

## Genetic Stock Identification Study Proposal

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The Pacific Fishery Management Council's (PFMC) Scientific and Statistical Committee previously reviewed proposals for Genetic Stock Identification (GSI) and non-retention at-sea sampling in November 2007 (Agenda item F.2.a) and March 2013 (Agenda item G.1.c). The current proposal was discussed during the Methodology Review, November 2015.

Here we propose examination of "Fine scale ocean distribution patterns of Klamath River Chinook salmon, in comparison to other stocks of interest, including the ESA-listed California Coastal Chinook." This work is funded by a 2015 Saltonstall-Kennedy grant to the California Salmon Council. The project narrative from the proposal is attached. The goal of this project, which is part of the larger West Coast Salmon Genetic Stock Identification (WCS-GSI) Project, is to improve resolution of the ocean distributions of Klamath River Chinook (KRC) and California Coastal Chinook (CCC), with emphasis on geographic differences that may be useful for developing management regulations. This will be accomplished through at-sea sampling of Chinook salmon during both normal commercial fishing activity and non-retention sampling during times and areas closed to commercial fishing. Samples will be analyzed with genetic identification and scale analysis methods to assign a stock of origin and age to each fish. Laboratory results and at-sea data (location of capture, length, etc) will be combined to produce fine-scale stock-specific distribution information that is not obtainable with current dockside sampling methods. These data will be available to develop methodology to incorporate both genetic data and fine-scale harvest data in management decisions.

The proposed project continues work from previous years (2010-2015), where data suggest 1) a late-season difference in stock distributions between the ESA-listed California Coastal stock and the Klamath River hatchery fish used as a management proxy; and 2) major distribution differences between Klamath River Chinook and Sacramento River fall run Chinook (SRFC) north and south of Point Reyes, a potential new management boundary.

Depending on the final season structure adopted by the PFMC, the WCS-GSI Project proposes targeting collection of approximately 6800 samples, including 3000 non-retention samples in closed times and areas. The exact location of non-retention sampling will be determined by management and scientific priorities, budget, and availability of sampling vessels. Table 1 is a

*draft* version of the proposed sampling plan, formulated with the understanding that the final sampling plan may be altered to accommodate the PFMC commercial season.

The fraction of Sacramento River fall Chinook encounters varies considerably by area-week and by year. We have observed stock fractions between 43-73%, with a yearly average of 54%. Fractions of CCC vary from 2-10%, with an annual average of 5%; fractions of KRC vary from 4-11%, with an annual average of 7%. At these rates we expect to observe at least a few individuals of each stock of interest in samples of 100 fish per area-month stratum.

Management zone	Port	1-31	1-18	19-30	1-14	15-31	1-13	14-29
		May	June		July		August	
OR-KMZ	Brookings		200	200	200	200	200	200
KMZ	Crescent City		100	100	100	100	100	100
	Eureka		100	100	100	100	100	100
Fort Bragg	Fort Bragg		200	200	200	200	200	200
San Francisco-N	Bodega Bay	400	200	200	200	200	200	200
San Francisco-S	San Francisco	200	100	100	100	100	100	100
	Half Moon Bay	200	100	100	100	100	100	100
Total samples		800	2000		2000		2000	
Non-retention samples		0	800		1400		800	

Table 1. Target sample sizes in numbers of fish for synoptic sampling in the Oregon and California Klamath Fishery Management Zones, south to San Francisco. Red cells are anticipated to require non-retention sampling.

*Estimated Impacts.* It is proposed to collect 3000 non-retention samples. Mortality during catch-and-release sampling is estimated at 31%, resulting in 930 mortalities. Actual mortality estimates for all stocks, including SRFC, will be provided by the STT during the PFMC 2016 salmon preseason management process.

**Project Narrative** 2014/2015 Saltonstall Kennedy (2014/15 S-K)

**Application Organization:** California Salmon Council

**Title:** Fine scale ocean distribution patterns of Klamath River Chinook salmon, in comparison to other stocks of interest, including the ESA-listed California Coastal Chinook

*Vision/ Goal*

Data from previous years (2010-2014) suggest 1) a late-season difference in stock distributions between the ESA-listed California Coastal Chinook and the Klamath River fall run Chinook used as a management proxy; and 2) major differences in the relative catch rates of Klamath River fall run Chinook and Sacramento fall run Chinook north and south of Point Reyes, a potential new management boundary. We will collect at-sea samples and associated metadata to evaluate rates of catch per unit effort on a stock-specific basis between Humbug Mountain and Pigeon Point (Klamath Management Zone in Oregon and California, Fort Bragg Management Area, San Francisco Management Area) and analyze the temporal stability of these observed differences. We will use precise capture location and depth data to produce fine-scale stock-specific distribution models which are not possible with current dockside sampling methods. These data will be available to develop methodology to incorporate both genetic identification data and fine-scale harvest data in management decisions.

*Objectives*

1. targeted sampling effort to distinguish the distributions of Klamath, Sacramento, and California Coastal Chinook stocks between Humbug Mountain and Pigeon Point
  - contract with commercial fishermen to collect at-sea samples and associated metadata during normal fishing operations
  - collect non-retention samples and data in times and areas closed to commercial fishing, as allowed by the Pacific Fishery Management Council and permitted by state enforcement agencies
  - analyze biological samples with genetic methods to assign stock of origin to individual fish
  - analyze scale samples to construct age cohorts
  - compare catch per unit effort for Klamath, Sacramento, and California Coastal Chinook stocks in each management zone (or portion thereof)
2. geographic analysis of stock distributions in the ocean fishery
  - use precise capture location and depth to generate time-series maps of stock distribution throughout the fishing season

The U.S. west coast commercial Chinook salmon (*Oncorhynchus tshawytscha*) fishery is managed on a stock-specific basis. Access to the fishery has been severely limited in the past decades due to concerns about harvest of fish from weak stocks, sometimes in years when other stocks are healthy and abundant. In 2006, commercial salmon fisheries were heavily constrained in California and Oregon to reduce harvest of Klamath River fall run Chinook (KRFC) and the Klamath Management Zone (KMZ) was closed entirely. In 2008 and 2009, nearly all Chinook fisheries south of Cape Falcon, Oregon were completely closed to meet conservation objectives for the Sacramento River fall run Chinook (SRFC). In 2010, commercial fisheries south of Point Arena were open for only eight days, again to meet conservation objectives of SRFC. In 2011, 2012, and 2014, commercial fisheries were restricted due to the U.S. Endangered Species Act (ESA) consultation standard for California Coastal Chinook (CCC) evolutionarily significant unit (ESU). In 2012-2014, commercial fisheries were restricted south of Point Arena to limit harvest of Sacramento River winter-run Chinook (PFMC 2014).

Though the specific stock of concern is not consistent, the need to understand stock distribution throughout the historical fishing season (May-September) remains. In-river and ocean conditions change from year to year, often affecting stocks differently; a stock may be abundant and productive for a number of years, then require implementation of harvest restrictions. Current fishery management strategy responds to changes in population numbers on a stock-specific basis by limiting effort in certain times and areas; this strategy inherently requires a stock-specific temporal-spatial analysis of catch data.

Previous data have shown 1) a late-season difference in stock distribution of CCC and KRFC (Satterthwaite et al. 2014); and 2) a stock composition difference north and south of Point Reyes (unpublished data). The current proposal aims to evaluate the differences observed in previous data and determine if these trends persist from year to year. Differential distributions of three stocks of salmon (KRFC, CCC, SRFC) have management implications for the commercial salmon fishery: concerns about one or more of these stocks have constrained fisheries for decades. In instances where one stock is weak but others are abundant, there is potential to direct fishing effort toward more abundant stocks. Current monitoring tools and distribution models lack the fine-scale temporal-spatial data and ability to differentiate these stocks.

#### *1) late-season difference in distribution of California Coastal and Klamath River fall run Chinook*

Since 2000, commercial and recreational fishermen in California have had limited fishing opportunity in some years due to restrictions in place to protect the California Coastal Chinook ESU. Low returns of naturally spawning fish to rivers in the spawning range of this ESU (e.g., the Eel and Russian rivers) prompted the National Marine Fisheries Service (NMFS) to list the CCC ESU as Threatened under the ESA in 1999, requiring that the best available science be used to protect them. Current estimates of abundance and harvest of Pacific salmon are based on dockside recovery of coded wire tags (CWTs) which are inserted into snouts of juvenile fish before they leave hatcheries. Unfortunately, naturally spawning fish, such as the entire CCC ESU, are largely untagged; management relies on the tagged KRFC hatchery fish as a proxy. "Information on abundance and productivity trends for the naturally spawning component of the CC Chinook salmon ESU is extremely limited" (NMFS 2007). Even less is known about the geographic and temporal distribution of CCC fish as they mix in the ocean with salmon of other,

more abundant, stocks. CCC salmon are not the target of the Pacific commercial salmon fishery, but are intermixed with other stocks, including the historically abundant SRFC, and are harvested as bycatch. This bycatch is limited through an ESA consultation standard that sets the maximum age-4 ocean harvest of KRFC at 16% (NMFS 2000, KRTAT 2002).

Though CCC fish are not coded wire tagged, they are easily distinguished from KRFC with genetic methods. Genetic stock identification (GSI) is capable of assigning stock of origin to all fish, not just those fish which have CWTs inserted at the hatchery.

Differences in estimated KRFC and CCC ocean spatial distributions have been identified from an analysis of contacts per unit effort (CPUE) based on GSI data from 2010 and 2011. Satterthwaite et al. (2014) found that CPUE (in this case, fish per hour) were similarly distributed for KRFC and CCC early in the fishing season (analysis possible only in 2010), but later in the season (July or August) were relatively higher for CCC in the Fort Bragg Management Area and for KRFC in the KMZ (this pattern held qualitatively in both 2010 and 2011). The comparison was confounded by the closure to commercial fishing of the area between Humboldt South Jetty and Horse Mountain since the early 1990s, largely for the purpose of protecting CCC populations. Figure 1 shows monthly CPUE ratios for KRFC and CCC.

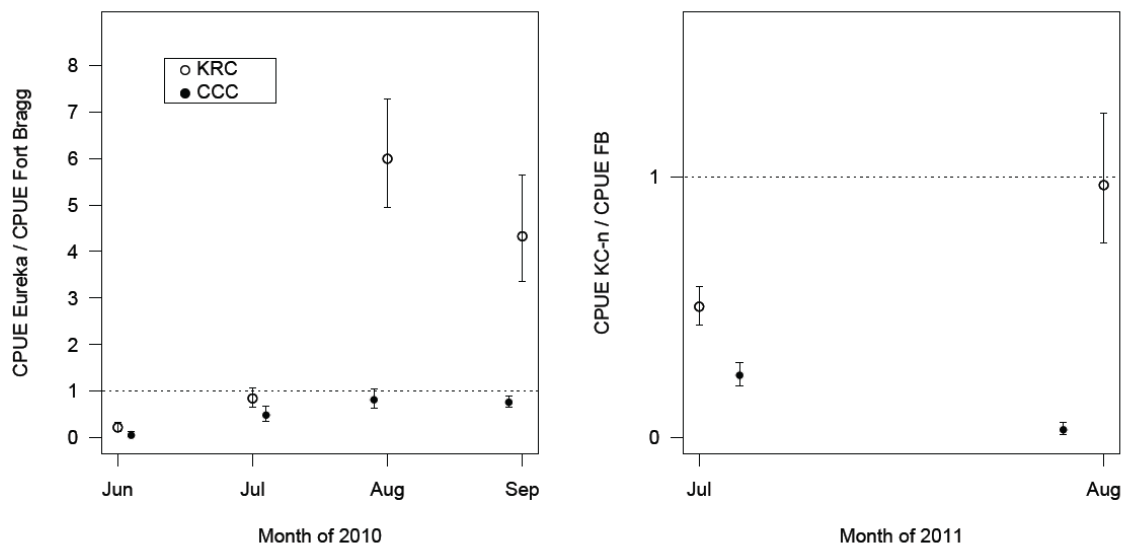


Figure 1. Monthly CPUE ratios for the Klamath Management Zone and Fort Bragg Management Area. Circles are posterior medians, error bars are 68% credible intervals.

If this pattern proves consistent from year to year, a more effective management strategy could allow greater harvest of the abundant KRFC while simultaneously protecting CCC fish. This strategy would be a drastic change from the current management technique of avoiding KRFC in order to protect CCC.

## 2) catch rate difference north and south of Point Reyes

The San Francisco Management Area spans Point Arena to Pigeon Point, CA, a distance of over 100 nautical miles. Point Reyes is approximately equidistant between Point Arena and Pigeon Point and has been proposed as a potential new management boundary. A management boundary at Point Reyes would allow harvest in waters of one portion while fishing is restricted in the other. Current management strategies consider the entire region from Point Arena to Pigeon Point as a single unit. There is evidence that relative catch composition differs north and south of Point Reyes (Table 1), which is not surprising considering the relative location of the Klamath and Sacramento river mouths. We expect higher ocean abundance of KRFC north of Point Reyes than south of Point Reyes.

Particularly in years when KRFC constrain salmon fisheries (2007, 2014, for example), disparate regulations north and south of Point Reyes would allow sustainable harvest of SRFC in the southern portion while achieving conservation goals for KRFC.

GSI and CWT data from past years (2010-2014) show differences in the stock composition of the commercial Chinook fishery north and south of Point Reyes during some times of the year. Comparisons of stock-specific CPUE indicate that KRFC are a larger component of the fishery north of Point Reyes than they are south of Point Reyes. Table 1 shows the CPUE of KRFC and SRFC north and south of Point Reyes, within the San Francisco Management Area for each year 2010-2014. Relative catch contributions are calculated as ratios of SRFC to KRFC, i.e., north of Point Reyes in 2010, 4.8 times as many SRFC fish were sampled as compared to KRFC. The ratio of SRFC to KRFC is higher to the south of Point Reyes than it is to the north in all years except 2013.

### Catch per unit effort (fish per hour)

	2010	2011	2012	2013	2014
<b>SF-N (Point Arena to Point Reyes)</b>					
Klamath	0.05	0.03	0.15	0.06	0.06
Sacramento fall	0.26	0.73	1.33	0.99	0.97
Relative catch contribution	4.8	26.7	8.9	15.7	15.2
<b>SF-S (Point Reyes to Pigeon Point)</b>					
Klamath	0.008	0.002	0.12	0.05	0.01
Sacramento fall	0.41	0.66	1.33	0.67	0.86
Relative catch contribution	50.8	326.0	11.4	14.2	76.2

Table 1. Catch per unit effort north and south of Point Reyes within the San Francisco Management Area. Relative catch contribution is a ratio of CPUE (Sacramento:Klamath).

In addition to fine-scale latitude differences in catch ratios, previous data have shown dissimilarity in the bottom depth of capture location between SRFC, KRFC, and CCC stocks (unpublished data). These stocks, together with some stocks from the Columbia River, show distinct responses to bathymetry, with clear probability maxima for bottom depths between 200-500 meters. Reasons for these distinctive spatial patterns are unclear, but might reflect different feeding strategies. These results suggest that Chinook stocks may be fished selectively, for example, restricting fishing to certain depths to decrease pressure on weak stocks.

Current dockside sampling records location of capture by management area, as reported in fishermen interviews; in the case of the San Francisco Management Area, all fish caught between Point Arena and Pigeon Point are analyzed as a single geographic component. In contrast, at-sea sampling by the commercial salmon fleet provides exact date-time stamps, GPS locations of capture, and depth information. Data from samples collected at sea more precisely identify geographic and temporal concentrations of fish in the ocean during exposure to the commercial fishery.

Genetic methods provide stock of origin data for all fish independently of CWTs, including naturally spawning fish. At-sea sampling methods produce fine-scale geographic and depth data; combined with stock identity and age information derived from laboratory analyses, we can produce high-resolution geographic and temporal maps of age-specific stock distribution. Figure 3 shows examples of high-resolution maps identifying stock-specific catch probabilities in 2010-2012. Our current data are insufficient to calculate time-series of catch probabilities throughout the fishing season or to conduct rigorous comparisons of stocks. The work proposed here will address this information gap by sampling in geographic areas where more data are needed, refine sampling methods to obtain data that are more representative of the commercial fishery, and construct cohort-specific data for sampled fish. Improved stock differentiation and increased temporal-spatial precision have potential to refine current management methods.

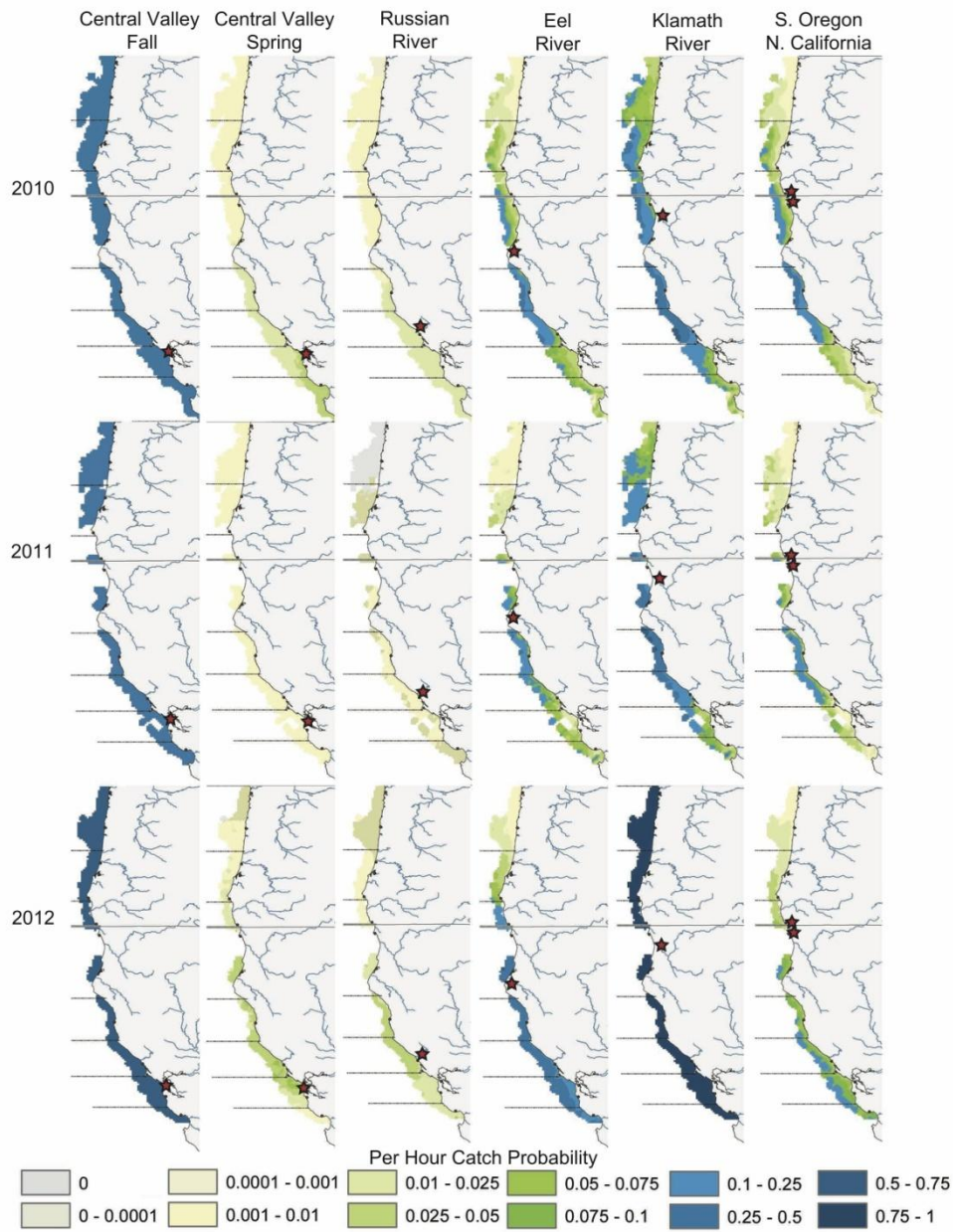


Figure 3. Probability of catch in 2010-2012. Values are model outputs and do not correspond directly to catch per unit effort. Stars represent point of ocean entry for each stock.



## 1. Project goals and objectives

### *Program priority*

As outlined in Saltonstall Kennedy Grant Program Theme #2.A, this project will improve the cost effectiveness, accuracy, timeliness, and methods for the collection, reporting, and dissemination of fishery-dependent data; provide advanced sampling techniques to improve data collection in otherwise inaccessible habitats, and improve current stock assessments by refining estimates of population dynamics; and improve current sampling methods for fisheries not included in existing surveys. As outlined in Theme #3.B, this project will improve stock definitions and understanding of stock boundaries.

The primary focus of the proposed work is an evaluation of the distribution of Klamath River fall Chinook in the KMZ (California and Oregon), Fort Bragg, and San Francisco Management Areas. Preliminary data from 2010 and 2011 indicate a late-season difference in stock distribution of KRFC and CCC in the KMZ and Fort Bragg Management Area. Major stock distribution differences have also been identified north and south of Point Reyes, and in shallower and deeper water. Data from this proposal will be combined with previous datasets to determine whether the observed patterns in stock distributions are sufficiently stable for 1) a reevaluation of the use of the KRFC as a proxy for CCC stocks; and 2) the division of the large San Francisco Management Area into smaller zones, allowing harvest regulations to be implemented which will reduce impacts on ESA-listed and other conservation stocks and increase harvest opportunity on the more productive stocks.

This project will utilize at-sea sampling techniques and genetic methods to investigate the distribution of KRFC in comparison to other stocks in the west coast commercial salmon fishery. Specifically, we will 1) collect samples and associated metadata at sea during normal commercial fishing operations; 2) use non-retention sampling methods in times and areas closed to commercial fishing; 3) analyze tissue samples to determine the stock-specific catch per unit effort throughout the fishing season; 4) analyze scales to construct age cohorts; and 5) analyze precise capture locations and depths to characterize fish aggregations, stock distributions, and boundaries in relation to management boundaries.

### *1) collect samples and associated metadata at sea during normal commercial fishing operations*

The optimal strategy is synoptic sampling of the areas managed as commercial fisheries by the Pacific Fishery Management Council (PFMC) during the primary period when adult fish are present and fisheries were historically open (May-September). However, such a project is very costly and exceeds available resources. As such, the primary goal of the proposed project is to evaluate specific areas where significant changes in fishery management may be possible with several years of additional data.

The sampling target is 100 fish per week in each fishery management area or portion thereof, a potential target of 2,100 fish sampled in each area during this 21 week period in each year. Sampling areas are KMZ-OR, KMZ-CA, Fort Bragg Management Area, SF-N (Point Arena to Point Reyes, and SF-S (Point Reyes to Pigeon Point).

Sampling in open times and areas will begin on May 1, 2016. Though the season structure is not yet determined by PFMC, we anticipate the Fort Bragg, SF-N, and SF-S areas to be open for

large portions of the period May-September. Sampling effort and analysis will be scaled up or down in each management area to match available resources and season restrictions. We expect approximately 6,800 samples in May-August, 2016 (Table 2).

Management zone	Port	May	June		July		August		September	
OR-KMZ	Brookings		200	200	200	200	200	200		
KMZ	Crescent City		100	100	100	100	100	100		
	Eureka		100	100	100	100	100	100		
Fort Bragg	Fort Bragg		200	200	200	200	200	200		
San Francisco-N	Bodega Bay	400	200	200	200	200	200	200		
San Francisco-S	San Francisco	200	100	100	100	100	100	100		
	Half Moon Bay	200	100	100	100	100	100	100		
<b>Total samples</b>		<b>800</b>	<b>2000</b>		<b>2000</b>		<b>2000</b>		<b>0</b>	

Table 2. Sample targets for each major port in the study area. Red cells denote anticipated closed times and areas, based on season structure for the past 3 commercial seasons. Green cells denote anticipated open times and areas.

We will contract with commercial fishermen to collect samples and associated metadata during normal fishing operations. Each major port within the sampling region will have a local representative to train samplers, receive samples and data, enter data for retrieval by laboratory staff, and deliver samples to the laboratory. Samples and data should be delivered to port representatives within 3-5 days of collection.

*2) use non-retention sampling methods in times and areas closed to commercial fishing;*

To further evaluate the relative differences in catch contribution of KRFC and CCC in the KMZ, we must necessarily collect samples in the KMZ, an area which has been largely closed to commercial fishing for the past decade. We anticipate both the CA and OR sections of the KMZ to be closed for at least a portion of the 2016 fishing season. We have developed non-retention sampling methods for collection of tissue samples, scales, and associated metadata. Sampling in closed times and areas will begin on May 1, 2016. We expect 2,400 non-retention samples in May-August, 2016.

*3) analyze tissue samples to determine the stock-specific catch per unit effort throughout the fishing season*

Genetic stock identification allows most stocks of Chinook salmon to be readily distinguished by laboratory analysis of small fin clips that are stored on blotter paper at room temperature. DNA is extracted from the fin clip and genotyped with a set of single nucleotide polymorphism (SNP) markers for which a large number of fish of known origin have also been genotyped (Clemento et al. 2014). These genotypes serve as the baseline reference database, and the fish of unknown origin is assigned to one of the populations in the baseline database, if it is present, using a maximum likelihood algorithm. This baseline is designed specifically for use in estimating stock composition in PFMC-managed fisheries. The SNP markers are both cheaper and faster to assay than the microsatellite methods used in the past 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. Scientific partners have 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, as GSI can not accurately identify a fish that comes from an unrepresented stock. This baseline also has a method for identifying non-Chinook salmon, which are occasionally sampled in error.

Catch per unit effort is an indicator of local abundance, calculated as the number of legal-sized fish caught per hour. CPUE is stratified by month and area, as appropriate. Fish that are caught in retention fisheries but not sampled are included in effort calculations even though genetic and age data are unavailable, i.e., stock-specific CPUE is adjusted to include all fish regardless of whether or not they are sampled.

#### *4) scale aging analysis to construct cohort-specific data*

Circuli patterns on scales will be used to determine the age of Chinook salmon sampled with retention and non-retention methods.

We are in negotiation with both the California Department of Fish and Wildlife (CDFW) Ocean Salmon Project (OSP) and the Oregon Department of Fish and Wildlife (ODFW) to process and analyze scales for age determination. Scales will be analyzed only after stock of origin is determined; only those scales from fish of stocks of interest (KRFC, CCC, SRFC) will be assessed for age.

Scales will be delivered to the appropriate agency as they are collected throughout the season. Age data are anticipated by April, 2017.

#### *5) analyze precise capture locations and depths to characterize fish aggregations, stock distributions, and boundaries in relation to management boundaries*

We will map concentrations of Chinook salmon with respect to their stock of origin, age, size, and depth of capture. These models and visualizations will be available to state, regional, and federal fisheries managers for incorporation into management as a new tool for reducing bycatch of threatened Chinook salmon stocks in the mixed-ocean commercial salmon fishery.

An at-sea sampling scheme that is representative of the entire commercial fishery is difficult to achieve. Sample sizes are necessarily small due to budget and equipment limitations. We do not obtain a truly random sample because not all fishermen are eager to participate. Fishermen have competing economic interests; they may switch fisheries or, alternatively, increase sampling effort when salmon are less abundant in an effort to ensure income stability. It is unclear how well GSI data collected during non-retention sampling represents the harvest stock compositions that result from normal, retention fishing (O'Farrell et al. 2012). In lieu of a sampling scheme that strictly represents the entire commercial fishery, we will coordinate with the California and Oregon Departments of Fish and Wildlife to compare genetic datasets to total commercial landings. Despite differences in geographic precision (at-sea samples have precise latitude, longitude, and depth information; dockside samples are associated with a management zone only), genetic data can be better understood within the context of total harvest. Currently, we account for total catch of sampling vessels, but do not consider total catch of the larger fleet.

We will work to incorporate these distribution models into current management schemes. GSI can assign stock of origin to all fish regardless of CWT implantation (naturally spawning CCC fish, for example) within the ocean harvest, but estimates of total ocean harvest will require rigorous sampling methods to represent the entire fishery or statistical methods to scale genetic data to total landings.

*previous work*

In 2006 and 2007, the states of California, Oregon, and Washington implemented pilot projects to explore the application of GSI to salmon management. Saltonstall Kennedy (S-K) grant number NA08NMF4270421 (see Supporting Documentation) was awarded to fund collection and analysis of at-sea samples in 2008, but the commercial Chinook fishery was closed, even to non-retention sampling, until 2010 due to concerns for the SRFC run meeting conservation objectives. Accordingly, data collection was delayed until 2010.

Goals of the prior S-K-funded project were to 1) determine the distribution of Klamath River Chinook (KRFC) and other Chinook stocks in times and areas closed to salmon commercial fishing due to restrictions on ocean harvest of Klamath River Fall Chinook and ESA-listed stocks, including some times and areas that have been closed for over 20 years; 2) provide information that may allow fishery managers to design fisheries that provide greater harvest of strong (abundant) stocks while limiting weak stock impacts to ensure compliance with allowable fishery impacts on weak stocks; and 3) establish a uniting collaborative process among fishermen, scientists, and fisheries managers on the U.S. west coast by working together to achieve goals and objectives.

We contracted over 330 commercial fishermen on 174 vessels to collect data in California and Oregon. Vessel operators and associated crew on 86 vessels in California and 88 vessels in Oregon participated in 2683 days of retention and non-retention sampling. A total of 9,603 fish were sampled from May through September, 2010. Scientific partners analyzed over 8,900 tissue samples with genetic methods for stock of origin; state management partners analyzed over 8,300 scale samples for age.

We developed a basic method for displaying stock distributions using catch per unit effort for each stock of interest because CPUE provides better representation of relative local abundance than stock composition estimates which are unscaled for fishing effort or total catch. We explored a number of alternatives for presentation of fishery information, several of which were incorporated into user portals on the Pacific Fish Trax (PFX) website. The PFX portals query a secure online database which was used as a data repository for at-sea data, individual fish stock assignments, and raw microsatellite genetic data for Oregon.

Further details of the results from the prior Saltonstall Kennedy grant can be found in the final report (see Supporting Documentation).

As a continuation of the work in the prior Saltonstall Kennedy award, we will continue data collection efforts to address geographic areas where data are sparse or nonexistent, specifically the KMZ in CA and OR, refine sampling methods to be more representative of total harvest of the commercial fleet, and construct age cohorts for sampled fish. Our ultimate goal is to

incorporate GSI data into current fishery management schemes through improved technology and outreach to all stakeholders. Data from the work described in this proposal will be combined with data from previous years to determine whether the observed pattern in stock distributions is sufficiently stable to support a change in management strategy for conservation of the CCC ESU and/or implement a new management boundary at Point Reyes.

## 2. Project impacts

### *Fishing community cooperation and participation*

This project directly engages fishermen in data collection activities and the management process. Rather than a top-down approach to managing fisheries, commercial salmon fishermen are active partners in project design, sampling methodology improvements, and data collection and management.

### *Increased fishing opportunities*

To protect the weakest salmon stocks, fisheries managers are often compelled to institute closures over large areas and time periods. Inferences about relative local abundance can reduce uncertainty in the use of indicator stocks for conservation and fishery management. Reduced uncertainty potentially can lead to reduced precautionary harvest restrictions and increased fishing opportunities. With increased understanding of stock distribution, we may be able to more finely direct fishing opportunity to places where weak stocks are less prevalent. One method for directing fishing effort might be the use of new management boundaries (i.e., Point Reyes).

### *Fine scale stock distribution model*

Samples collected at sea are accompanied by a date-time stamped GPS location and recorded depth of capture. In contrast, dockside sampling is not able to record exact harvest location or depth. Current dockside sampling methods capture harvest location on the scale of the management zone, as reported in fishermen interviews, and port of landing. The current monitoring techniques analyze CWTs collected dockside and do not take into account the precise geographic location or depth of harvest. We will incorporate precise geographic data into a rigorous analysis of stock distribution in the ocean fishery.

### *Reduced bycatch of ESA-listed stocks*

Though ESA-listed Chinook stocks are the same species as the target of commercial fisheries, they are managed as bycatch. Use of more accurate and precise management tools will allow for access to the commercial salmon fishery while simultaneously protecting the stocks of concern. Though very little information is available for the CCC ESU, it is ESA-listed and therefore not considered healthy. More precise management tools have the potential to target decreased harvest of stocks of concern, rather than decreased harvest of proxy stocks, which may or may not have the desired result.

We also may identify hitherto unrecognized conservation concerns and move to address them. While such action may result in short-term fishing limitations, allowing stocks to recover will increase and stabilize future fishing opportunities.

### *Near real-time management information*

GSI is capable of producing catch composition estimates within days of sample collection. CWTs, on the other hand, do not produce usable datasets while the fishery is open. While we have not yet been able to produce GSI results in real-time, we are decreasing processing time and improving communication networks in order to inform fishermen and managers of catch composition within a week of harvest.

### *Development of fishery-independent techniques*

While this project focuses on sampling the U.S. west coast commercial Chinook fishery, the methods can be adapted to a wide variety of fisheries in other locations. We do not attempt to extrapolate these data to be representative of the recreational fishery which has daily limits and more spatiotemporal coverage along the coast, but these methods are easily adaptable to the recreational salmon fishery.

### 3. Evaluation of project

We will collect and analyze sufficient samples to create stock-specific distribution maps of the commercial salmon harvest between Humbug Mountain and Pigeon Point. We will provide an accounting of contracted fishermen, sampled areas, numbers of samples collected, and age and genetic results. We will provide maps of distributions and summaries of catch compositions, distribution of effort and catch, and standardized distributions of stocks of interest including KRFC, CCC, and SRFC. An indicator of success will be the degree to which genetic results, scale age data, and meta-data are incorporated in analytic and visualization tools available to fishermen, managers, and the general public via the Pacific Fish Trax website.

We will test the hypothesis that the observed distribution differences of KRFC and CCC are stable over multiple seasons. We will continue to analyze the stock composition differences of KRFC and SRFC north and south of Point Reyes. An indicator of success will be creation of a statistical analysis of these patterns and successful collaboration with fisheries managers to develop a sampling scheme with both dockside and at-sea methods that represents landings of the entire commercial fishery.

Success will also be judged by the continued acceptance of the concepts embodied in the project and the cooperation and support of fishermen, managers, scientists, and the general public. Expected products from this project include 1) a database of effort, catch locations, stock identifications, and ancillary data for analysis; 2) synthesized and summarized final report to the granting agency; 4) presentations to local fishermen's organizations; 5) technical presentations to scientific and management meetings; and 6) technical white papers and memoranda for use in management.

### 4. Need for government financial assistance

In California, sampling has been supported by disaster relief funds (2010-2012), S-K funds (2010-2011, see details in section 1 above), and NOAA Cooperative Fisheries Research funds (2012-2014).

In Oregon, sampling has been supported by Oregon Watershed Enhancement Board (2006-2007), disaster relief funds (2008-2011), special federal grant appropriations (2008-2010), S-K Funds (2010-2011), and NOAA Cooperative Fisheries Research funds (2010-2014).

This project is currently unfunded for the 2015 and 2016 commercial fishing seasons. We are seeking \$184,000 in Cooperative Fisheries Research funds from NMFS for California and ~\$200,000 for Oregon and Washington. If awarded, these funds will assist in the collection of data and samples between Point Arena and Pigeon Point (Fort Bragg and San Francisco Management Areas) when those areas are open in 2015. Sampling closed areas is difficult and expensive due to regulatory requirements and the need to compensate fishermen fully for their time and cost of operation. At the same time, there is a need for comprehensive distribution information that includes both open and closed areas. Funds from this proposed project will be used to sample closed times and areas in 2016 to augment the sampling from open areas.

#### 5. Federal, state, and local government activities and permits

Data and sample collection during open fishing season will require no additional permits.

Samples will be collected during normal fishing activities after fish are harvested under standard commercial permits.

Data and samples that are collected in times and areas closed to commercial fishing will require both federal and state permits, including a Scientific Research Permit from NOAA National Marine Fisheries Service, a Scientific Collecting Permit from CDFW, a Scientific Taking Permit from ODFW, and an incidental take permit from the International Pacific Halibut Commission (IPHC). We have precedence and experience in acquiring the federal and state permits necessary to conduct this sampling. Please see Supporting Documentation for copies of prior permits.

Licensed commercial fishermen will contract with the respective state representatives to collect samples under the appropriate permits issued by NOAA, CDFG, ODFW, and IPHC.

#### 6. Project work plan

##### a) project design

##### *at-sea sampling*

When the commercial season is open, samples are collected during normal fishing activities by the commercial salmon fleet. See Table 2 for details on sample targets. Handheld GPS units are turned on when gear is set in the water and set to record track marks of effort every five minutes. After fish are landed on the boat, fishermen record a waypoint on handheld GPS units. All fish, regardless of whether or not they are sampled, are recorded on the GPS units. In order to distribute sampling effort evenly over the season, fishermen are limited in the number of samples collected each day, week, and month. Only legal Chinook salmon are sampled. Coho salmon and sub-legal fish are not sampled.

Fishermen are trained to collect a small piece of tissue from any fin except the adipose fin and 8-10 scales from the key area of the fish. Tissue samples are stored on blotter paper and scales are stored on wax paper. Both are dried as quickly as possible and stored at ambient temperature. Samples are placed in an envelope with data fields for GPS data point (generated by GPS unit),

length of fish (measured in mm), hatchery marks (presence of adipose fin), and depth of capture estimate (gear depth estimated in fathoms).

#### *non-retention sampling methods*

During closed times and areas, fishermen are trained to collect tissue and scale samples, as well as associated at-sea data, with non-lethal fishing methods. In order to minimize mortality to fish, all fish are brought aboard using a shallow, knotless net. Each vessel is required to have at least two people on board to minimize damage to the fish and time spent out of the water. Fish are released immediately after sampling, after approximately one minute out of the water.

Sample collection and handling is identical to normal, retention sampling described above. Only legal Chinook salmon are targeted for sampling. Because measurements are not collected until the fish is aboard, however, fishermen are instructed to collect samples from fish that appear to be legal. Sub-legal fish are later removed from analyses. Coho salmon are not sampled. As required in the commercial fishery, all hooks are barbless to allow easy removal.

#### *Laboratory genetic analysis*

Tissue samples will be shipped by Priority Mail to the University of California Santa Cruz Marine Sciences Campus, where project collaborators will catalogue them and separate scale samples for delivery to the appropriate scale aging laboratory. Tissue samples will then be digested in a protease digestion buffer and DNA extracted using silica membrane-based plates with DNEasy 96 Tissue Kits following the manufacturer's protocols. Purified genomic DNA will then be arrayed into 96- well plates for high throughput SNP genotyping. Genotypes will then be collected from 96 SNP loci using 96.96 Dynamic SNP Genotyping Arrays™ with an EP1 system (Fluidigm Corporation, South San Francisco, CA) according to the manufacturer's protocols. Genotypes were called using the Fluidigm SNP Genotyping Analysis Software (version 2.1.1). This panel of SNP markers included 95 loci specific for Chinook salmon and one for identification of coho salmon (see Clemento et al. 2014 for SNP marker details).

#### *Genetic stock assignment*

Genetic stock identification (GSI) analysis will be performed with the *gsi\_sim* software and using the method described in Anderson et al. (2008). A baseline reference database that includes SNP genotypes of 8,031 fish from 69 populations grouped in 38 reporting units (units are generally composed of multiple populations that are genetically similar or are subject to similar management regimes) from Alaska, British Columbia, Washington, Oregon, and California (Clemento et al. 2011). Coho salmon are occasionally misidentified as Chinook salmon in fisheries and ecological sampling and the baseline includes both the diagnostic SNP marker mentioned above and genotype data from a collection of 47 coho salmon from California to identify coho salmon (Clemento et al. 2014). We will employ the simulation-based method for defining low-confidence individual assignments described by Clemento et al. (2014), with such assignments defined as those that have a z-score of the distribution of simulated genotypes of  $< -3.0$  and either a reporting unit posterior probability  $< 0.9$  or fewer than 90 loci successfully genotyped.



### *Scale age analysis*

Scales are delivered on wax paper, at ambient temperature (Nicholas and Van Dyke 1982). We will preferentially select scales from the KRFC, CCC, and SRFC stocks, as these stocks are the most relevant to current management and conservation priorities.

Scales will be analyzed with contemporary mounting, digital imaging and digital reading techniques. For each sample, approximately 5-10 scales are cleaned and mounted onto a glass slide. Each slide is examined and the best 2-3 scales are digitally imaged using an Olympus Colorview IIIu camera coupled to a transmitted light microscope and Olympus analysis FIVE imaging software. Scale images are randomly sorted into stock-specific reading assignments to reduce reader error associated with reading scales from salmon stocks with varying life history types. CDFW OSP has found that reading scales concurrently from different salmon stocks (specifically run-type) within the Central Valley increases reader error.

Scale samples are read by a single experienced reader and field length data are only taken into consideration after the initial determination of age by the reader. Flain and Glova (1988) demonstrated that aging scales by an individual experienced reader can be more accurate than aging scales using multiple readers. Individual ages are determined from scales by counting winter annuli, a standard method for scale aging of Pacific salmon (Bugaev 2004). Annuli can be identified as bands of closely spaced or broken circuli. Age compositions are based on direct counts of winter annuli. Age assignments for SRFC and KRFC samples collected in September are not adjusted to reflect the use of September 1 as the “birth date” for these stocks in west coast ocean harvest models.

When available, known-age scales from CWT and/or parentage based tagging samples will be added to reading assignments to evaluate reader accuracy and potentially correct for bias; bias will be corrected using a modified maximum likelihood estimator (MLE) based on Kimura and Chikuni (1987). These scales will be collected from adipose fin-clipped salmon containing CWTs observed during dockside monitoring of commercial salmon fisheries and/or fish returning to hatcheries.

### *Catch per unit effort statistics*

The GSI-derived stock identity results will provide distribution data on all the reporting groups in the baseline reference database that are encountered in the fisheries, and when coupled with the scale-age results will provide stock-age-time-area-specific encounter data. The number of encounters will then be standardized (divided) by the associated sampling effort to yield CPUE. To calculate stock-specific CPUE, the effort denominator is adjusted to account for all fish caught on the sampling vessel each day in each management zone. Each fish has a proportion of effort assigned to it, calculated as the fraction of time required to catch it.

### *Spatial distribution analysis*

Normalizing the area-specific CPUE estimates for each stock, age, and time period estimates the respective distributional coefficients (fraction of the coast-wide age stock susceptible to fisheries in that time and area). It is not necessary to know the stock-age (cohort) ocean-wide abundance to estimate these coefficients because CPUE is normalized and coefficients refer to the same cohort in the same time period. Nonuniformity of the estimated distributional coefficients would

reflect a non-uniform distribution of the stock over the area, as well as the associated sampling and/or measurement error contained in these data. Relative density does not translate directly into numbers in each management area without accounting for catchability, unfished areas, or the possibility that effort and fish are distributed differently within the fished area. Spatial variation in catchability could also be problematic. Nevertheless, if fishermen are efficient samplers of the underlying fish abundance (i.e., no aggregations of fish go unexploited for long, and within management areas effort is well targeted toward areas with fish), we expect our distribution estimates to provide a good approximation of how the density of each stock varies through space (Satterthwaite et al. 2013).

Where possible, the estimated distributions will be compared with those derived from the CWT database.

The NEPA Questionnaire is attached in Supporting Documentation.

#### b) Roles and responsibilities

Sampling will be conducted by California and Oregon commercial fishermen contracted with the California Salmon Council and Oregon Salmon Commission, respectively. Each state will contract with local liaisons in each major fishing port, as well as a coast-wide fleet manager to coordinate sample delivery, data entry, payments to fishermen, etc. Fishermen coordinate with local port liaisons to meet sampling targets, submit samples and at-sea data, and maintain sampling equipment. Port liaisons will be in daily contact with a fleet manager who will monitor progress towards sampling targets, communicate results to the fleet and the public, and coordinate with laboratory personnel.

Genetic analysis will be conducted at the UCSC/NOAA Cooperative Institute laboratory where the set of SNP genetic markers and baseline database were developed.

We are currently in negotiation with both CDFW and ODFW to process and analyze scales for age data. Both state agencies have extensive experience imaging and reading scales collected inland, dockside and at sea.

We have established working relationships with the commercial salmon fleet, the laboratory performing genetic analysis, and two scale-aging laboratories. Sampling equipment will be available to the sampling fleet upon announcement of the commercial season structure in mid-April 2015, prior to the start of the grant period.

#### c) Data Sharing Plan

Though this project will not generate any environmental data, data sharing plans are being drafted for all at-sea data, genetic assignments, and scale analysis.

At-sea data, including catch, fishing effort, and fish biology, will be shared immediately with all collaborators via an online data management system accessed by project participants (<https://fp.pacificfishtrax.org>). Stock assignments and age data will be uploaded electronically as soon as they are verified by respective laboratory staff.

The Pacific Fish Trax website is currently configured to accept data entry from local port liaisons and lab staff. Associated at-sea metadata are visible to samplers immediately upon data entry (within several days). Genetic stock assignments are posted to PFX as they become available (within 2 months of sample collection). Fishermen have full access to the data from their samples, but data from other boats are visible only in aggregated formats. In order to protect privacy and business practices of commercial fishermen, data are visible only when grouped with at least two additional vessels.

d) Major products/deliverables and dissemination of results

We are submitting a separate proposal for funds to continue development of the PFX website into a comprehensive fisheries informatics system. Within the existing framework, we will incorporate new data sources, analytical capabilities, and improved usability. The PFX platform will enable secure data sharing between project partners, maintain privacy of sampling vessels, and develop tools for scientists as well as the general public to explore fisheries and oceanographic data with map-based visualizations.

e) Project milestones

In month 1 of the project (January 2016), David Goldenberg and Nancy Fitzpatrick will negotiate with CDFW, ODFW, and other appropriate scale aging laboratories to collaborate on scale aging work and sharing of CWT and GSI datasets.

In months 3 and 4, various members of the team will attend and participate in PFMC meetings, where the commercial salmon will be negotiated and disseminated.

In month 4, pending the publication of the commercial salmon season regulations, Sarah Bates, Carlos Garza, Pete Lawson, and Nancy Fitzpatrick will obtain necessary permits from NOAA, CDFW, and ODFW for collection of non-retention samples. Sarah Bates and Michael O'Farrell will also finalize the sampling plan; David Goldenberg will solicit fleet participation via mail, and contract with port liaisons. David Goldenberg, Sarah Bates, and Nancy Fitzpatrick will conduct in-port meetings and train port liaisons, who will in turn fishermen samplers. Similar meetings will be held at the end of the salmon season, in month 10.

Throughout the salmon season, in months 5-9, liaisons will deliver samples to the genetics laboratory and enter at-sea data directly to the online database. Stock assignments will be generated by Carlos Garza's team and disseminated as they are available, within 2 weeks of sample delivery to the laboratory, in months 6-10. Scales will be delivered from the genetics laboratory to the scale laboratory, in months 6-10. Age data will be disseminated as they are available, by month 15 (April 2017).

In month 10, Sarah Bates will clean datasets and generate estimates of CPUE for all stocks in all months and zones.

In months 11-12, Sarah Bates and Peter Lawson will generate map-based stock comparisons; in month 13, Sarah Bates and Peter Lawson will generate estimates of time-area distribution patterns. In months 11-12, William Satterthwaite and Michael O'Farrell will synthesize at-sea and biological data. In months 13-15, we will compare GSI data to CWT data.

In month 15, various members of the team will attend and participate in PFMC meetings to present data and findings.

See Supporting Documentation for Gantt chart of major milestones described here.

## 7. Project management

This proposal is part of a coordinated effort to understand stock distributions in the west coast commercial Chinook fishery. Members of the project management team described below are currently working together in a well-established collaboration.

David Goldenberg, CEO of the California Salmon Council, will act as the principal investigator for this project. He will be responsible for administration and work cooperatively with the science and technical teams. He will be the main contact with S-K Administration to sign all contracts, provide regular reports and financial data, and receive and disburse grant funds. Mr. Goldenberg will schedule all meetings and supervise workflow so that the project goals are accomplished in a timely manner. Mr. Goldenberg will be the responsible party for meeting all goals and objectives of the study on behalf of the industry in California, as well as hiring port liaisons and fishermen for work conducted in California. He will coordinate with his Oregon counterpart, Nancy Fitzpatrick, Lead Administrator of the Oregon Salmon Commission. Nancy Fitzpatrick will be responsible for hiring a port liaison and fishermen for work conducted in the state of Oregon.

Drs. Gil Sylvia, Oregon State University (OSU), and Pete Lawson, OSU and NMFS, will provide overall leadership to all science components of the project, and ensure that industry and scientists are collaborating to achieve project goals and objectives. They will coordinate the collection of scientific data and amalgamation of the databases.

Dr. John Carlos Garza leads the genetics laboratory at the University of California Santa Cruz (UCSC) Marine Sciences Campus that is part of the UCSC/NOAA Cooperative Institute. He will oversee the laboratory and data analysis by UCSC staff and assist with report preparation.

Drs. O'Farrell and Satterthwaite, both NMFS, will assist in matters of project implementation, including advising on potential changes to the allocation of sampling effort over time and space and modification of sampling practices to promote the generation of representative data. Jeff Feldner, PFMC member and former fisherman, will provide consultation for at-sea sampling and industry-scientist relations.

Dr. O'Farrell will provide expertise on the use of scientific products derived from the project for use in Pacific salmon fishery assessment and management through PFMC.

Dr. Satterthwaite will provide statistical and analytical code and assistance related to comparisons of stock-specific CPUE and stock proportions across current and proposed management boundaries.

Sarah Bates, Fleet Manager and fisherman, will coordinate sample collection, data and sample delivery to the laboratory, basic data analysis, and communications with the commercial fleet.

This project does not anticipate using consultants, but for financial purposes, USCS, OSU, and the Oregon Salmon Commission collaborators are considered subcontractors to the California Salmon Council.

Please see Supporting Documentation for CVs of key project participants, as well as letters of support for NOAA staff:

David J. Goldenberg, CEO, California Salmon Council

Nancy Fitzpatrick, Executive Director, Oregon Salmon Commission

Gil Sylvia, Chairman, Fish Trax Systems, Inc. and Director, Coastal Oregon Marine Experiment Station

Peter Lawson, Fisheries Biologist, NMFS Northwest Fisheries Science Center

John Carlos Garza, Supervisory Research Geneticist, NMFS Southwest Fisheries Science Center, and Adjunct Professor of Ocean Sciences, UCSC

Michael O' Farrell, Research Fishery Biologist, NMFS Southwest Fisheries Science Center

William Satterthwaite, Research Ecologist, NMFS Southwest Fisheries Science Center

Jeff Feldner, PFMC Board member

Sarah Bates, Fleet Manager, California Salmon Council

#### 8. Participation by persons or groups other than the applicant

##### *Federal agencies*

NOAA staff will provide statistical and analytical assistance related to laboratory genetic analysis, stock assignments, comparisons of stock-specific CPUE, advise on any adaptive changes to the sampling plan, and assist in development of tools for fine-scale spatial analysis.

##### *State agencies*

The California Salmon Council is a state entity with oversight by both the California Department of Food and Agriculture and CDFW.

The Oregon Salmon Commission is an industry-funded state commodity commission with oversight by the Oregon Department of Agriculture.

The University of California Santa Cruz is a research oriented public institution with full service genetic analysis facilities and expertise.

##### *Fishing communities*

The fleet manager, port liaisons, and all samplers will be contracted from within the commercial salmon fleet. Commercial fishermen will contract with the California Salmon Council and Oregon Salmon Commission to collect data and samples at sea, enter data in ports, and deliver samples to the laboratory. Members of the fishing fleet participate in sample design, refine sampling methods, communicate with enforcement agencies as appropriate, and provide valuable feedback about feasibility of project design.

#### 9. Outreach and Education

Members of the commercial salmon fleet have been integral in developing and planning this project. All sampling and associated in-port activities are conducted by members of the fishing

community. The contract, if approved, would be awarded to industry representatives. The fishermen involved in this project are committed to resolving issues that affect their ability to engage in successful fishing and make full use of the Chinook stocks that are currently under fishery management plans.

#### *Outreach to fishermen*

We will distribute reports of aggregated catch numbers (on a weekly basis) and stock composition estimates (as they become available) to the commercial salmon fleet. These reports will inform fishermen about fishing activities coast wide and may assist in fishing decisions. Reports will be published on the PFX website, as well as mailed directly to project participants.

Meetings will be held in major fishing ports at the beginning and end of the commercial fishing season to educate fishing communities about project goals and objectives, train fishermen in sample collection, and subsequently review project results.

#### *Dissemination of information to fisheries managers*

Stock-specific catch per unit effort data will be available to the PFMC Salmon Assessment Team by the March 2017 Council meeting. We will collaborate with regional and state managers to provide any other requested datasets in usable formats.

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