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

Purpose and Goals

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

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

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

Council Research and Data Needs

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

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

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

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

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

NMFS Strategic Plan for Fisheries Research

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

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

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

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

Need for this EFP

The application of GSI technology to management has many aspects beyond the identification of stocks. Considerable preliminary work in 2006 toward implementation of this technology has been done in pilot projects in California and Oregon. Work in 2007 is designed (1) to extend the development of techniques and methodologies based on 2006 experience, (2) to provide relief to fishermen via payment for participating in sampling programs, and (3) to start to answer questions relative to distribution of Chinook stocks that may prove useful for management. It is

too early to actively apply GSI technologies to fishery management on the west coast, although a simulation of a potential in-season weak stock quota management application may be conducted based on data collected during this study.

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

Project Organization and Personnel

To be developed

Objectives

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

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

database will require several years. We anticipate providing preliminary results to fisheries managers after 3 years of sampling, with continuing improvement in the information in future years.

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

1). Inshore/offshore differential in Klamath impacts

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

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

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

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

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

3). Rapid-turnaround weak stock quota management

It has been suggested that we could monitor catch composition in a fishery and manage for a numerical limit on weak stock (e.g., KRFC) impacts. There are several concerns with this approach: rapid turn around in this case is at least 48 hours longer than the time needed to implement quotas based on overall catch; it will be impractical in most cases to sample all landings, so a statistically valid sampling plan needs to be developed; accuracy of setting weak-stock quotas depends on accuracy of stock assessments and models of

stock distribution (i.e., setting an appropriate quota will not be possible without the ability to produce more accurate stock abundance projections). With the results of the 2007 fishery we hope to simulate this management technique and explore the potential improvement in management precision. The intended benefit is to develop a tool that enables managers to allow fishing on abundant stocks to proceed without exceeding predicted impacts on stocks of concern.

Research Design and Methodology

Methodology

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

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

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

In addition, to the extent that funding and impacts on Klamath River fall Chinook allow, the same number of boats may be contracted under an EFP to conduct sampling in management

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

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

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

Literature Cited

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

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