press "Find" button
2. Use the arrow to highlight the "Waypoints" icon
3. Press "Enter"
4. You will see a list of waypoints, with the last one made as the last one on the list.
5. Use the arrow keypad to select the waypoint that you want to check, and press "Enter"
6. Press "Quit" to exit the screen

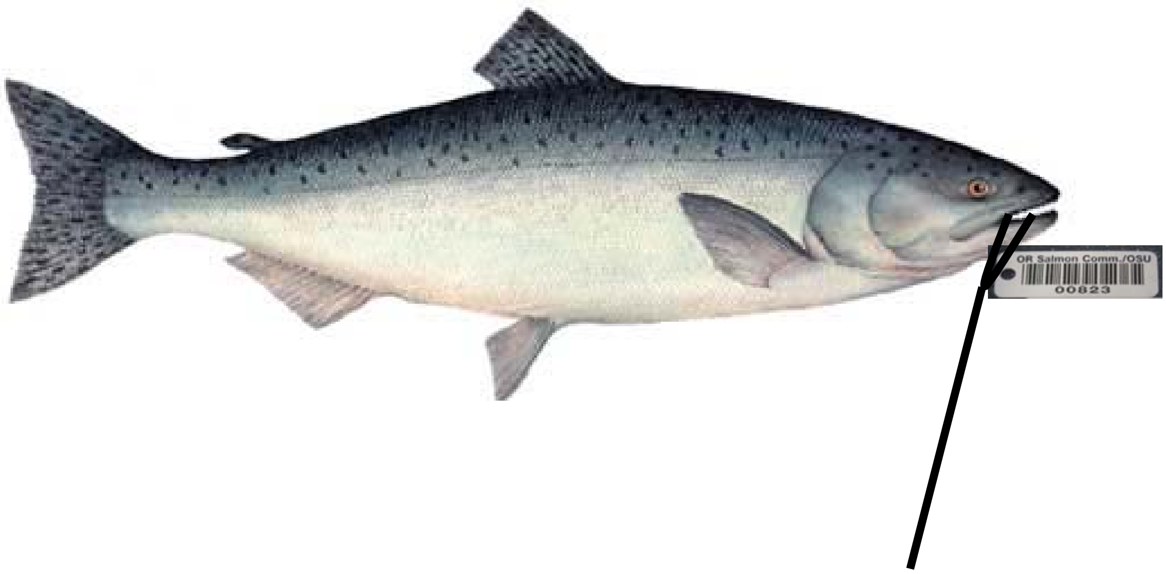
* If you want to see a different waypoint, press the "Quit" button, and it will take you to the previous screen with the list of numbers.

The GPS unit automatically saves your track in five minute intervals when it is on. You won't see anything indicating that it is recording, but as long as the GPS is on, it is recording.

Placing Metal Bar Code Tag on Fish Procedure

Make incision through jaw, thread zip-tie through tag and jaw and pull the zip-tie shut

The metal tag's barcode number matches the number on the envelope



Filling out Envelope Data Procedure:

Use the envelope that you removed the barcode from to record data for that fish

We use date and time to match capture location to GPS data (we use this to double-check that the waypoint matches the fish).

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

Vessel Name____________________

Date __________________________

Time __________________________

Depth of capture __________ fthms

Fork Length _________inches (to 1/4)

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 Month, Day, Year

Time Time you landed fish, same as Waypoint number time

Depth of capture – in fathoms

Fork Length - Round to ¼ inch

Hatchery markings – check for clips to adipose, vent, or for dye-markings. If no marks, check “No Mark”

Check to indicate that scale & tissue samples were taken. We are not collecting stomachs this year.

Waypoint number * (one per fish)

Additional notes (white salmon, etc)

If you find a pit-tag, place in envelope.

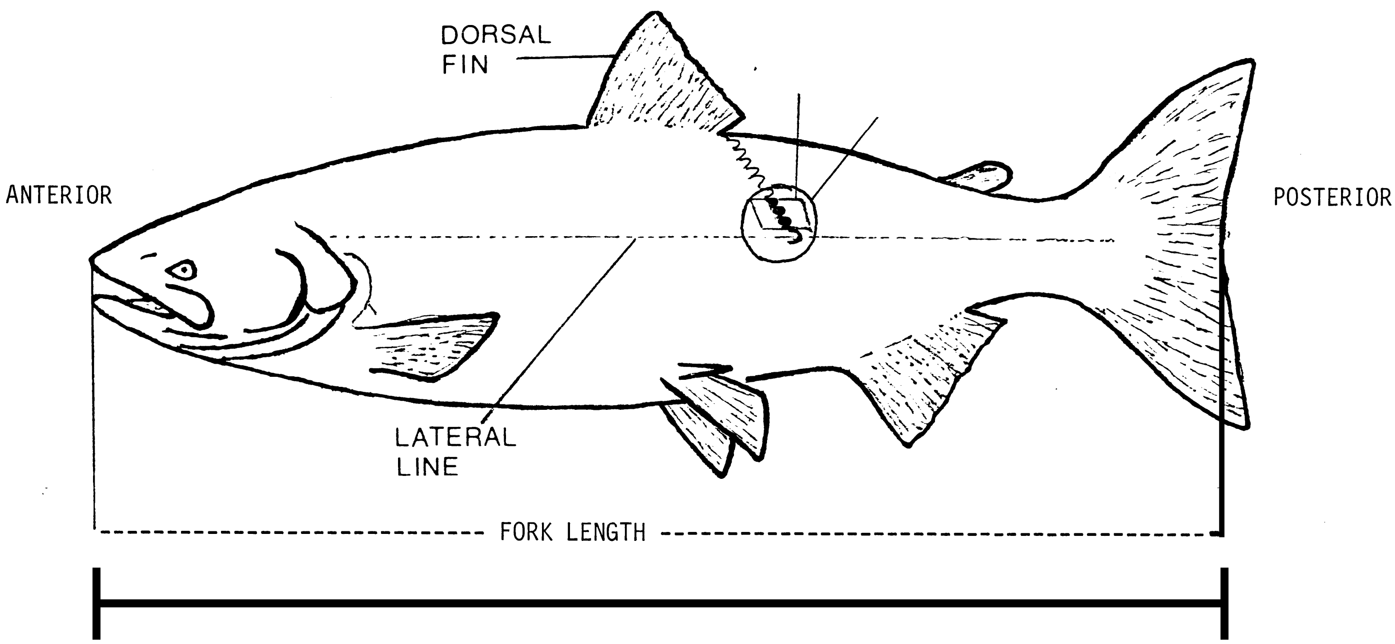
**** **USE CLEAN SCISSORS** ****

* Older envelopes have “Notes or lat/long (optional) written on the bottom of the envelope.

Write the waypoint number in this area regardless of what the envelope instructs.

Fork Length Measurement Procedure

Write length in inches on envelope, and round to ¼ inch.



FORK LENGTH

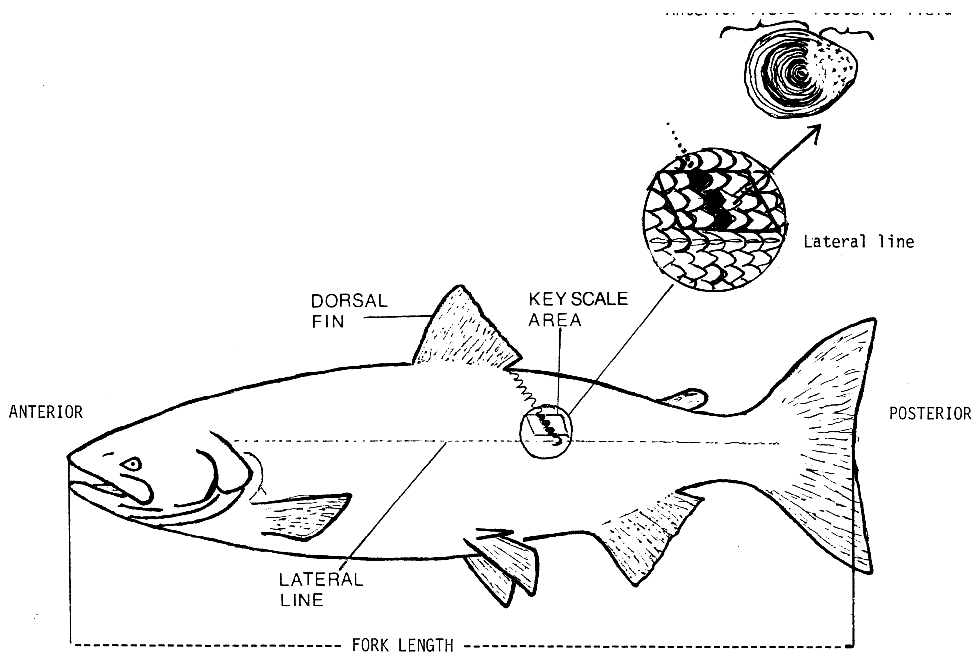
Scale Sampling Procedure

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.

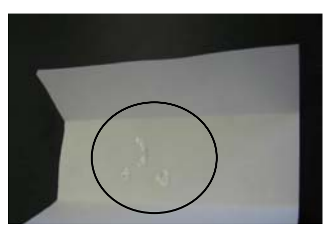


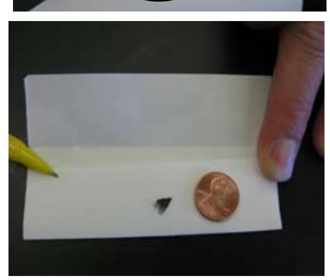
Take 8 - 10 scales before tissue sample

Place in middle of paper

Fold paper once over scales

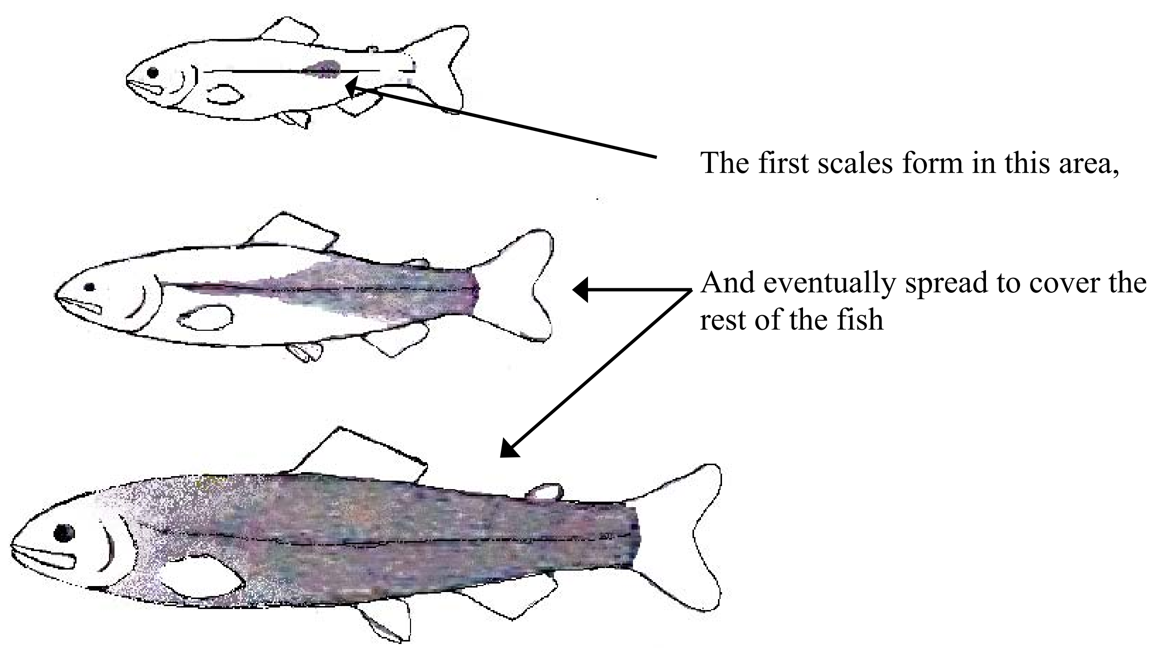
DNA tissue sample will go on next fold (pictured to right)





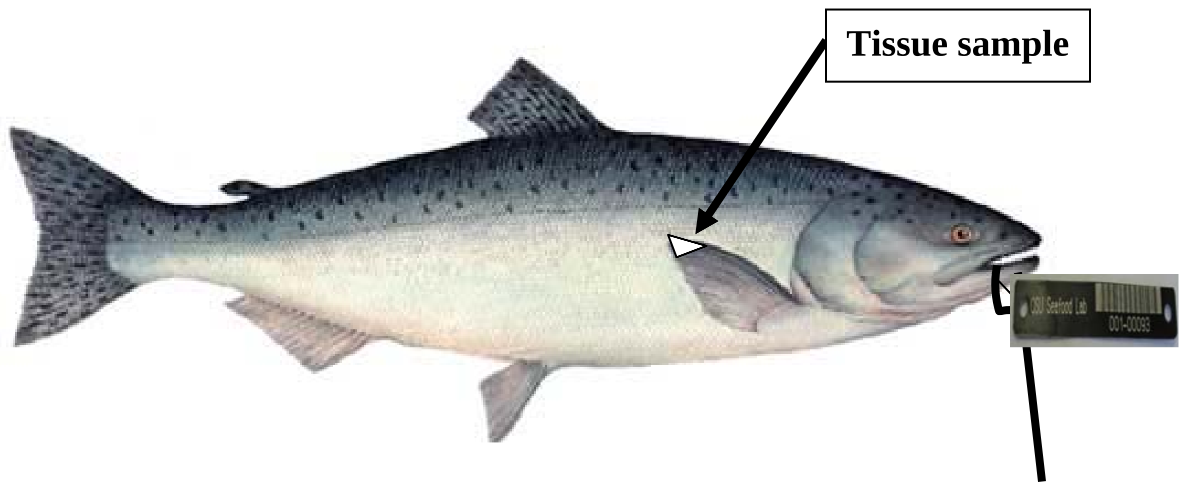
Note on Key Area:

When a juvenile salmon hatches and emerges from the gravel, it does not yet have scales. When it is about 3.5 cm long (1.3 inches), scales start to form in the area we designate as the Key Area. Therefore, key area scales are the biggest and more life history information has been "recorded" on them compared to scales from elsewhere on the fish. We can still age scales taken from near the key area but as these scales will be smaller, we would be unable to use these scales for analyses that required measuring features such as the ocean entrance mark. We may be unable to age scales taken further from the key area, especially from the back or belly.

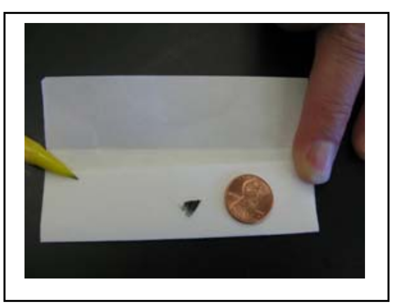


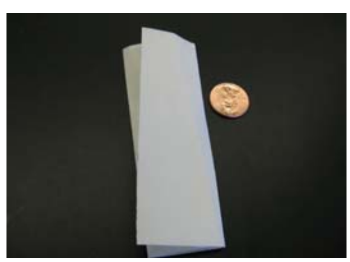
Genetic Sampling Procedure

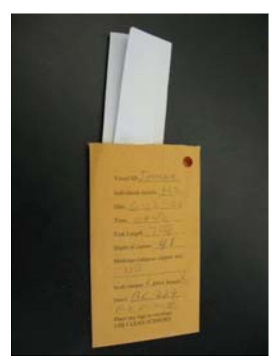
1) Use ONLY **CLEAN** scissors and forceps
2) Remove small portion from pectoral fin (not larger than a dime)
3) Place fin snip flat on second fold of paper (scales should be separate from tissue sample)
4) Place tissue flat on paper
5) Fold paper over
6) Slide paper in envelope
7) Close envelope
8) Place envelope somewhere safe and dry. The faster the tissue dries, the better the DNA is preserved.
9) Keep the envelopes clean. Blood from other fish will contaminate samples.
10) Rinse scissors & forceps well in salt water - using the deck-hose to rinse is fine



Place small piece of tissue on paper, fold and place paper inside envelope







CROOS collection of salmon heads for otolith collection

For information only

- Heads with CROOS tags will be collected by some processors / buyers.
- Collection of heads from buyers will be coordinated by Jeff Feldner and Jessica Miller.
- Fish with coded-wire tags detected by ODFW will have tags removed and returned to OSU

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 heads of Chinook salmon tagged with Project CROOS barcodes will be saved by some processors and buyers and returned to researchers at Oregon State University. Data from otoliths will be used in conjunction with Genetic Stock Identification to study migration and schooling patterns of Chinook.

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.

Notes and Protocol Addendums:

Throw away all protocols you received last year!

Appendix 12

Liaison Protocols

Project CROOS

Lab - to-Liaison Protocol

On-line Version: 25 September 2007

Downloading GPS units & Checking Waypoints

Objective 1: to save the GPS data, labeling it with the fisherman's last name and the day's date (the date of the day you are downloading the data). This will be saved as two file types 1. as a Garmin File, and 2) as a text file. Save this data in the folder labeled with the date you will be sending the data into the laboratory.

Objective 2: to check sample quality, and check that sample envelopes can be matched to waypoints recorded in GPS data

1. Count the number of envelopes turned in by the fishermen. Check for sample quality, completeness of data, and that waypoint numbers were written on all envelopes.
2. Turn on computer
3. Double-click the MapSource icon on desktop to open GPS software to open the software. Wait for it to open
   - a popup window "Locked Maps Detected" might show up. If so, place the arrow over the screen-button "Skip" and hit enter
4. Plug USB cable into computer and then to GPS unit (look under the black plastic flap on back of GPS).
   - If a popup window says "Found New Hardware", select "Yes" (usually middle option), then "Next", and "Finish"
5. Turn GPS on.
6. Make sure you are starting with a blank file in the MapSource GPS software. If you already have a file open it will overwrite the data for the file you have open. If you have a file open, start a new file by going to "File" and select "New"
7. Find button that says "Transfer" - this is located on the menu bar at the top of the MapSource window
8. Use arrow to highlight button that says "Receive from Device"
   a. hit enter
   b. Make sure the computer has identified the GPS. If not, make sure the GPS is turned on and then click "Find device."
9. Make sure all boxes are checked before you transfer data. Put arrow over "Receive" and hit enter
   a. If you get an error message, check that the GPS is turned on
   b. The data should download from the GPS and the GPS will turn itself off when it has finished
   c. Unplug GPS and cable and set aside
10. When computer indicates transfer is finished click on "ok"
    a. You can select one of four tabs in the software. To check waypoints, move the arrow over the second tab, "Waypoints".
    b. Check for whether the number of waypoints matches the number of samples you received
    c. If not, check if more than one fish was recorded with the same waypoint

11. Next you will save the file you just downloaded, first as a Garmin file (the automatic file format, and then as a text file. Microsoft Excel can't read a Garmin file, which is why the data needs to be saved two different ways.

- Go to "**Fil**e"
- "**Save as**"
- Click on the "Desktop" icon to find your folder (if it is on your desktop)
- **Open the CROOS_Data folder** (highlight it and double-click)
- Inside the CROOS_Data folder, **open the folder labeled with the date you will be sending samples to the laboratory**
- Name the file you will be saving:
  In the popup window "File Name:" **type the last name of fishermen and today's date**, (it automatically saves it as a '.gdb')
- Press "Save"
  This saves the file as a Garmin .gdb file

Next you will save the same file, but this time you will save it as a **text file** instead of the Garmin file.

- Go to "**Fil**e"
- "**Save as**"
- In the "Save as Type:" drop-down menu select **"Text** (Tab-delimited)". This will place a .txt in the file's name.
- Press "**Save**"

To check your work, open the folder (on the desktop) that you just saved the samples to. You should see the two files that you just saved. One should have the extension **.gdb**, and one should have the extension **.txt**

You won't see both files if you open the folder while in the Garmin program – you must open the file from your desktop

Example: You should have two files:

Miller052507.gdb
Miller052507.txt

After you have checked that both files are in the Folder you just saved to, close the Garmin Software. You are now ready to clear the GPS tracks and waypoints from the fishermen's GPS unit and restock the fishermen's kits.

Delete all waypoints and track logs:

- Turn the GPS unit on
- Hit “Page” button to get to Trip Computer screen
- Press the “Menu” button
- Select “Reset”, press “Enter”
- Move arrow to highlight the following boxes, pressing “Enter” for these 3
    - “Clear Track Log”
    - “Delete Saved Tracks”
    - “Delete all Waypoints”
- Use arrow to move to box that says “Apply” and press “Enter”
- Move arrow to highlight “OK” and press “Enter”

The GPS unit is ready for the next trip

If you want to check and make sure the waypoints are deleted:

- Press the ‘Find’ button
- Select ‘Waypoint’ and press ‘Enter’
- The GPS should say ‘None Found’. If there are still waypoints present, repeat the steps above

Restock Fishermens At-sea collection kit

Inside each tacklebox there should be:

~ 65 Envelopes (20 per day, 3 days of sampling per fishermen)
~ 75 zip-ties
2 scissors
2 tweezers
1 measuring tape
2 pencils
1 GPS
4 batteries
~ 10 rubber-bands

You are now ready to take the next fisherman’s GPS unit, re-open MapSource and repeat the process.

Converting Fishermen's GPS .txt file to Excel File & Data Entry

1. Open file "Liaison_Macro.xls" (on your desktop)

Popup window may show up – select "Enable Macro" to allow the macro to run

Once Excel is open:

From the Excel program, go to "**File**" (top left side of toolbar)
- "**Open**"
  - Navigate to the folder that holds the file you want to open. Double click the folder to open it (the .txt file won't show up until the next step)

- At bottom of drop-down menu "Files of type" select "all files"

the .txt file should now be visible - if it is not showing up, be sure you checked "select all files"

- Select the fisherman's text file that you want to open
  - Select "**Open**"

In next Popup window, make sure "**Delimited**" is checked
- "**Finish**"

The text file will be open in the Excel program

Now you are ready to run the Macro

2. Press the "Control" and then "z" button simultaneously (be sure to press control first). Tap it only once - if you tap it twice, the Macro will run twice!

This sorts the data and makes columns for data entry

3. Now the file needs to be saved as a Microsoft Excel File

- Go to "**File**" (top left side of toolbar)
  - "**Save as**"
    - In bottom of popup window "**Save as type:" select "Microsoft Excel**"
      - **Click on 'Save'**

This saves the file with all the formatting changes as an Excel file.
This file should automatically save in the same folder as the txt file. It should have the same name but a different extension (.txt is a text file, .xls is an excel file).

Data Entry:

Go to far-left column and type the last name of the fishermen in the first open cell (Cell A2)

- After you've typed in the name, press enter
- Move the arrow on the screen over the far right hand bottom part of the cell you just typed the fishermen's name in. When you see the arrow change into a small cross, double click to fill in all the cells in this column with the person's name

Go to the Barcode_ID column

- Arrange all your envelopes so they are in the same order as the waypoints
    - Scan first envelope. Make sure the waypoint written on the envelope matches the waypoint for the barcode you just scanned in
        - Press the down arrow on your keyboard
            - Scan the next barcode
                Repeat until finished

If there is an extra waypoint, either type in "extra" in the "Barcode_ID" column (where you would be scanning the barcode) or delete the entire row

To delete the entire row

- Move your arrow to the far left cell of the row you want to delete (to the left of their name)
- When your arrow changes to looks like this: ➡
- Press the left-mouse button (or left keypad button) to highlight the entire row
- On the top toolbar, go to "Edit" (to the right of "File" on the top toolbar) and select "Delete"
    - If you delete the wrong column go back to "Edit" and select "Undo Delete"

Save your work again by going to **File**, **Save** (it should already be an Excel file format from when you saved it before

Enter data for all the envelopes.

DOUBLE CHECK:
Waypoints match the Barcode Number
Data entered for the envelope matches the barcode

Data Entry Codes & Fractions to Decimals

Convert Fractions to Decimals for all numbers
Fractions to Decimals: ¼ = 0.25 ½ = 0.5 ¾ = .75

- Depth_Capt
- Fork Length
- Hatch_Marks
    - 0 = No Mark,
    - 1 = Ad Clip (Adipose Fin Clip)
    - 2 = Vent Clip (Ventral Fin Clip)
    - 3 = Dye-Mark
    - 5 = Other (pit-tag or something else not on this list- type the tag type in the notes section
    - 9 = NO DATA

- Notes (white salmon, anything else noted by the fishermen)
- Temp (ignore for now)

Save your work again.
Close the file

Place the Sample Envelopes that you just entered in the "ready to send to the laboratory" box.

Done with those samples!

If you are ready to mail your samples to the laboratory, proceed to page 10 for instructions on how to copy your data folder to the USB, move this data folder into the "Backup" folder, and make a new folder with the NEXT date you will be sending samples to the laboratory.

Troubleshooting data entry in Excel:

1. **If one waypoint has more than one fish assigned to it**:
   a. Move your arrow to the far left cell of the row you want to copy (to the left of their name)
   b. When your arrow changes to look like this: ➡
   c. Press the left-mouse button (or left keypad button) to highlight the entire row
   d. With your cursor over the highlighted row, right click once
   e. Click on ‘Copy’
   f. Highlight the row below the one you are copying (steps a. through c.)
   g. With cursor over the highlighted row, right click once
   h. Click on ‘Paste’
   i. If you need to make more repeat the steps.
2. **If you accidentally enter two barcodes in one cell:**
   a. Highlight the cell with the two barcodes
   b. On your keyboard press ‘Backspace’
   c. Re-enter the barcodes
3. **If the envelope time doesn’t match the GPS waypoint time:**
   a. Check the envelope before and after and see if they match the waypoint times
   b. Check the lat and long (if the fisherman wrote them down on the envelope) to see if they match
   c. If it is within a few minutes, it is fine
   d. Remember to tell the fisherman to write the time from the GPS waypoint on his envelope, not the time from his clock
4. **If the GPS was not cleared and he has a lot of extra waypoints:**
   a. In the excel file you can highlight the rows with the extra waypoints, right click once, and click ‘Delete’
   b. If you don’t feel comfortable deleting, enter ‘extra’ in the barcode ID space and leave a note in the notes column that says it was a previous trip that wasn’t cleared on the GPS
5. **If there is CWT information on the envelope:**
   a. Enter the CWT number in the notes column for that fish
6. **If you make a mistake, or delete something you didn’t want to:**
   a. Don’t panic
   b. Go to ‘Edit’ in the menu and click on ‘Undo’

Instructions on how to copy a Folder to USB Drive

- Open the CROOS_Data folder so you can see the Folder with the data you are going to be copying
- Highlight the folder you want to copy
    - Go to "File" (on the top toolbar)
        - Select "Copy"
- Put the USB Drive in your computer
- Open the USB Drive Folder so the window comes up on the computer screen (you may need to shrink the window so you can see the Croos_Data Folder window and the USB window)
    - Go to "File
        - Select Paste

The folder should appear in the window of the USB drive

Now you are ready to eject the USB drive and send the samples to the laboratory

Instructions to eject the USB drive

- Move your screen-arrow to the right-hand side of the lower toolbar and place it the safely eject USB icon (this icon has a green arrow facing to the left)
- Click the left-mouse button (or keypad button)
- A popup window will show up with "Safely Remove Hardware and select "Stop"
- Select the "USB drive" on the list of drives
- Select OK

Some computers are different – highlight the eject USB drive icon, left-click the icon, highlight the USB drive you want to eject and click

Instructions on how to move a folder into the Backup Section

- After you have copied the folder you just copied to the USB, you are ready to move this folder to the backup folder.
- In the window with the Croos_Data folder, highlight the folder you want to move to the backup folder.
- Drag this folder into the "Backup" folder
- It should disappear from the CROOS_Data window.
- Make a new folder for samples you will be receiving (you may have already done this step)
    - Label this folder as the next date you will send data to the laboratory
- Don't put any data in the "Backup" folder unless it has been sent to the laboratory

Place USB in the box with the samples that you are sending to the laboratory.

Port	Port Liaison Contact Information	Hours
Garibaldi		
Newport		
Winchester Bay		
Coos Bay / Charleston		
Port Orford		
Brookings		

Role	Name	
Fleet Liaison		
OSC Administrator		
OSC / Oregon Sea Grant		
CROOS Science Coordinator/Data Analyst		

Appendix 13

Contract Work Statements

FLEET MANAGEMENT WORK STATEMENT

EXHIBIT A

PERSONAL/PROFESSIONAL SERVICES CONTRACT

I. STATEMENT OF WORK:

a. Authority. Pursuant to ORS 576.304 (4), 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, Oregon State University and others are working on a project to collect and use genetic information to address the Klamath weak stock crisis for Oregon's ocean salmon fishery. The Collaborative Research on Oregon Ocean Salmon (CROOS) project for 2007, composed of Oregon-based fishermen and scientists, is receiving funding from the Oregon Watershed Enhancement Board (OWEB) and National Marine Fisheries Services. The 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. The vessels will collect the data using GPS units and 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. Train port liaisons on requirements for vessel communication and answer questions as they arise
3. With scientific team, develop sampling protocols
4. Train vessels on sampling protocol
5. With Commission, plan fleet structure for number of boats fishing each opener
6. Communicate with port liaisons at least once a day during all sampling periods
7. Communicate with scientific team and port liaisons
8. Keep daily records of vessels and days fished as reported from port liaisons
9. Maintain master list of vessels in project
10. Communicate progress of fleet sampling performances and relay instructions from the scientific team to the port liaisons and vessels when needed.
11. At end of each opener, communicate with port liaisons and scientific team on total boats fished, number of fish sampled
12. Work with the Commission and the scientific team to adapt the project and make changes as necessary
13. Assist the Commission and the scientific team with the final report

d. Delivery Schedule. This contract shall begin and terminate according to Section 1 of the Contract.

_____ (Initial) CONTRACTOR understands and agrees that all information collected from fishermen is strictly confidential. This information will be given only to the fleet management team and laboratory personnel responsible for data collection and analysis.

LIAISON WORK STATEMENT

EXHIBIT A

PERSONAL/PROFESSIONAL SERVICES CONTRACT

I. STATEMENT OF WORK:

a. Authority. Pursuant to ORS 576.304 (4), 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, Oregon State University and others are working on a project to collect and use genetic information to address the Klamath weak stock crisis for Oregon's ocean salmon fishery. The Collaborative Research on Oregon Ocean Salmon (CROOS) project for 2007, composed of Oregon-based fishermen and scientists, is receiving funding from the Oregon Watershed Enhancement Board (OWEB) and National Marine Fisheries Services. The 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. The vessels will collect the data using GPS units and record the data on the collection envelopes. 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 project
2. Be responsible for activities set forth in c.3 – c.8 below for a pod of 5-15 specifically assigned 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 daily with general locations of boats
7. Communicate with fleet management on total boats fished, number of fish sampled
8. Perform other assigned duties that may arise that are necessary for the successful completion of the project.

Delivery Schedule. This contract shall begin and terminate according to Section 1 of the Contract.

_____ (Initial) CONTRACTOR understands and agrees that all information collected from fishermen is strictly confidential. This information will be given only to the fleet management team and laboratory personnel responsible for data collection and analysis.

VESSEL WORK STATEMENT

EXHIBIT A

PERSONAL/PROFESSIONAL SERVICES CONTRACT

I. STATEMENT OF WORK:

a. **Authority**. Pursuant to ORS 576.304 (4), 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, Oregon State University and others are working on a project to collect and use genetic information to address the Klamath weak stock crisis for Oregon's ocean salmon fishery. The Collaborative Research on Oregon Ocean Salmon (CROOS) project for 2007, composed of Oregon-based fishermen and scientists, is receiving funding from the Oregon Watershed Enhancement Board (OWEB) and National Marine Fisheries Services. The 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. The vessels will collect the data using GPS units and 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 project
2. Participate on specific dates as directed by the Commission/fleet management 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 date with fishing location, sampling progress, number of fish sampled
5. At end of each fishing trip, drop off samples and download GPS data per protocol (see Exhibit D attached)
6. Invoice the Commission after each fishing period 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.

Delivery Schedule. This contract shall begin and terminate according to Section 1 of the Contract.

____ (Initial) Contractor understands that information gathered in performance of the project will be available to management entities and project researchers. Any information relating to aggregate catch that will appear on publicly released documents or websites will not be identified by vessel, or name of fisherman. In addition, if, in any calendar week of open fishing seasons, fewer than three vessels make landings in any given port, that landing (catch) information will not be made available.

Contractor agrees that information relating to an individual fish for the purposes of marketing or promotion may be associated with contractor's personal identity (vessel name, fisherman name, etc.)

___ Yes ____ No ________________________________ (signature)