The West Coast Salmon Genetic Stock Identification Collaboration Annual Activity Report, 2010

David Goldenberg, California Salmon Council
Nancy Fitzpatrick, Oregon Salmon Commission

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 100s 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 improving science to support management of multi-stock ocean salmon fisheries, three individual state-based projects (Oregon's Project CROOS, Collaborative Research on Oregon Ocean Salmon; California's Genetic Stock Identification Project; and a similar project in Washington) teamed together in 2007 to form the West Coast Salmon Genetic Stock Identification Collaboration (WCS-GSI Collaboration), led by the California Salmon Council, Oregon Salmon Commission, and Washington Troller's Association. Partners include Oregon State University, Oregon Department of Fish and Wildlife, Oregon Sea Grant, Community Seafood Initiative, National Marine Fisheries Service Northwest and Southwest Fisheries Science Centers, Northwest Regional Office, California Department of Fish and Game, University of California, Santa Cruz, Washington Department of Fish and Wildlife, and Northwest Indian Fisheries Commission.

The vision of the WCS-GSI Collaboration is to support a working partnership between fishermen, scientists, and fisheries managers in Washington, Oregon, and California that benefits fish and strengthens west coast salmon fisheries by protecting weak stocks, providing sustainable harvest, and improving economic opportunities and fishing practices through better understanding of stock specific ocean distribution and migration patterns of salmon. This vision is supported by the three main project goals:

1) Improve understanding of the ocean ecology of salmon by integrating stock-specific distribution patterns over space and time with biological and environmental data;

2) Integrate multiple disciplines to develop and apply new scientific technology to improve fisheries management strategies across geo-political boundaries; and

3) Improve and stabilize economic opportunities for fishermen and coastal communities.

Overview and Summary of 2010 Activities

- GSI sampling was conducted for the first time on a coast-wide scale. The data collected will contribute to a comprehensive picture of stock distributions, migration patterns, and catch rates in the waters off Oregon and California.
- The Pacific Fishery Management Council allocated sampling impacts for the 2010 season and National Marine Fisheries Service Northwest Region issued a Scientific Research Permit to support non-retention sampling in closed times and areas.
- Approximately 9,600 Chinook salmon tissues were collected using high spatial resolution at-sea sampling protocols in both retention and non-retention fisheries. Sampling was conducted from Cape Falcon, Oregon to the California/Mexico border from May through September, 2010.
- Genetic analysis is nearly complete. Age of fish will be estimated using scale aging analysis.
- Genetic analysis techniques are being refined to improve discrimination of stocks in Council-managed fisheries.
- Two experimental fishery-independent surveys were conducted in August to test methodologies that could be used to sample stock distributions and catch composition.
- A Master of Science degree was awarded to Robert Ireland. His thesis was titled "The distribution and aggregation of Chinook salmon stocks on the Oregon Shelf as indicated by the commercial catch and genetics." The research was based on data from Oregon fisheries in 2006 and 2007.
- Research on stock composition of Chinook landed as bycatch during the Pacific Hake fishery continued.
- Electronic data collection methods and web-based tools (see Pacific Fish Trax website section, below) are being developed to support rapid data-sharing and use by multiple user-groups.
- The Pacific Fish Trax (PFX) database was used as a data repository for Oregon and California at-sea data and all genetic data for Oregon.
- Web-based tools accessible through secure PFX portals were used by port liaisons, fleet managers, and laboratory personnel for in-season project management. This was the first year that coordinated and standardized data collection occurred in Washington, Oregon, and California.
- A strategic plan for the WSC-GSI Collaboration was adopted and a data sharing and use code of conduct agreement is nearly complete.

Future actions

- Oregon and California are co-writing a 2010 annual report, which should be complete by mid- 2011.
- A workshop for fishermen, managers, and the general public will be held in California to communicate results and solicit feedback.
- A fisheries information system workshop is planned to be held in Portland, Oregon (May 3 and 4), and a symposium is proposed for the American Fisheries Society meeting in Seattle, Washington (September 4-8).
- Data from 2010 will be analyzed by members of the WCS-GSI Collaboration to explore opportunities for science and management applications.
- Website portals for fishermen, managers, and the general public will be developed and tested. A fisherman's portal is nearly ready to "go live."
- Sampling plans for 2011 are being developed.

Limited funds are available to the WCS-GSI Collaboration in 2011. Long term funds for ocean research need to be a part of federal efforts to aid the fishery and improve management and science. The tri-state partnership between California, Oregon and Washington will support a Coast-wide integrated approach for ocean salmon science and management, and has potential to provide economic benefits to the fishing industry.

2010 Sampling Activities

Coordinated data collection occurred along the majority of California and Oregon coastal waters from May through September, 2010. Approximately 9,600 Chinook salmon were sampled by more than 160 participating fishermen from 16 ports (ten in California and six in Oregon). In addition, the Washington Troller's Association voluntarily collected some samples (< 100) along the coast of Washington and analysis by WDFW is pending. The majority of sampling in California was hook-and-release (non-retention) in closed times and areas, while Oregon sampling was primarily during regular commercial fishing activities. The sampling goal was to collect 200 fish per week in each fishery management area. This goal was achieved in only a few weeks because catch rates were low, ranging from 2.3 to 5.4 fish per boat-day (Table 1), and because boats were not uniformly available to collect samples. Sample sizes were larger in areas with sizeable fleets and open fishing at least part of the season (NOC, SOC, Ft. Bragg). Logistics and expense of non-retention sampling limited sample sizes in other areas. The fishing incentive is also greater when fish can be retained for sale.

Monthly numbers of boat-days and fish samples (all projects combined) for each fishery management zone, with San Francisco split into two sub-regions at Pt. Reyes, are presented in Table 2. Retention- and non-retention boat-days and sample sizes are shown in Tables 3 and 4.

Table 1. Summary of fish sampled, number genotyped to date, days fished and fish per boat-day in ten fishery management areas in Oregon and California, May through September 2010.

Management area	Fish	N genotyped	Boat days	Fish/ Boat-day
Cape Falcon to Florence south jetty (NOC)	2437	2003	560	4.4
Florence south Jetty to Humbug Mountain (SOC)	1832	1698	539.5	3.4
Humbug Mountain to California/Oregon border (KMZ-OR)	249	241	99.5	2.5
OR/CA border to Humboldt south jetty (KMZ-CA)	1054	1053	207	5.1
Horse Mountain to Point Arena (Ft. Bragg)	1802	1779	332.5	5.4
Point Arena to Point Reyes (SF-N)	770	773	284	2.7
Point Reyes to Pigeon Point (SF-S)	726	721	313	2.3
Pigeon Point to Mexican Border (Monterey)	710	721	293	2.4
Totals	9603	8989	2682.5	

Table 2. Monthly numbers of fish sampled and boat days of effort in eight Oregon and California fishery management zones during 2010. The month of September was closed over all management areas and all sampling was non-retention; all other months were mixed retention/non-retention fisheries. Area abbreviations are from Table 1.

	May		June		July		August		September	
Area	Fish	Boat days	Fish	Boat days	Fish	Boat days	Fish	Boat days	Fish	Boat days
NOC	402	77.5	1084	170.5	401	82	520	197	30	33
SOC	450	110.5	611	156.5	73	32	597	207.5	101	33
KMZ-OR	0	0	43	39	10	8	61	25.5	135	27
KMZ-CA	0	0	71	38	135	51	478	58	370	60
Ft. Bragg	99	9	173	45.5	494	94	544	116.5	492	67.5
SF-N	47	24	113	58	399	82	160	60	51	60
SF-S	114	53	290	58.5	120	79.5	120	56	82	66
Monterey	19	44	27	54	398	99	158	60	108	36
Totals	1131	318	2412	620	2044	527.5	2638	780.5	1378	382.5

Location of fish sampled and spatial extent of effort (combined retention and non-retention) in Oregon and California in 2010 is presented in Figure 1. Figure 2 displays reporting-group-specific catch-per-unit-effort, as well as fish sample locations and effort distribution for June.

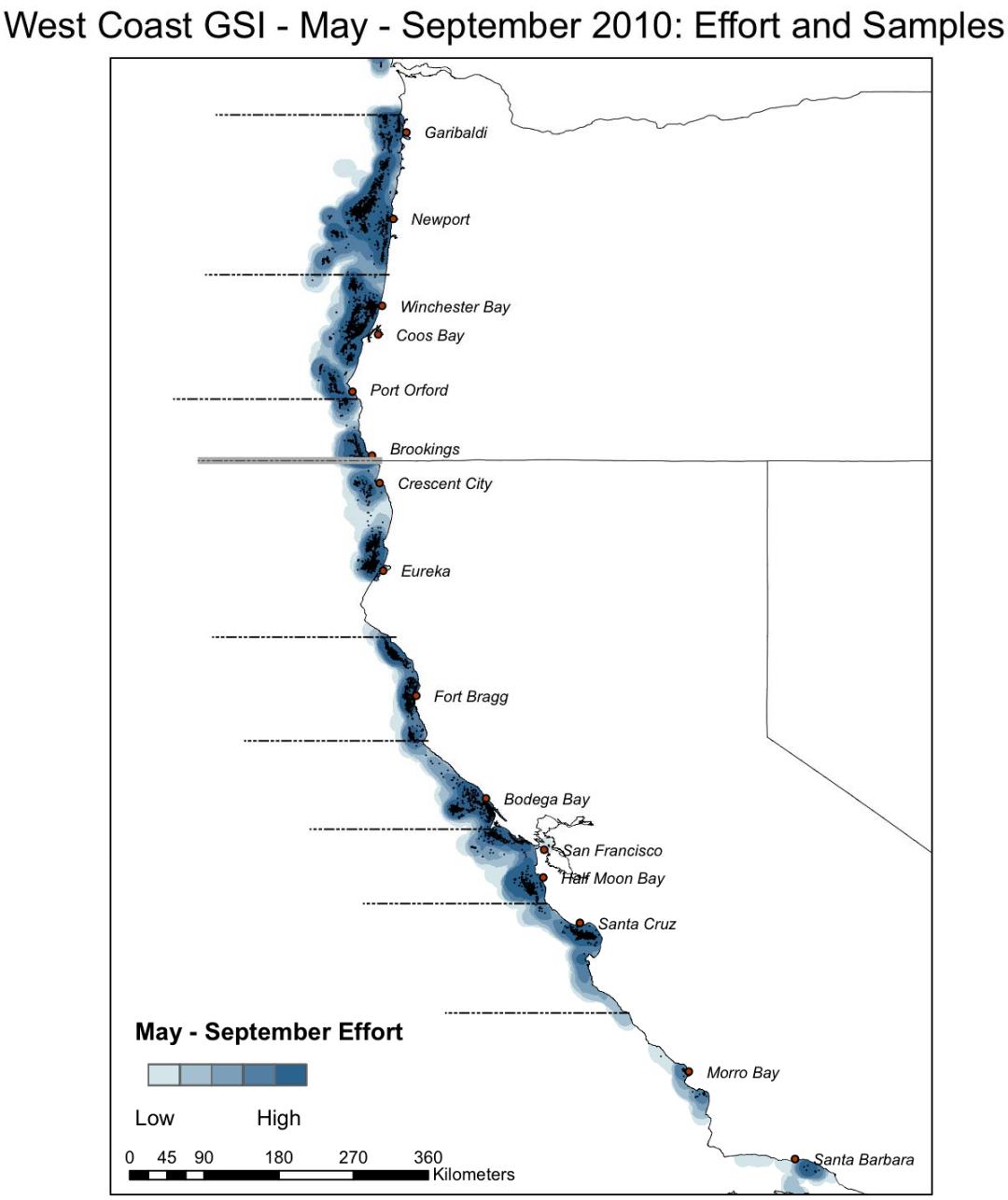


Figure 1. Distribution of catch (black dots) and effort (shaded heat map) in WC-GSI sampling, 2010.

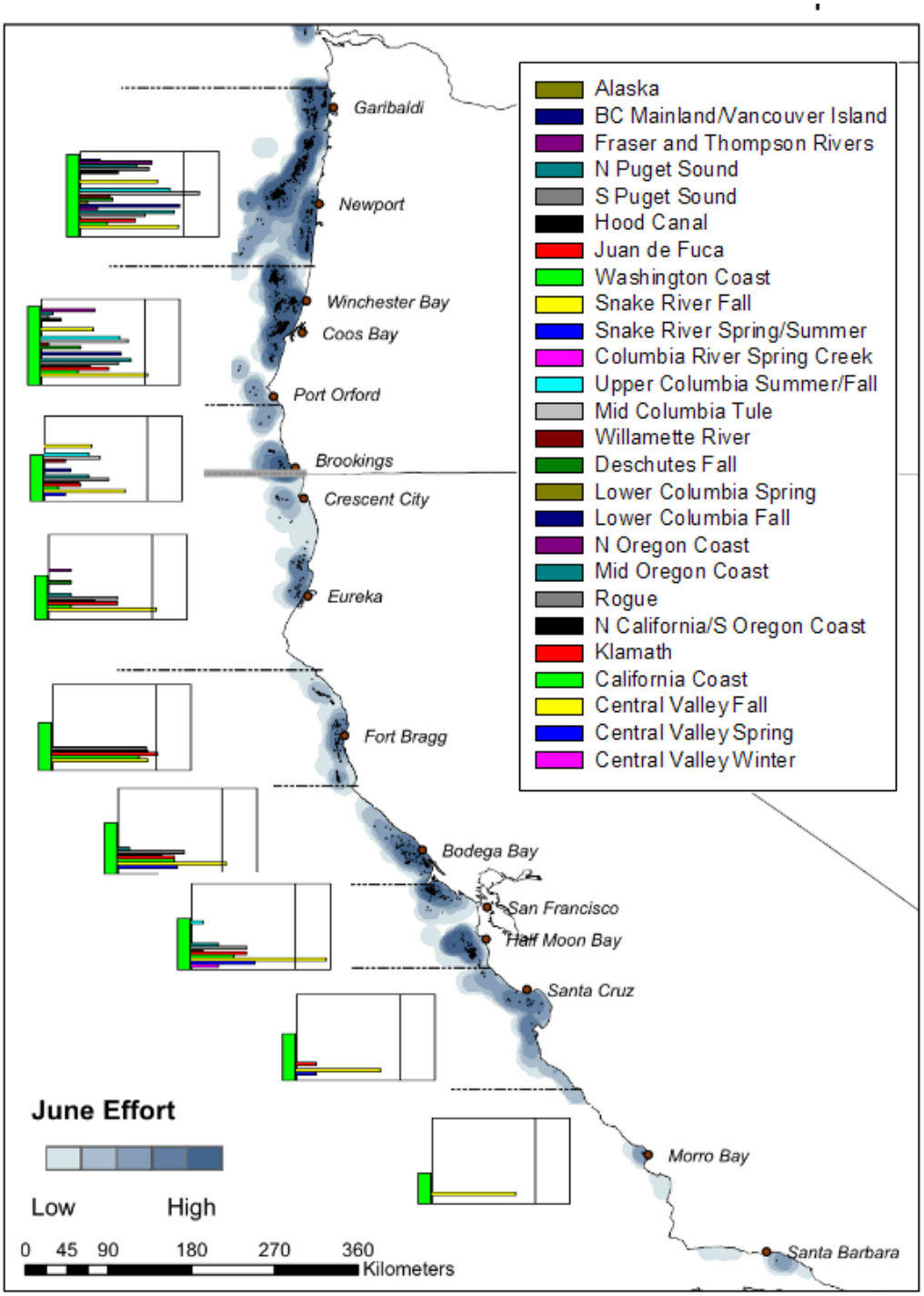


Figure 2. Preliminary stock-specific catch per unit effort (CPUE) from Santa Barbara, CA to Tillamook, OR from June, 2010 GSI sampling. Twenty six (26) stocks or stock groupings are represented. The map also displays sampling effort and catch locations. Stocks are ordered north to south. CPUE scale is logarithmic; vertical line indicates one fish per boat day. Vertical green bar on left axis is log effort.

Table 3. Monthly numbers of non-retention and retention boat-days of effort during 2010 in eight Oregon and California fishery management zones. The month of September was closed over all management areas except for sufficient impacts to conduct experimental genetic stock identification sampling and all sampling was non-retention. Area abbreviations are from Table 1.

	May		June		July		August		September	Totals	
Area	Non-retention	Retention	Non-retention	Retention	Non-retention	Retention	Non-retention	Retention	Non-retention	Non-Retention	Retention
NOC	n/a	77.5	n/a	170.5	n/a	82	n/a	197	33	33	527
SOC	n/a	110.5	n/a	156.5	n/a	32	n/a	207.5	33	33	506.5
KMZ-OR	n/a	0	39	*	n/a	8	*	25.5	27	66	33.5
KMZ-CA	0	*	38	*	51	*	58	*	60	207	0
Ft. Bragg	9	*	45.5	*		94[1]	0	116.5[1]	67.5	122	210.5
SF-N	24	*	58	*	32	50[2]	60	*	60	234	50
SF-S	53	*	58.5	*	34.5	45[2]	56	*	66	268	45
Monterey	44	*	54	*	30	69[2]	60	*	36	224	69
Totals	130	188	293.0	327.0	147.5	380.0	234.0	546.5	382.5	1187	1441.5

* Closed except for sufficient impacts to conduct experimental genetic stock identification sampling (sample quota of 800 fish per month per zone)

[1] Open July 1-4, 8-11 and July 15 through the earlier of July 29 or an 18,000 Chinook quota and August 1 through the earlier of August 31 or a 9,375 Chinook preseason quota

[2] Open July 1-4, 8-11

Table 4. Monthly numbers of non-retention and retention fish samples collected during 2010 in eight Oregon and California fishery management zones. The month of September was closed over all management areas and all sampling was non-retention. Area abbreviations are from Table 1.

	May		June		July		August		September	Totals	
Area	Non-retention	Retention	Non-retention	Retention	Non-retention	Retention	Non-retention	Retention	Non-retention	Non-retention	Retention
NOC	n/a	402	n/a	1084	n/a	401	n/a	520	30	30	2407
SOC	n/a	450	n/a	611	n/a	73	n/a	597	101	101	1731
KMZ-OR	n/a	0	43	*	n/a	10	n/a	61	135	178	71
KMZ-CA	0	*	71	*	135	*	478	*	370	1054	0
Ft. Bragg	99	*	173	*	0	494[1]	n/a	544[1]	492	773	1038
SF-N	47	*	113	*	55	344[2]	160	*	51	426	344
SF-S	114	*	290	*	63	57	120	*	82	669	57
Monterey	19	*	27	*	161	237	158	*	108	472	237
Totals	279	852	716	1695	414	1616	916	1722	1378	3703	5885

* Closed except for sufficient impacts to conduct experimental genetic stock identification sampling (sample quota of 800 fish per month per zone)

[1] Open July 1-4, 8-11 and July 15 through the earlier of July 29 or an 18,000 Chinook quota and August 1 through the earlier of August 31 or a 9,375 Chinook preseason quota

[2] Open July 1-4, 8-11

California Sampling
From 24 May, 2010 through 30 September, 2010, 86 members of the California commercial salmon fleet conducted 1055 days of hook-and-release sampling in closed areas from the Oregon border to Santa Barbara. An additional 374.5 days of sampling were conducted during retention periods in July (south of Horse Mountain) and August (Horse Mountain to Point Arena only). Sampling activities during non-retention periods were conducted under a Scientific Research Permit issued by NMFS, NWR to Dr. Churchill Grimes, and coordinated with the California Department of Fish and Game. Catch rates were communicated with the Department of Fish and Game as soon as they were available in order to monitor progress towards the quota fishery between Horse Mountain and Point Arena.

A total of 5062 tissue and scale samples were collected. Genotypic analysis is complete and final stock composition estimates have been distributed to the project participants, Pacific Fishery Management Council (Council) staff, Salmon Technical Team members, and the other interested stakeholders. One interest of the California project is the evaluation of Point Reyes as a distributional break that could potentially be recognized in fisheries management. Preliminary estimates indicate consistent differences in stock composition to the north and south of Point Reyes.

The California portion of the project used a novel set of genetic markers and associated database for genetic analyses of samples collected by California participants. This novel set of single nucleotide polymorphism (SNP) markers and the associated genetic baseline is designed specifically for use in estimating stock composition in PFMC-managed fisheries. These markers are both cheaper and faster to assay and have lower genotyping error and missing data rates. The baseline database includes much denser sampling of California Chinook salmon stocks and representative stocks from nearly every reporting group (and >99% of all fish) found in ocean fisheries off California and Oregon. This baseline has undergone extensive power analysis and a report describing it and the associated power analyses is currently in preparation. In response to a request by the Salmon Technical Team to use GSI data to evaluate the contribution of Mitchell Act hatcheries to Council-managed fisheries, the SWFSC project participants have also developed a new maximum likelihood method for evaluating whether a fish assigned to one of the baseline stocks actually came from a genetically similar stock not represented in the baseline. This is important because neither the novel SNP baseline nor the coast-wide microsatellite baseline can always accurately identify fish that come from these stocks. This method is also intended to identify non-Chinook salmon, which have comprised almost 1% of the sampled fish in California.

Oregon sampling
Sampling in Oregon was conducted from May through September in three management zones: Cape Falcon to Florence south jetty (NOC), Florence South Jetty to Humbug Mountain (SOC), and Humbug Mountain to the California border (KMZ-OR). Non-retention sampling was used in the KMZ-OR in June and in all areas in September, under a Scientific Research Permit issued by NMFS, NWR to Dr. Peter Lawson and a Scientific Collecting Permit issued by the State of Oregon. A total of 4518 fish were sampled in 1199 boat-days (Table 1). In Oregon, sampling was concentrated north of Humbug

Mountain, with lower effort and lower catches in the KMZ-OR, except for September, when a body of fish moved through the area during non-retention sampling. A total of 4354 samples were genotyped and after those that failed to amplify were removed from the dataset, the remaining n = 3942 were available for genetic analysis. Data density (number of loci that amplified) for these fish was 95%. Mixed stock analysis was performed using Program ONCOR and the GAPS baseline version 3.0 Final results have been made available to project participants and the Pacific Fishery Management Council.

At-sea data entry systems

There are several advantages to enabling fishermen to enter data at sea during the normal course of fishing. It potentially speeds and simplifies the data entry process, reduces errors, and permits transmission of catch locations and effort patterns shore-side to reduce the time-lag for management. We developed and tested two prototype devices, including an at-sea trial. One prototype is based on standard flat-panel touch screens. The other is a custom-designed box with easily-readable LCD displays. Both designs have merit, but neither implementation was satisfactory in our tests. Further development is underway.

Oceanographic data collection

One goal of the WCS-GSI Collaboration is to determine how stock-specific ocean distributions of Chinook salmon relate to time, space, and physical oceanography. Fishing boats can be used to collect fine-scale oceanographic information directly associated with fish distributions. In Oregon, we tested a variety of oceanographic data loggers that record either temperature or temperature and depth, and are small enough and inexpensive enough to attach to fishing lines. These devices are intended to provide location-specific sea-surface temperatures, temperature/depth profiles, and to calibrate depth of gear. In 2010 we tested and compared devices from four manufacturers ranging in price from $100 to $800 each. On each participating boat data loggers were attached to a single fishing line, usually with one device at the surface and a second near the cannonball at the bottom of the line.

Evaluations included comparison of readings with a research-grade CTD (conductivity, temperature, depth) instrument, and deployment on selected fishing vessels. Performance of the devices varied widely in terms of accuracy of measurements, data capacity, and ease of use. Data analysis is in progress.

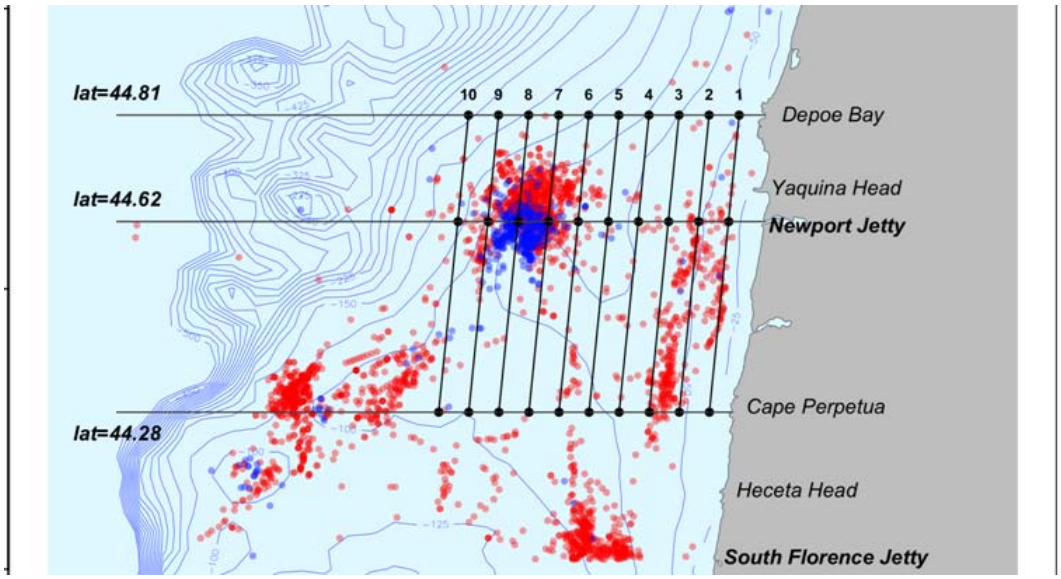
Through the use of these devices, in combination with a variety of other sources of physical and biological oceanographic measurements, we hope to be able to relate fish distributions, including stock-specific distributions, with observable and predictable variations in the ocean environment.

Fishery-independent surveys

Two experiments were conducted in August to test the design of fishery-independent surveys that could be used pre-season to sample stock distributions and catch composition. Tests were located in an area off the coast of Newport with a history of GSI sampling (Figure 3). These studies were designed to compare catch statistics in the fishery-independent surveys with statistics from simultaneous commercial fishing. In

each study, nine or ten boats were commissioned to survey for one day and to fish normally for one day. Boats were equipped with oceanographic data loggers to measure sea temperatures and calibrate depth of gear.

a.



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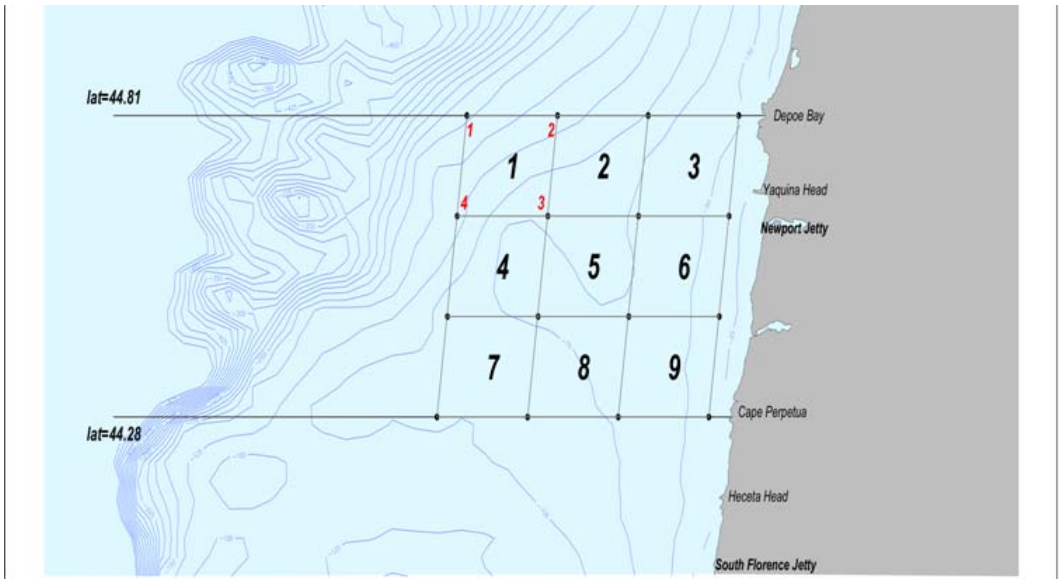

Figure 3. Two fishery-independent survey designs tested near Newport, Oregon in August 2010. a. ten transects, 20.76 miles in length, spaced at 3 mile intervals. Dots indicate locations of fish caught in 2006 (red) and 2007 (blue). b. a nine-cell grid covering the same area as the transects in a.

The first test specified ten parallel transects, each 20.76 miles long and spaced at 3-mile intervals (Figure 2a.). Boats started at the north end of their assigned transect and fished to the south. Reaction of the fishermen to this design was that this was not a normal or efficient pattern of fishing; they were not permitted to "back-tack" over areas where they caught fish, or to avoid water that showed little promise of producing fish. In response we designed a second sampling pattern based on a 9-cell (3 x 3) grid in the same area as the transects they had run previously (Figure 2b.). Nine fishermen were each assigned a grid cell, with the instruction to catch as many fish as they could within that cell. They fished their cell for one day, and fished normally for one day.

Catch rates were low during the tests, and boats fishing the survey patterns caught fewer fish than boats fishing normally. Data are being analyzed, but it is clear that the fishery-independent surveys will need to catch fish at a higher rate than we achieved in 2010 in order to provide information useful for fishery management. Experience gained with this experiment will allow us to conduct further tests more efficiently.

Hake bycatch

Chinook salmon bycatch in the shoreside hake fishery was sampled in Oregon and Washington. Approximately 850 samples were collected in 2010, compared with 166 (2009) and 450 (2008). Most of the Chinook in the hake fishery bycatch are young fish below the legal length limit for the commercial salmon fishery. The samples this year give us our first opportunity to compare stock composition in the hake fishery with a simultaneous commercial troll fishery. Once all samples for 2010 have been received by the laboratory genotyping and data analysis will begin. A report will be available by summer 2011.

Website and database development

The Pacific Fish Trax website (www.pacificfishtrax.com) is a cutting edge tool designed to meet the needs of a variety of audiences including the general public, seafood consumer, fishermen, managers, and scientists. The front-end of the website is designed to meet the needs of the general public and anyone who is interested in finding out more about where their seafood comes from and the people that bring seafood to market, from the harvester and vessel that caught the fish to the seafood processor and coastal community where it was processed. The website also incorporates a mapping function where fishery information comes alive when a barcode or unique number is entered into the website. A map shows where the seafood was caught off the west coast and other specific information about that particular fish is posted. This information can include oceanic conditions data or other information that would be of interest to consumers. The back end of the web site is designed for exchange of information between fishermen, managers and scientists individually and collectively. A system to house fishery specific data has been designed to support the front end and mapping sections of the website. Specially designed portals are used by different audiences to access the information in the database. Password protected portals for fishermen and project management has been developed—other portals are in various stages of planning and development.

The front-end of the Pacific Fish Trax database is designed to interface with the back-end of the website, which contains tools for project management and a web-accessible database designed to receive and store standardized data, allowing for efficient data sharing among project participants and user-groups. All data contained in the back-end database is password protected using levels of security access that parallel those used by financial institutions. Database standards and definitions are based on those approved by the West Coast Salmon Genetic Stock Identification (WCS-GSI) Collaboration, and were designed to be compatible with the coded-wire-tag and Genetic Analysis of Pacific Salmonids databases to the fullest extent possible. In 2010, all Project CROOS data collected from 2006 – 2009 was transferred to the PFX database and all new fisheries data collected during the 2010 season was uploaded in near real-time via port liaisons data portals.

Data analysis and presentation

The data set collected in 2010 provides an opportunity to explore new ways of looking at Chinook salmon distribution and abundance in the ocean. In our initial explorations we have continued to work at the current management scale of months and management areas. The sampling methodology used also enables a finer scale analysis, as exemplified by Robert Ireland's Master's Thesis, "The distribution and aggregation of Chinook salmon stocks on the Oregon Shelf as indicated by the commercial catch and genetics," although findings from the thesis are not presented here. There is also a manuscript in preparation for publication in a peer-reviewed journal.

Presentation of data is important because it influences the way the data are interpreted. We are introducing a basic method for displaying stock distributions using catch per unit effort (CPUE) for stock units because CPUE can provide a better representation of relative abundance than a simple stock composition pie chart. This is the technique used in Figure 2 and Figure 4 to display and contrast time- and area-specific results. Each histogram shows CPUE, computed from both retention and non-retention sampling, for 26 stock groupings, arrayed from north to south, Alaska to Central California. Colors help to isolate stocks of interest. In these graphs the upper yellow bar represents Snake River fall Chinook, the lower yellow bar is Central Valley fall Chinook. The lower red bar shows Klamath River Chinook. The vertical green bar to the left of the horizontal histogram indicates total log effort for that time and area. Effort and CPUE axes are logarithmic to facilitate display of a wide range of data values. The vertical line near the right of each histogram is at a CPUE of one fish per boat day. Most catch rates were well below this rate, while some were well above. The range displayed is 0.01 to 5.0.

There are important limitations to our presentation of CPUE data in this report. There is a strong indication that boat-day, the basic unit of effort, has a different meaning in retention and non-retention fisheries. Specifically, fewer fish were caught per boat-day in non-retention fisheries than in retention fisheries, perhaps because of the stronger incentive to fish in the retention fisheries. Additionally, non-legal size fish were sampled in non-retention fisheries, but not in retention fisheries. This could change the stock composition if non-legal size fish are behaving differently from legal size fish in the ocean. These are some of the details that need to be worked out before the data can be

interpreted rigorously. However, we are presenting several sample graphics to illustrate potential uses for these data. More nuanced analyses of these data will change the picture to some extent.

Results for the month of June are depicted in Figure 2. This figure graphically displays the areas sampled, the locations of individual sampled fish, and the reporting-group specific CPUE histograms for each area. The vertical green bars show that effort was highest in the two northern areas and lower from KMZ-OR to the south. Effort in the south was lower because it was strictly controlled by the non-retention experimental design. The stock histograms show a strong declining gradient in the number of stocks in the fishery from north to south. Catch rates of Central Valley fall Chinook (the lower yellow bar) were relatively consistent near 1 fish per boat day throughout the range, with a lower rate in the KMZ-OR and the highest rate in SF-S. Similar interpretations could be made for a variety of other stocks.

Figure 4 is a matrix of CPUE histograms arrayed by month (horizontal) and area (vertical) for the entire sampling season. This summarizes, at a glance, patterns in both space and time. First, we see that there was no sampling in May in the KMZ, and no fish identified to stock in the KMZ-OR in July. As in Figure 2, the change in stock composition from north to south is evident, and shown to be consistent over the season. Picking out a single stock, Klamath Chinook (lower red bar) were concentrated in and around the KMZ. In the SF-N and SF-S areas Klamath catch rates dropped off in August and September compared with May through July. This particular comparison is apt to be valid because fisheries in these areas were non-retention except for two short periods in July (Table 3) although the majority of sampled catch in SF-N in July came from the open fishery (Table 4). Northern fisheries had high catch rates of the abundant Mid-Columbia Tules, with rates dropping off to the south and later in the season. Most stocks from the Columbia River and north were contributors to fisheries north of the KMZ, but rarely recorded in the KMZ or south. Closer examination of Figure 4 may reveal many more patterns of interest, although strict interpretation should be limited until we understand better how to compare samples from retention and non-retention fisheries.

Changes in the distribution of individual stocks, as indexed by catch rates (CPUE), can be visualized using contour plots such as demonstrated in Figure 5. We caution against over-interpreting this figure for the reasons given above. However, there is an intriguing suggestion of a migration from the south during late summer when we expect maturing fish to be returning to the river. In the Oregon areas (NOC, SOC) catch rates were moderately high early in the season, but declined in the NOC, again corresponding with the spawning migration. With the addition of age and maturity data this kind of analysis could be used to track migration patterns of immature and mature fish separately. There was no sampling in KMZ-OR or KMZ-CA in May, and very little sampling in KMZ-OR in June or July (Table 2), partially accounting for the area of low catch rates in that region of the figure. The smoothing algorithm used tends to cause areas with high catch rates to "spill over" into areas with lower rates. The mismatch between retention fisheries, primarily in the north, and non-retention fisheries, primarily in the south, makes close interpretation of this figure impossible because stocks vulnerable to the fisheries and

CPUE both potentially differed. Notwithstanding these difficulties, the contour plot shows the possible benefits of comprehensive sampling. The “holes” show how missing data cause loss of information and difficulty of interpretation. Consistent fisheries, or an understanding of how to compare dissimilar fisheries, would also enhance the usefulness of this analytical technique.

Contour plots like Figure 5 could be used to help visualize many aspects of the data. For example, the difference between distribution maps for two stocks could be used to show areas of stock overlap and separation, leading to finer-scale strategies for stock targeting. Plots based on age or maturity could help reveal migration patterns. Overlays with charts of ocean environmental data could help discern ecological relationships or identify important marine habitat.

Application of these data to fishery management remains a challenge. The current analytical and modeling system is built around coded-wire tags, harvest and escapement estimates, and stock size predictions. From the GSI sampling in 2010 we have been able to construct a preliminary map of stock catch rates similar to those used in some fishery harvest models, and with relatively fine resolution of stocks, times and areas. Additional work is required before these data can be interpreted for fisheries management.

Results from the sampling in 2010 demonstrate some of the possibilities for use of GSI in salmon management. Maximum benefit would derive from a consistent program of coastwide sampling. The analyses and graphics presented here are early attempts at synthesizing the 2010 data set. The WCS-GSI Collaboration expects continuing conversations within the management, fishery, and science community over the usefulness of these data, the costs and benefits, and directions for future research and development.

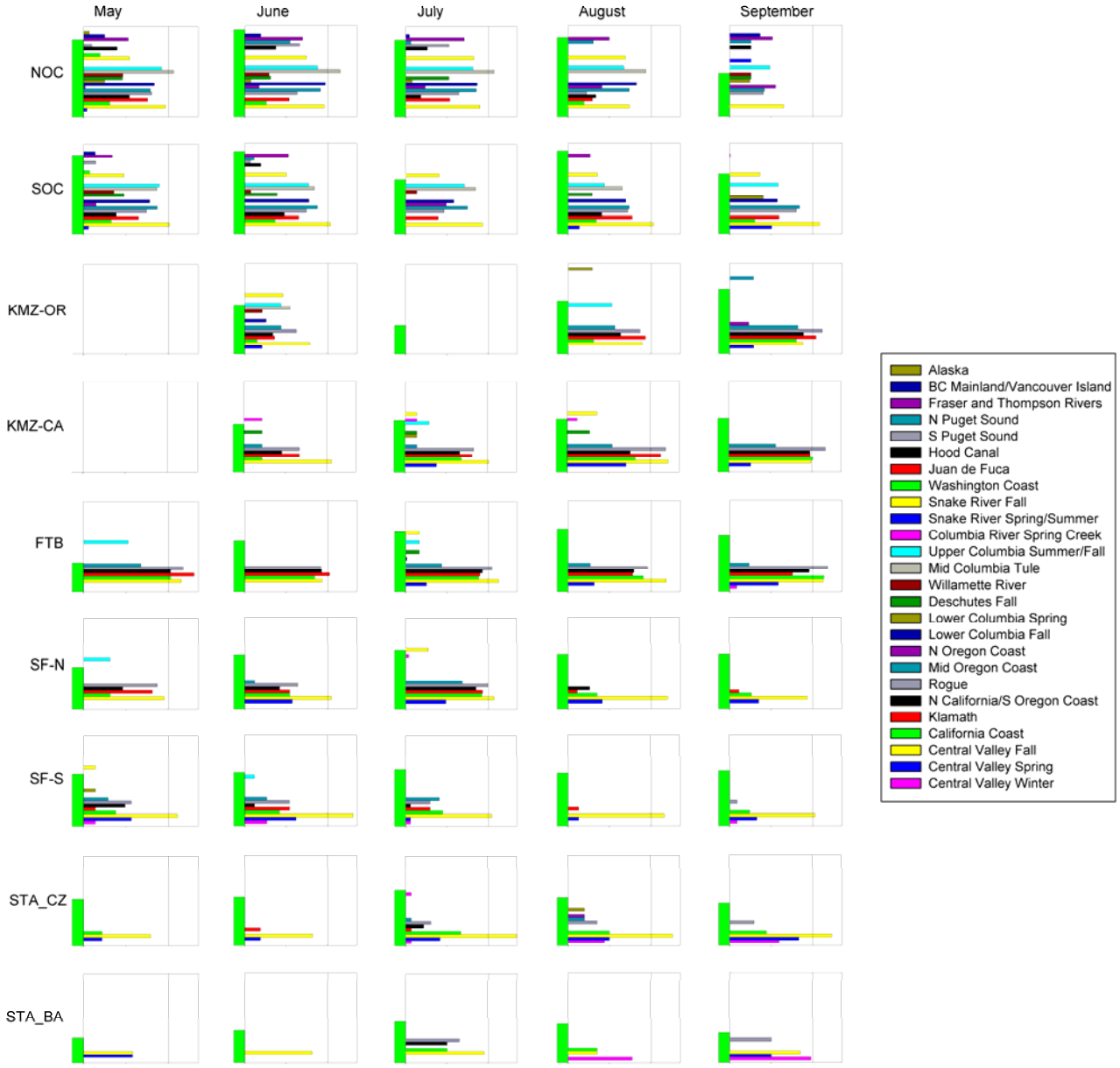

Figure 4. Catch per unit effort (boat day) by month and management area or sub-area for 26 stocks or stock groupings. Stocks are ordered north to south. CPUE scale is logarithmic; vertical line indicates one fish per boat day. Vertical green bar on left axis is log effort. NOC:North Oregon Coast; SOC:South Oregon Coast, KMZ-OR: Oregon Klamath Zone; KMZ-OR: California Klamath Zone, FTB: Fort Bragg; SF-N: San Francisco area north of Point Reyes; SF-S: San Francisco area south of Point Reyes; STA_CZ: Santa Cruz; STA_BA: Santa Barbara and Morro Bay. There was no effort in KMZ-OR or KMZ-CA in May, and sampling effort but no stocks identified in KMZ-OR in July.

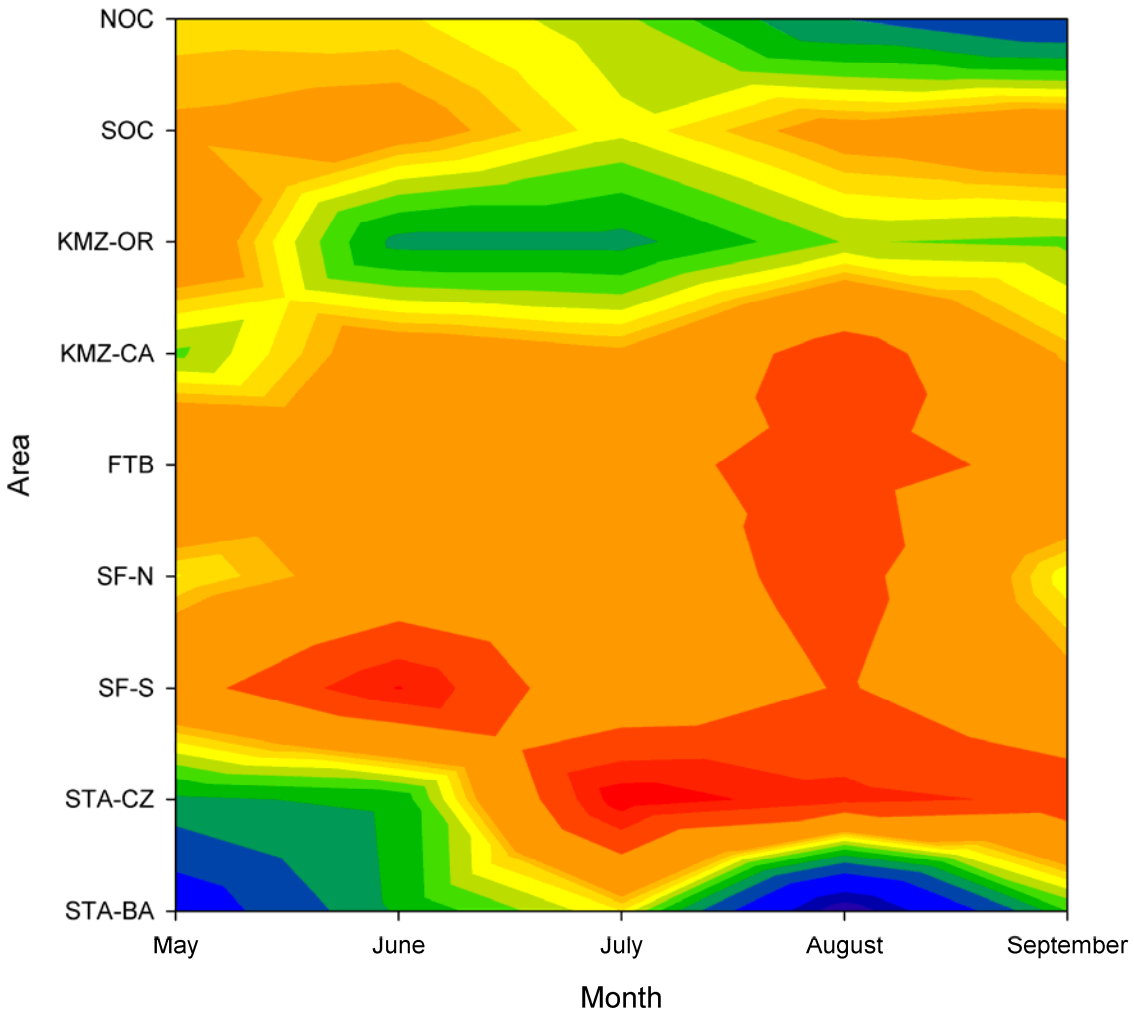

Figure 5. Filled contour plot of Central Valley Fall Chinook catch per unit effort (CPUE) by Month and Area. Color range is from blue (low) to red (high) CPUE.