Mr. Mark Cedergreen
Chairman
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, Oregon 97220-1384
May 18, 2011

RE: Electronic Monitoring Pilot Study Report for West Coast Groundfish Trawl ITQ Program

Dear Mr. Chairman,

The purpose of this letter is to submit to the attention of the Pacific Fishery Management Council a report summarizing results and recommendations from the Electronic Monitoring (EM) pilot study that was conducted as part of the recent Exempted Fishing Permit work off of Morro Bay, California. The stated goal of this research is to help in the development of an objective, reliable and cost-effective monitoring program based on individual accountability using video based Electronic Monitoring tools, as well as to explore how Electronic Monitoring could be implemented in the West Coast Groundfish Fishery.

Over the last several years Council members and staff have demonstrated great leadership and innovation in designing an ITQ program and addressing the top concerns that come with this management transition. The Council's work on Community Fishing Associations and Risk Pools to help resolve community stability and overfished species management issues are examples of the strong work being done by the Council on this program. These efforts are having a national impact as other fisheries look to the West Coast Groundfish Fishery for examples and models of how to best design and implement Catch Share management programs.

Just as crucial to the success of this ITQ program will be designing cost effective methods for the fishery to achieve its monitoring goals. In this first year of the ITQ program, the fishery relies on federal assistance to support monitoring costs. As we all know, once that assistance in no longer available, the additional cost placed on the industry will have significant consequences, particularly on small vessels and vessels engaging in gear switching. It is very likely that the additional costs could be the tipping point for many smaller scale fishery operations and communities that have traditionally participated in the fishery. It is imperative that the fishery makes progress on the design of more cost effective monitoring now, so to prepare for this inevitable cost burden. We and many other fishery stakeholders believe that Electronic Monitoring will be an important component of the solution.

The attached report describes the Electronic Monitoring pilot work that included video and sensor data that was collected from six vessels and monitored by this equipment over a 5 ½ month period including a total of 332 hauls for over 125 sea days. This robust data set compared piece counts for the number of fish recorded from 3 different sources collected independently of each other: observer, fishermen logbooks, and EM. Overall agreement was strong between the 3 sources, with Electronic Monitoring being comparable to both observer and fishermen logbook data. EM data had 1% less pieces than observer data, with high agreement on piece counts for sablefish (1% difference) and grouped rockfish (4% difference). There was a 0% difference in piece counts between EM and logbook data, and 1% more and 4% less for sablefish and rockfishes respectively. Out of 329 fishing events captured on video, only one was unusable due to poor lighting during a night haul when the deck lights failed.

At this moment in the development of the ITQ structure, we encourage the Council to work with NMFS to take the action necessary to begin the implementation of the new Electronic Monitoring program for this fishery. We would also submit the following recommendations, which we feel would facilitate the start of an Electronic Monitoring program and improve the chance for long terms success.

- While we believe Electronic Monitoring can be useful in the monitoring of all types of groundfish vessels, it is clear that lower volume operations, such as fixed gear boats, make for an easier operation to monitor. In order to get a start with Electronic Monitoring and develop more experience with these systems, we would encourage that the Council pursue a “low hanging fruit” strategy and allow fixed gear boats to be the first to utilize a new Electronic Monitoring system.
- We would encourage the use of depth and other spatial restrictions for the early implementation of Electronic Monitoring to help separate the development of this program from the complexity of the most severe overfished species concerns.
- We urge implementation of an Electronic Monitoring pilot program in the West Coast Trawl ITQ program beginning no later than Jan. 1, 2012 to minimize the dislocation that will occur in the trawl ITQ program due to the cost of existing 100% human observer coverage. There is real urgency in this recommendation as we know that many long term business planning decisions will be made by fishermen in the first two years of the Trawl ITQ program, and immediate implementation will reduce cost inputs in business planning, reducing the negative community impacts from consolidation of the smaller boat operations.
- We request that the council pursue development of a trailing amendment, including criteria that an authorized EM system would need to meet, under the next round of trailing amendments to the trawl rationalization program.

Thank you for your continued efforts to design and implement an ITQ program that will meet the objectives of the many fishery stakeholders that participate in this fishery. This Council’s leadership has been the key ingredient to all progress in this program to date, and we strongly encourage you to take up Electronic Monitoring as a top priority for your future efforts.

Sincerely,
Michael Bell
Senior Project Director
The Nature Conservancy of California

USE OF AN ELECTRONIC MONITORING SYSTEM TO ESTIMATE CATCH ON GROUNDFISH FIXED GEAR VESSELS IN MORRO BAY CALIFORNIA- PHASE II

by

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May 19th, 2011

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EXECUTIVE SUMMARY

Bryan, J, Pria, M.J. and H. McElderry, 2011. Use of an Electronic Monitoring System to Estimate Catch on Groundfish Fixed Gear Vessels in Morro Bay California- Phase II. Unpublished report prepared for The Nature Conservancy by Archipelago Marine Research Ltd., Victoria British Columbia, Canada. 51 p.

In 2010, TNC contracted with Archipelago to expand upon a 2008 pilot project in Morro Bay and test an EM system's capability to accurately record fishing events to meet the catch monitoring needs for the IFQ in an economically marginal fishery. This 2010 study represents a unique opportunity to gain further insight on how to develop an objective, reliable and cost-effective monitoring program for a fixed gear, small vessel fleet based on individual accountability using video based electronic monitoring (EM) tools as well as to explore how an audit-based monitoring system could be implemented in order to decrease the cost burden for individual fishermen.

EM systems consisted of up to four closed circuit television cameras, a GPS receiver, a hydraulic pressure transducer, a winch rotation sensor, and a system control box. EM sensor data, comprised of date, time, location, pressure and rotation sensor readings and EM system metadata, were recorded continuously while the system was powered, which was for the entire duration of the fishing trip (i.e. from the time the vessel leaves port to engage in fishing to the time that the vessel returns to port). Readings from the GPS, pressure and rotation sensors were used to detect fishing activity and triggered video recording. All of the sensor data and video footage was subsequently reviewed to create a complete characterization of fishing effort and catch and discards for participating vessels, which then could be compared to data from observers and fishing logs.

Six vessels were monitored over a five and a half month period and for a total of 332 hauls detected over 125 days at sea. EM system data collection was 91% overall for all participating vessels and trips and the majority of the data lost was of low risk since it occurred during transit to and from the fishing grounds. Every vessel carried an observer and skippers filled out a haul-by-haul fishing logbook for every trip. The EM data collected was matched up and used for catch assessment comparisons with 97% of all hauls recorded by observer and fishing log.

EM and observer fishing event and catch data were available for over 105,000 total fish catch items and a total of 276 fishing events. EM data had 1% less pieces of catch than observer overall, with high agreement on piece counts of sablefish (1% difference) and grouped rockfish (4% difference), the two most important species groups of this study (for market and conservation reasons, respectively). There were 328 events compared between EM and fishing log data. The total piece comparison between EM and fishing log data was very good, since fishing log data contained 0% different total catch items and 1% more and 4% less items for sablefish and rockfishes respectively. Out of 329 fishing events captured on video, only one was unusable due to poor lighting during a night haul when the deck lights failed and the catch was processed using headlamps. While sun glare and backlighting by deck lights during night hauls

can adversely affect video quality, determining catch count and composition was typically unimpacted.

Development of an EM based audit methodology was one of the deliverables of this project. Since EM data collection and data processing and analysis occur at different stages, the technology allows for capture of all fishing activity at-sea without the need to engage in data interpretation for all of it. However, since EM captures all of the fishing activity, it can be used to fully reconstruct a fishing trip in cases where the fishing log is not deemed accurate. Benefits of an audit-based monitoring program include (Stanley *et al.*, in press): cost and logistically effective 100% data capture, fishermen with a vested involvement in reporting, transparent and trusted catch estimates, financial motivation to comply, and an independent estimate of catch.

The proposed audit methodology follows the example presently in use in BC, Canada. Fishing logbook entries for retained and discarded catch for an agreed percentage of hauls are compared to the EM monitoring results. Dockside monitoring programs are used to check the amount and composition of retained catch when a vessel returns to port. The fishing log is compared to the EM and dockside monitoring data and scored on its accuracy, and has to meet several pass/fail standards as well. As long as the fishing log data is accurate, an update to that fishing licence's quota is issued and the vessel is free to resume fishing. If there are discrepancies in the fishing log, a series of escalating actions occur to resolve the discrepancies and encourage future compliance and then an update to that fishing licence's quota is issued. Estimates of the cost for such a program would be difficult to determine for the West Coast fishery presently, primarily due to uncertainties regarding the level of video review, frequency of data collection and turnaround time for updated vessel quota reports needed to support adequate monitoring needs. These in turn would have to be determined by fishery managers who would set guidelines on the appropriate level of video review and data collection needed to meet the monitoring requirements for this fishery. The only system to currently compare it to is an audit-based EM program that delivers a finished data product integrating hail, fishing log, dockside monitoring, EM data and reporting for a yearly average cost per vessel of 194 $CND per seaday (~200 $USD) for a British Columbia hook and line fishery. The EM only portion of that is 136 $CND (~140 $USD). The costs for an operational EM program along the U.S. West Coast fishery could potentially be higher or lower than this estimate depending on management requirements.

Consistent with the findings of the 2008 study, EM has been demonstrated to be an effective tool for at sea monitoring, delivering fishing effort and catch data comparable to on-board observers. There is no need for continuing to concentrate future research efforts on comparing EM data with observers. Next steps should concentrate on developing a comprehensive monitoring program involving the tools previously mentioned such as further testing of an audit-based comparison between fishing logbooks and EM with verification on retained fish from the dockside monitoring component and supplemental observers as necessary. Operationally, this will include incorporating vessel specific monitoring plans, formalized feedback protocols for both technicians and fishermen, maintaining full retention rules for rockfish, providing in season updates for fishermen, consideration of management needs, and the associated decreased risk of fishing below 200 fathoms for this fishery were all recommended.

Further work involving EM as an audit-tool should concentrate on defining the audit process. The audit framework described herein should be used as a basis for discussion on how a program of this type would work not only for just the Morro Bay fixed gear fishery, but for other fixed gear vessels and port communities that will participate in the IFQ trawl rationalization program elsewhere along the West Coast. Fisheries managers would be required to establish the requirements of the program and fishermen would then be able to engage on how to achieve those requirements. Some of the questions that require an answer from fisheries managers include: which species should be tested in the logbook audit, what is the desired turnaround time for audit results, and what should the incentives and disincentives be to achieve the desired data quality from logbook data?

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1. INTRODUCTION

In 2005, a U.S. non-governmental organization, The Nature Conservancy (TNC), purchased thirteen federal limited entry trawl-endorsed permits. Starting in 2008 TNC has licensed or leased six of these permits to up to six local fishermen to explore the economical and environmental feasibility of establishing a fixed gear fleet (longline and trap) off the coast of Morro Bay and Port San Luis, California under a community based fishing association (CBFA). In order to do so, TNC received an exempted fishing permit (EFP) each year that allowed, among other things, the use of these permits on fixed (both long line and pot/trap) gear as an alternative to trawl gear. The fishery mainly concentrated on targeting sablefish and shortspine and longspine thornyheads although the permit's quota included other catch like flatfish, dogfish, and lingcod.

As part of the EFP regulations, all fishing trips were required to carry a human observer on board to record fishing effort and catch information. Of particular importance was documenting full retention of rockfish, since the weights of all species were recorded at the time of offload to ensure that the strict hard quota caps for these species are not exceeded. A fishing logbook was also designed for the EFP, and fishermen kept fishing effort and catch records for all species retained and released on each fishing event for every trip.

The West Coast Groundfish Trawl Fishery recently implemented a new management program in January 2011 with the transition to a catch share program, also known as trawl rationalization or Individual Fishing Quotas (IFQ). Under this program, 100% observer coverage is required for all vessels in this fishery. Due to the great uncertainty surrounding the financial viability of a small groundfish fleet paying for 100% observer coverage, the EFP project proponents believed it was important to invest in and test alternative monitoring methods such as Electronic Monitoring (EM).

Over the past decade, Archipelago Marine Research Ltd. has pioneered the development of EM technology and a number of pilot studies have been carried out to test the efficacy of this technology. To date there have been over 30 studies spanning diverse geographies, fisheries, fishing vessels and gear types, and fishery monitoring issues. The capabilities of EM have been reviewed in McElderry (2008). Also, over the last six years Archipelago has been involved in the designed and implementation of an audit-based EM catch program in the British Columbia (BC) hook-and-line fishery.

TNC contracted with Archipelago to test the feasibility of implementing an EM program to monitor the Morro Bay fixed gear fishery. Archipelago had conducted a pilot study with this fishery in 2008 and the results had demonstrated EM was an effective tool for monitoring fishing effort and catch data for the Morro Bay fixed gear fishery (Pria *et al.*, 2008). This 2010 pilot study sponsored by TNC represented a unique opportunity to gain further insight on how to develop an objective, reliable and cost-effective monitoring program for a fixed gear small vessel fleet based on individual accountability EM and create a framework for how an audit-based monitoring program could be applied.

The three main objectives of the 2010 Morro Bay EM pilot study were to:

- expand the scope of data collected with EM from the Morro Bay fixed gear fishery to include more vessels and a longer time period of data collection;
- compare fishing effort and catch data from EM with observer and fishing log data; and
- create a framework on how an audit-based monitoring program could be implemented in the fishery.

2. MATERIALS AND METHODS

2.1 EM DATA CAPTURE TECHNIQUES

EM System Specifications

Six vessels participated in this study, referred to by the letters A to F in order to protect their privacy. Vessels A to D used long line gear and vessels E and F used trap pot gear to fish. Each vessel was provided with a standard electronic monitoring system consisting of a control box, a suite of sensors including GPS, hydraulic pressure transducer and/or a drum rotation sensor and up to four waterproof armoured dome closed circuit television (CCTV) cameras (Figure 1). All six vessels used hydraulic winches to haul their gear, therefore having a pressure sensor trigger the recording was the most efficient method of collecting imagery data of fishing activity. Vessel E had a pressure sensor attached to its hauler but since it also used a drum to wind the ground line on, a drum rotation sensor was placed on the vessel towards the end of the study to test if sets could be detected that way.

The control box continuously recorded sensor data (comprised of date, time, location, vessel speed hydraulic pressure, rotation sensor readings, and EM system metadata), monitored performance and controlled imagery recording according to programmed specifications, as well as provided continuous feedback on system operations through a user interface. Detailed information about the EM system is provided in Appendix I.

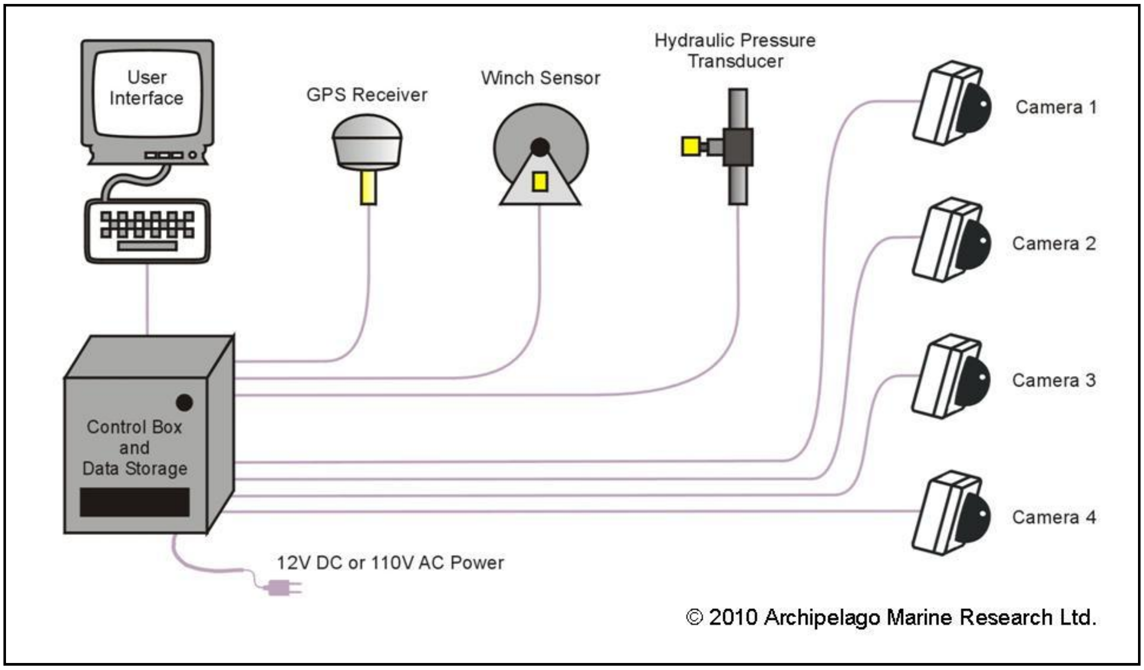


Figure 1. Schematic diagram of the electronic monitoring system, which can record video data from up to four cameras per vessel.

The EM system's GPS receiver was mounted to existing structures above the cabin away from other electronics and provided independent information on vessel position, speed, heading, and time. The electronic pressure transducer was installed on the supply side of the hydraulic system and provided an indication when hydraulic equipment (winches, pumps, lifts, etc.) were operating. CCTV cameras were mounted on each vessel in locations that provided unobstructed views of catch and fishing operations.

EM control boxes, monitors, and keyboards were mounted in a secure dry area in the vessel cabin. Sensor cables were run through bulkheads where hydraulic and electrical lines were already in place standard operation of the vessels. The control box software was designed to boot up immediately when powered on or automatically after power interruption.

EM data capture specifications

EM sensor data were recorded continuously while the EM system was powered, which was intended to be for the entire duration of the fishing trip (i.e. from the time the vessel leaves port to engage in fishing to the vessel's return to port). Sensor data were recorded every 10 seconds with a data storage requirement of 0.5 MB per day. The control box software was set up to trigger image capture when hydraulic pressure exceeded threshold levels set by the technician or the winch sensor detected rotation. Image recording ended 20 minutes after the sensor trigger ceased for all vessels and all imagery included text overlay with vessel name, date, time, and position.

Each EM system was capable of receiving video inputs from up to four CCTV cameras at selectable frame rates (i.e., images per second). Using a frame rate of 5 fps the data storage requirement was 60–100 MB per camera per hour, equating to a system capacity of roughly 83 days of continuous recording when using three cameras and a 500 GB hard drive.

Field Operations

Planning for the EM project component began in July 2010 with a meeting in San Luis Obispo, California with by participating fishermen and staff from TNC, Tenera Environmental Ltd. (Tenera) and Archipelago. The meeting included an overview presentation of EM technology and discussions surrounding project timelines, vessel requirements, project communications, and project methodology. It was also an opportunity for Archipelago's staff to meet with the local subcontractor, Tenera, and discuss each others roles and responsibilities.

The field component began in the second week of July 2010 and continued through late December 2010. An Archipelago senior EM technician installed the EM systems on five of the vessels while training two staff from Tenera to be qualified field technicians who then installed the last Vessel in the project on their own. The EM service technician's responsibilities included the retrieval of all EM data, troubleshooting EM systems at the dock, and contacting Archipelago if any system problems arose. Staff at TNC also contributed to data retrieval from study vessels. All data collected during the project were treated with complete confidentiality.

Installations began with EM technicians and the vessel's captain discussing EM system component placement, wire routing, fishing deck operations, and the vessel's power supply. Hydraulic pressure transducers were installed on the pressure side of the hauler circuit and out of the way from vessel operations and the pressure threshold was tested. The GPS receivers were fixed to existing structures above the cabin roof, and the control box, monitor and keyboard were all secured in the vessel cabin. Due to the characteristics of the participating vessel's gear, only vessel E was installed with a drum rotation sensor in addition to a pressure sensor. This was done only for the last three trips recorded to explore if such a sensor could be used to detect gear setting by a pot gear vessel in addition to the hauling events detected by the pressure sensor installed.

Power to the EM system was supplied as 120V AC by each vessel's inverter. Upon completion of the installation, the EM system was powered up and sensors and cameras tested to ensure functionality. The skipper was also given an overview of the EM user interface and basic EM functionality. The skippers were asked to monitor the status of the EM system throughout fishing trips and left with a laminated user reference card.

Vessels participating in the pilot project carried an EM system for 6 to 28 fishing trips each. The on-site EM technician or TNC staff monitored EM system performance during data retrieval or service events between the fishing trips. Servicing included several operational checks of the equipment and retrieval of the sensor and imagery data collected. The first data retrieval was after two weeks to catch any problems with new installs quickly, after which data collection and took place every 4 weeks. Since memory requirements were relatively small for each trip, data retrieval intervals could have been extended to include up to 80 days of fishing.

During the initial service adjustments to sensor placements, threshold settings, and camera angles were sometimes necessary since sensor signatures resulting from at sea activity did not always reflect those encountered at dockside and the camera views selected did not always completely capture the activities intended. The sensor data retrieved was uploaded to a secure ftp site and imagery data were backed up on Tenera's servers for archiving and a 2.5" 1 TB external hard drive for shipping. The 1 TB hard drive was packaged and sent back to Archipelago's head office in Victoria, BC every other month.

2.2 EM Data Interpretation and Analysis

Data interpretation protocols were designed and communicated to the data technicians involved in the study before any of the data were processed and were based on the study's objectives, project methodology talks during the project planning stage, and experience accumulated from similar studies carried out in the past. Sensor data interpretation was carried out before image interpretation to access imagery from haul start times directly without having to review all of the imagery for a trip. The observer and fishing log data were not received until all of the EM data were interpreted to ensure unbiased interpretation.

Staff at Tenera was trained in the use of EM Interpret (EMI) and Video Analyser, two pieces of proprietary software created by Archipelago for interpreting the data collected by EM systems. The sensor and image data interpretation, described below, was performed almost exclusively by two part time staff hired from the local university campus as a way of providing opportunities and expanding the pool of skilled labour in the area. After the first couple months of the project, a series of work orders for the six Vessels were also reviewed by experienced viewers at Archipelago's headquarters in Victoria, BC, Canada as a form of QA/QC and the results were disseminated via an internal document.

Sensor Data Interpretation

All of the sensor data collected during the project were interpreted. Sensor data were imported into EMI and analysed to determine the completeness of each data set by checking for time breaks in the data record, as indicated by the duration between records exceeding the expected 10-second time interval. Sensor data were then analysed to interpret the geographic position of fishing operations and distinguish key vessel activities including transit, gear setting, and gear retrieval.

EMI facilitated sensor data interpretation as illustrated in Figure 2. Vessel speed and hydraulic pressure often correlate uniquely for various activities such as transit, setting, and hauling. Gear setting is indicated by medium vessel speed with a constant heading for a short period of time while on the fishing grounds and an absence of hydraulic pressure readings, usually preceded by a sharp turn or circle. Gear hauling is typically indicated by a spike in hydraulic pressure and a very slow speed, but the track of the vessel may or not be straight as the line is pulled in. Sets and hauls were defined as extending from the first float to the last float. The spatial plot provided a perspective on the various activities in relation to one another and was useful to help associate specific setting and hauling events. Setting and hauling events were matched to each other by interpreting physical proximity and timing. When displayed in this manner, the analyst reviewed the trip, interpreted vessel activity, and made annotations in the sensor record for haul and setting events. Haul start and end times from sensor data interpretation provided an initial reference for accessing image data. Catch assessments were only performed for hauls which we had complete data for, since comparing results from incomplete imagery data would obviously return erroneous findings.

Part of the sensor data interpretation also involved the evaluation of the EM system sensors. The electronic pressure transducer and drum rotation sensor signals were evaluated for completeness throughout each trip. The quality of the GPS receiver was evaluated to determine reliability of position and time signal. Poor GPS receiver signal is usually the result of an intermittent GPS signal caused by interference or a large satellite error in determining position. For each trip, each sensor's signals were rated as follows:

- Complete. The sensor performed to its full capacity.
- Incomplete. The sensor experienced intermittent failures or false readings.
- No data. The sensor did not operate during the trip.

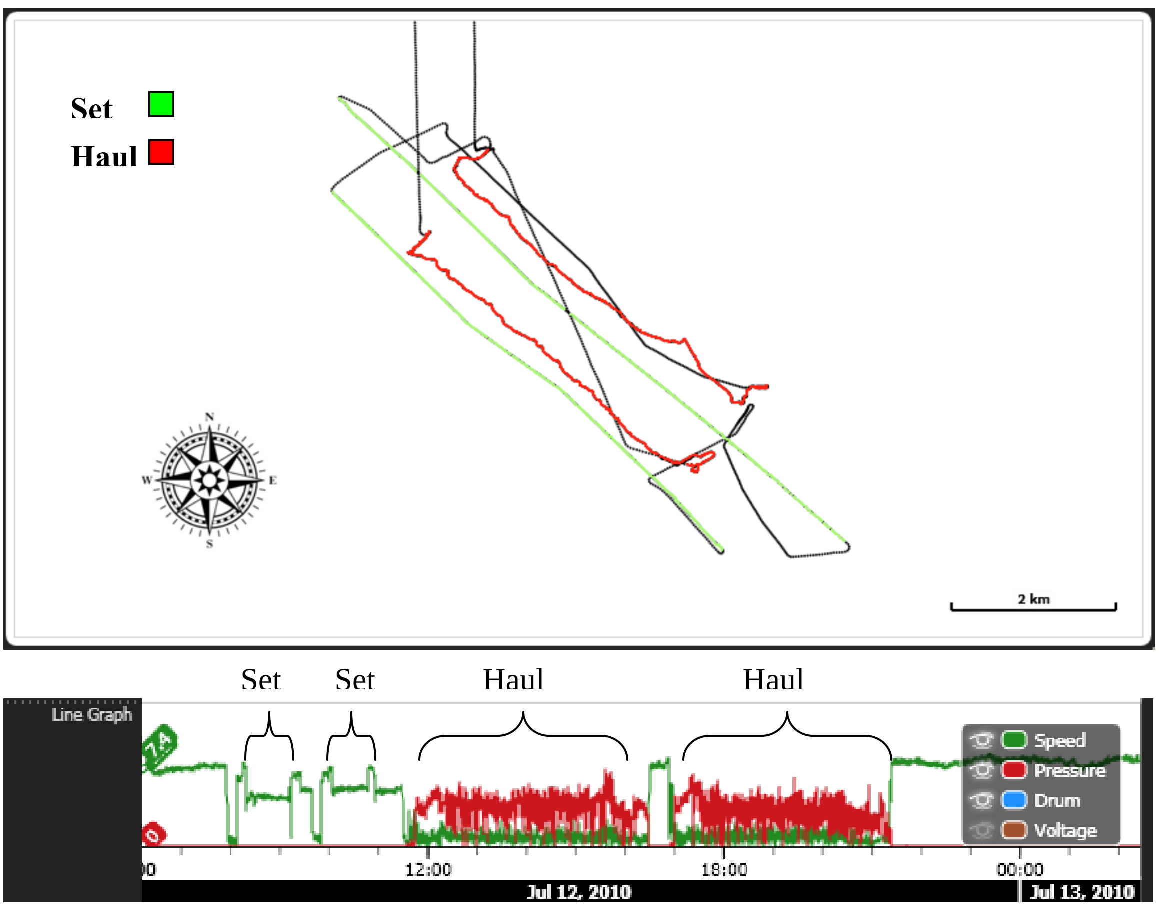


Figure 2. Example of sensor data from one of the project vessels for a trip. The time series graphs (lower) show vessel speed (knots), and hydraulic pressure (psi). Setting activity for horizontal longline was associated with constant and relatively high speed, relatively constant heading, and physical proximity to a haul.

Hauling for horizontal longline was associated with high hydraulic pressure and relatively low speed. The spatial plot (upper) shows the vessel's cruise track for the same period, with setting highlighted in green and hauling in red.

Image Data Interpretation

Image data were interpreted using Video Analyser, a proprietary software product that provided synchronised playback of all camera images and a data entry form for recording catch observations in a sequential manner. This application outputted the catch composition data in XML files that were then loaded into a relational database for the catch comparison analysis between EM and observer and fishing log data.

Since catch data can only be compared across different data sources for complete fishing events, image data interpretation was done for all hauls captured completely by EM. The first step of image interpretation was to assess whether all the intended imagery was recorded properly. This was achieved by comparing the haul start and end times from the sensor data with those available for image data. The hauls that were deemed to have complete imagery were reviewed for catch assessment and image quality.

The EM data technicians counted and identified target and non-target catch to the lowest taxonomical grouping possible and also kept track of catch disposition. EM catch disposition data included: retained, released, and drop-off (catch that fell off the gear before the fisherman had control over it).

Image quality was assessed as an average for each haul event viewed, according to the rank scale illustrated in Figure 3 and defined as follows:

- High. The imagery was very clear and the viewer had a good view of fishing activities. Focus is good, light levels are high and all activity is easily seen.

- Medium. The view was acceptable, but there may be some difficulty assessing discards. Slight blurring or slightly darker conditions hamper, but do not impede analysis.

- Low. The imagery is difficult to assess. Some camera views may not be available. Imagery is somewhat blurred or lighting has largely diminished. Some factors such as the fishing line going out of camera view or crew standing between the catch and the camera for extended periods of time may have also occurred.

- Unusable. The imagery is poorly resolved or obstructed such that fishing activity cannot be reliably discerned.

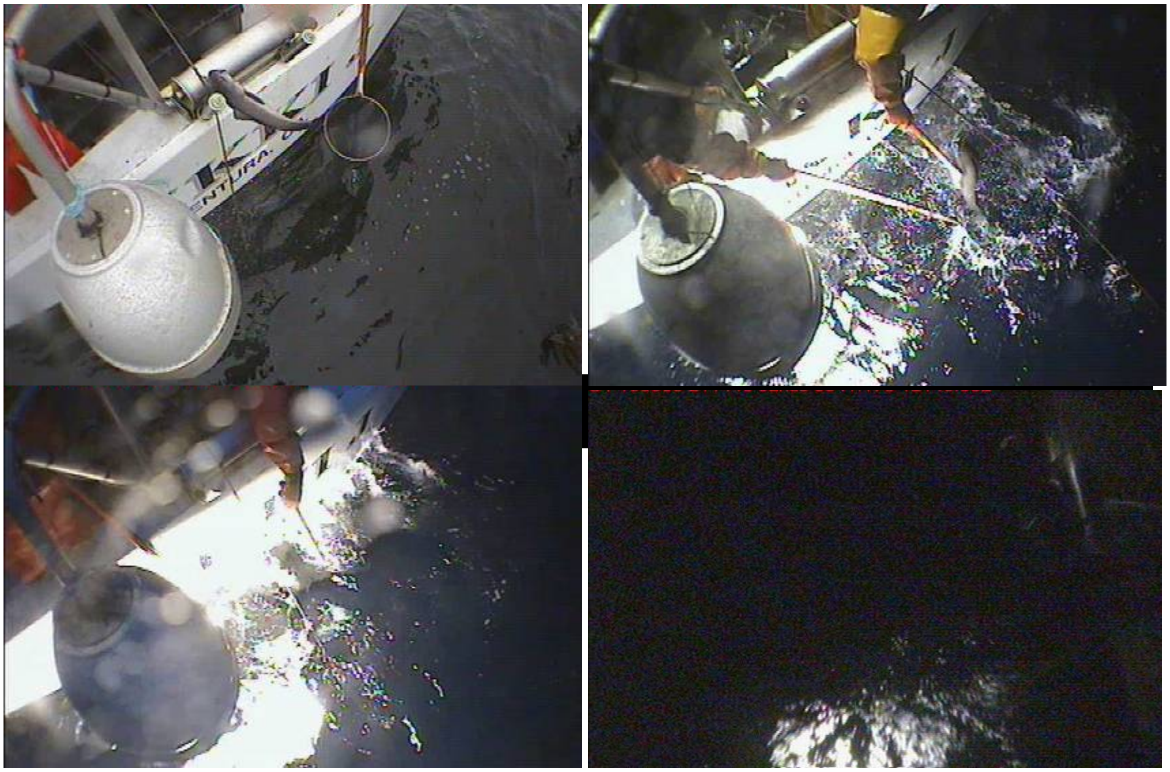


Figure 3. Example imagery to illustrate the different image quality assessments. From left to right, top to bottom: high, medium, low and unusable. Image quality is determined as an average of all cameras throughout an entire haul. Some cameras may yield a better angle and image clarity than others within the same haul but it is the overall ability to meet imagery review objectives that ultimately determines the imagery quality rating.

Data Analysis

Data checks were in place throughout the data interpretation steps and mainly involved the use of validation rules with minimal ad-hoc double-checking of some data. The data analysis itself was done once all of the sensor and image data were interpreted.

The data processing, tracking and management was done using Excel while the data outputs from all sources (sensor, imagery, observer data, and fishing log data) were available in relational databases allowing all the data analysis to be carried out using an MS Access database.

As one of the main goals of the study was to compare EM, observer, and fishing log estimates of catch species, it was important to appropriately match the three data sets. Fishing event matching between observer, fishing log and EM was done using the set start and haul end date and time as determined by each data source.

As part of the standard QA/QC process, a selection of EM imagery was viewed by a second data technician and the results were compared with both the EM and observer results used in this report. Fish counts and species identifications used in this report are referred to as “EM data” or “primary” and data resulting from secondary data technician review is referred to as “secondary”. The hauls reviewed were not chosen at random, as is typically done, but represented a 10% sample size of the hauls for each boat that focused on the greatest percentage mismatches between EM and observer total counts by haul to focus on problem areas.

3. RESULTS

3.1 EM TRIALS ON FISHING VESSELS

EM System Deployments and Data Captured

EM system deployment results are summarized in Table 1 and completely displayed in Appendix II due to the volume of data for 6 vessels. The data collection for the pilot study spanned a five and a half month period and each vessel completed between 6 and 28 fishing trips for a total of 125 days at sea. Every vessel carried an observer and filled out a haul by haul fishing logbook for every trip to allow data comparisons between the three sources. EM collected a total of over 2729 hours of sensor data at sea, and 762 hours of haul imagery associated with 332 fishing events.

The overall sensor data capture success was 91%, ranging from 4% to 100% per trip (two trips had 4% and 8% data capture and the rest had over 65%). Gaps in the sensor data record occurred most commonly during the vessel's initial or final transit from the fishing grounds to port.

Table 1. Summary of EM data collected by vessel.

Vessel ID	Number of Trips	Data Collection Period	Days at-sea	Sensor Data Collected (Hours)	Sensor Data Complete (%)	Haul Imagery Collected (Hours)	EM Detected Hauls
A	28	12 Jul to 24 Dec	28.7	654.1	95%	182.2	63
B	24	21 Jul to 23 Dec	26.5	516.7	81%	171.3	29
C	14	7 Jul to 31 Oct	18.8	450.7	100%	150.8	39
D	14	14 Jul to 7 Oct	19.2	410.4	89%	124.2	30
E	11	26 Jul to 25 Sep	17.1	399.3	97%	43.4	67
F	6	14 Jul to 20 Aug	14.4	297.9	86%	90.9	104
Totals	**97**		**124.6**	**2729.1**	**91%**	**762.7**	**332**

Sensor performance was high across all vessels (Table 2) with the hydraulic and drum rotation sensor working properly for 100% of the trips where they were installed and the GPS providing complete data for 95 of 97 trips. The two trips were there was a loss of GPS data (i.e. location and speed) occurred in a single vessel. In one instance GPS data was available for 16% of the trip but positional information was available for 2 of 3 hauls (classified as incomplete data). In the other instance GPS data was available for 23% of the trip but only during the transit to port with no location for the fishing event available (classified as 'no data'). GPS errors in these two trips did not impact imagery data triggering or detection of sets and hauls in the sensor data.

Table 2. Summary of sensor performance for all trips throughout the pilot study.

Vessel ID	GPS	Drum Sensor	Hydraulic Sensor
Complete	95	3	97
Incomplete	1	0	0
No Data	1	0	0
Not Installed	0	94	0
Totals	**97**	**97**	**97**

Table 3 shows the total number of hauls recorded by the observer and fishing log for each trip and the EM capture success for them. Observer data were collected for a total of 286 hauls, fishing log data for 338 hauls and 332 hauls were detected by EM and where hauls matched between either EM and observer or EM and fishing log data, comparisons were performed. Observers did not differentiate individual hauls for three multiday trips on Vessel F, recording one event per day instead for a total of 7 events. Fishing log and EM recorded individual hauls resulting in a large total haul difference between these and observer data. Six hauls were not captured by EM due to power interruption to the system which explains the remaining differences between hauls recorded by each data source. Five of the non-captured hauls corresponded to the same trip in which the EM system was only powered for 1.4 hours at the fishing grounds. The remainder non-captured hauls occurred in Vessel F.

Hauls were considered to be complete when EM data (sensor and imagery) were available for review for the entire haul. Only hauls with complete EM sensor data could be compared, as the incomplete hauls would have resulted in inconclusive catch comparisons. Vessel B had two hauls with time gaps at the start or end so only had 27 of 29 hauls detected complete, while Vessel F had one haul with a time gap at the end. This resulted in 329 of the 332 hauls that EM detected being classified as complete for further analysis.

Table 3. Summary of hauling events captured by observer, fishing log and EM.

Vessel ID	Trips	Observer Recorded Hauls	Fishing Log Recorded Hauls	EM Detected Hauls	EM Sensor Data Complete
A	28	63	63	63	63
B	24	30	30	29	27
C	14	39	39	39	39
D	14	35	35	30	30
E	11	67	67	67	67
F	6	52	104	104	103
Totals	**97**	**286**	**338**	**332**	**329**

Note: For vessel F, OBS recorded hauls by day rather than discreet events during some trips, thus the final event count was much lower.

Table 4 shows the total number of hauls with complete and usable video data and how many had catch records compared to observer and fishing log recorded hauls. Imagery data from one haul on Vessel B could not be used due to poor lighting during a night haul. This resulted in EM data being used for catch comparisons for a total of 328 hauls. The 328 hauls with usable video data had to be lined up with the corresponding haul entries from the observer (n=286) and fishing log (n=338) data in Table 3. When this was done, there were 276 comparisons between EM and observer data and 328 comparisons between EM and fishing log data.

The different approach for recording hauls for three trips for Vessel F resulted in 58 EM hauls being summed by day and compared to 7 observer entries. To further complicate matters, one of those days contained a haul that was missed by EM. Since no catch data was available for that haul, it created a situation where the other six EM hauls in that day had to be disregarded from further analysis. This is why the number for EM imagery data to observer data comparisons for Vessel F (and the grand total) is 51, much less than the total number of usable hauls from EM imagery.

Table 4. Imagery data totals based on Sensor data complete events (n=329)

Vessel ID	EM Imagery Data Complete	EM Imagery Data Usable	EM Imagery Data Unusable	EM Imagery Data to Observer Comparisons	EM Imagery Data to Fishing Log Comparisons
A	63	63	0	63	63
B	27	26	1	26	26
C	39	39	0	39	39
D	30	30	0	30	30
E	67	67	0	67	67
F	103	103	0	51	103
Totals	**329**	**328**	**1**	**276**	**328**

Aligning EM hauls with observer and fishing log data was mostly based on date and time of the hauls. However, this had to be manually verified due to inconsistencies in observer and fishing log data, as some haul information related to the beginning of the haul and the rest related to the start of the haul.

3.2 EM DATA

Interpretation of EM sensor data

The interpretation of EM sensor data was based on recognizing 'signatures' in the data collected. One of the most obvious was the high constant speed and lack of pressure sensor associated with a vessel transiting to and from the fishing grounds. While there are slight variations from vessel to vessel, hauling events were characterized by high hydraulic pressure and relatively low vessel speed, with both pressure and speed tending to fluctuate corresponding to work associated with catch retrieval. There were no specific sensors capable of detecting setting events since the vessels set the gear by hand directly from tubs. However, the combination of relatively high and constant speed, consistent heading, and geographical proximity to the haul was a reliable way to determine setting for horizontal long line events. Trap sets were often very hard to determine when they did not occur within the same fishing trip but EM data was used on occasion as supplemental information to link sets to hauls from the fishing logbooks by TNC.

Interpretation of EM imagery data

Image quality ratings for all 328 usable hauls are shown in Table 5. Image quality was rated as high or medium for 96% of the hauls reviewed and while there is a distinction made between high and medium quality video imagery, they both provide the ability to count, speciate and assign utilization to catch items. Low image quality was assigned to 4% of the hauls analyzed due to increased difficulties keeping track of catch dispositions as well as lower than usual image clarity for the purpose of speciation. Low image quality ratings were mostly due to back lighting from deck lights and camera pixilation during night hauls.

Table 5. Summary of EM imagery data quality assessments.

Vessel ID	High	Medium	Low	Total
A	13	47	3	**63**
B	3	21	2	**26**
C	19	19	1	**39**
D	3	21	6	**30**
E	0	67	0	**67**
F	97	4	2	**103**
Totals	**135**	**179**	**14**	**328**

Image playback speeds during interpretation varied from about 0.5 to 4 times real time according viewer experience, catch density, and image quality. Average viewing analysis ratios are shown in Table 6 and expressed as the length of the haul divided by how long it took to review the associated video. While the overall viewing ratio for the project was 0.59, for long line vessels the average ratio was 0.66 (range: 0.47 to 0.76) and for pot/trap vessels the average ratio was 0.31 (range: 0.28 to 0.33). Trap pot boats have a noticeably lower viewing ratio due to the very long interval between the first float and the first pot not needing to be watched for catch handling and all the fish coming aboard relatively quickly in a gang of fish pots. Imagery review was most efficient when image quality was high or medium, fish came on board one by one and always in camera view, fish handling on board was consistent, and discarding took place in camera view and in a way that facilitated piece counting. Hauling fish partially out of the close up camera view, gear tangles, inconsistent fish sorting, and fish discarded partially outside camera view and/or en mass required imagery playback to be slowed down or paused and rewound to minimize the likelihood of missing something.

Table 6. Summary of EM imagery viewing and hauling times

Vessel ID	View Time	Haul Time	Average Viewing Ratio
A	141.75	186.38	0.76
B	76.20	160.61	0.47
C	102.80	150.79	0.68
D	91.92	124.21	0.74
E	21.43	65.29	0.33
F	25.50	90.39	0.28
Totals	**459.60**	**777.67**	**0.59**

Comparison of EM and Observer Catch Observations

Catch comparisons between EM and observer data (Table 7) were done for the 276 hauls that were comparable with observer records. From these hauls, observer and EM fish catch data were compared across of a total of 39 catch categories including 28 species, 1 genus, 7 families, 1 class and 1 category for 'unknown fish'. The more general classifications to genera and unknown categories by EM correspond to a lower ability to speciate some catch compared to the observers.

Similar to the 2008 EM study, EM did not attempt to distinguish between 2 species of thornyheads (*Sebastolobus spp.*) as previous experience has shown that the confidence in this identification is very low. Due to this, observer entries for shortspine (*Sebastolobus alascanus*) and longspine (*Sebastolobus altivelis*) thornyheads were grouped for comparison to EM. EM interpreters attempted to speciate all other catch.

The overall fish catch comparison between observer data and imagery data shows catch by species (or species categories) and two indices of abundance. Percent occurrence reflects the percentage of analyzed hauls where the species were detected and gives an idea of how common a species is. Table 7 also shows total pieces as recorded by observer and EM along with the total piece difference (observer pieces - EM pieces) and a percent difference calculated as (observer pieces - EM pieces)/observer pieces. This percent difference value is only shown if the number of observer pieces was greater than 50 to prevent arbitrary inflation of the percentage in small samples. Displaying both percent occurrence and total number of pieces allows the reader to calculate the average number of pieces per haul for any given species or group. Only the most common fish species are listed in the table and all others are shown as species group totals for general comparison purposes. A table with all the associated species names can be found in Appendix III.

Both observer and EM data contained over 105,000 total fish catch items with sablefish (*Anoplopoma fimbria*) being the most common species in both data sets, followed by thornyheads (*Sebastolobus spp.*). Most importantly, overall EM data contained only 1% less catch items than observer data.

For target catch, there was high level of agreement between observer and EM piece count data for sablefish with EM having 1% less, and overall rockfishes (*Sebastes* and *Sebastolobus sp.*) with 3% less difference (observer-EM). This is especially important, since they are highly valuable market and conservation species respectively. There were however differences in total pieces by species category for both sharks, flatfishes and 'other' fish.

EM detected 8% more skates than observers and of those it did identify, EM could only confidently speciate about 50% of them, failing to spot sandpaper skates (*Bathyraja interrupta*) as in the observer data. Speciation for sharks was not consistent in the two data sets either, with EM greatly over representing brown cat sharks and failing to detect three species of shark identified by the observer. This created a 17% difference in count between observer and EM data at the total sharks level.

While EM categorized just over 1000 catch items as unknown fish, this accounted for only 1% of all EM records. Most of these catch items were hard to identify due to either night hauls (especially dusk/dawn fishing on Vessel D or crew blocking the field of view).

Table 7. Summary table showing the comparison of observer and EM total catch by species or species group.

Species Name	Obs Percent Occurrence	EM Percent Occurrence	Obs Pieces	EM Pieces	Total Piece Difference	Percent Difference
Thornyheads *	65%	59%	12,906	12,074	832	**6%**
Blackgill Rockfish	9%	1%	696	43	653	
Aurora Rockfish	9%	0%	107	0	107	
Chilipepper Rockfish	0%	0%	1	0		
Pinkrose Rockfish	0%	0%	1	0		
Rosethorn Rockfish	0%	0%	1	0		
Rockfish (unidentified)	0%	23%	0	1,117	-1,117	
Total Rockfish			**13,712**	**13,234**	**478**	**3%**
Sablefish	100%	100%	**83,872**	**82,834**	**1038**	**1%**
Dover Sole	54%	4%	579	55	524	
Deepsea Sole	0%	0%	2	0	2	
Flatfish (unidentified)	0%	47%	0	408	-408	
Total Flatfish			**581**	**463**	**118**	**20%**
Filetail Cat Shark	41%	0%	5,518	0	5,518	
Longnose Cat Shark	17%	0%	359	0	359	
Brown Cat Shark	7%	0%	60	166	-106	
Cat Sharks	0%	46%	0	4,772	-4,772	
Total Cat Sharks			*5,937*	*4,938*	*999*	***17%***
Spiny Dogfish Shark	15%	6%	89	28	61	
Sharks (unidentified)	6%	11%	35	68	-33	
Blue Shark	5%	2%	31	6	25	
Pacific Sleeper Shark	1%	5%	4	19	-15	
Total Other Sharks			*159*	*121*	*38*	***24%***
Total Sharks			**6,096**	**5,059**	**1,037**	**17%**
Longnose Skate	39%	7%	1,322	215	1,107	
Black Skate	10%	0%	164	8	156	
Sandpaper Skate	7%	0%	89	0	89	
Skate (unidentified)	1%	42%	14	1,488	-1,474	
Total Skates			**1,589**	**1,711**	**-122**	**-8%**
Pacific Grenadier	9%	0%	660	0	660	
Giant Grenadier	14%	1%	239	25	214	
Grenadier (unidentified)	2%	14%	16	681	-665	
California Grenadier	1%	0%	6	0	6	
Popeye Grenadier	0%	1%	0	97	-97	
Total Grenadiers			*921*	*803*	*118*	***13%***
Unknown Fish	0%	46%	0	1,076	-1,076	
Total Other Fish			**921**	**1,879**	**-958**	**-104%**
Overall Totals			**106,771**	**105,180**	**1,591**	**1%**

* Thornyheads are grouped in this table as EM did not differentiate shortspine and longspine thornyheads. However, observer data had these species broken down and included one piece of longspine thornyhead.

On the basis of individual fishing events, the scatter plot shown in Figure 4 indicates that for almost every haul there was a very close agreement in the total number of pieces between observer and EM. This is despite there being two distinct gear types (and hence catch handling procedures) and three orders of magnitude change in total catch. When comparing EM to observer counts, there would ideally emerge a 1:1 ratio of counts over a great number of hauls. While this trend is achieved for the most part, there is the complication of comparing piece counts that range from single to triple digits per haul. For hauls that contain over 30 pieces of fish (regardless of species) using percentages makes sense, while for hauls with smaller piece counts using the difference is more appropriate (For context: 2 fish are 2% of 100 fish but 50% of 4 fish).

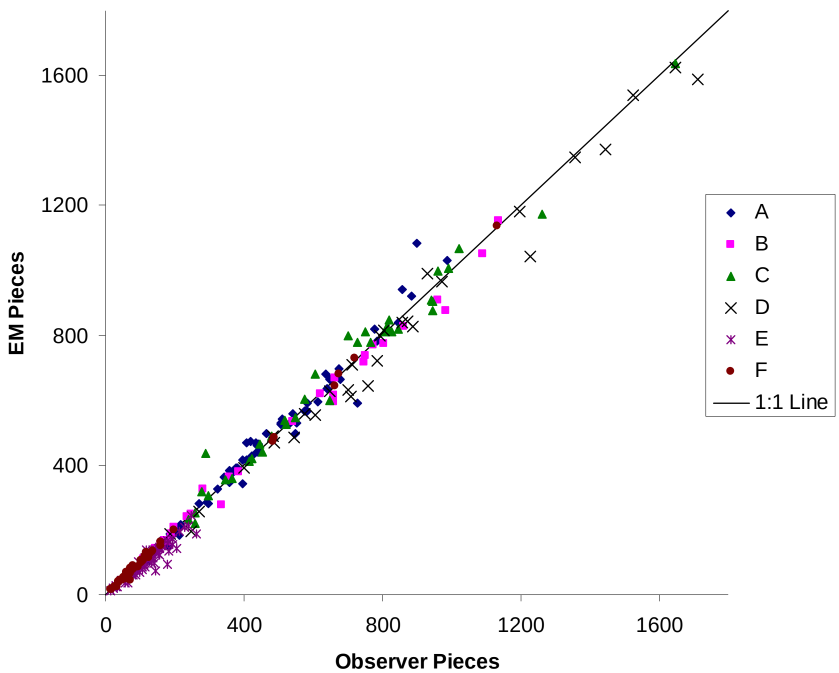


Figure 4. Scatter plot of observer data total catch versus EM data total catch per fishing event showing all Vessels and hauls. Only fish species were considered for this analysis.

Piece count differences by selected species and species categories at the haul level follow the trends seen in the total catch results (Figure 5). As the most important market species, Sablefish were very important to the fishery and piece count differences between EM and observer data show a very high level of agreement, with EM piece count being 3.76 pieces less than observer average of 304 fish per haul. Rockfish are an important species for conservation reasons and EM was accurate at reporting them, only under reporting an average haul of 75 fish by 2.72 pieces.

Sharks and flatfish were all slightly underrepresented by EM. Shark piece counts were 7.86 under the average observer count of 42 and flatfish were 0.78 pieces under the average observer count of 4 per haul. Skates were recorded by EM more often than by observers (0.98 more skates per average haul of 13) and seen on 125 of 328 hauls. The category for ‘other’ fish held a variety of species, including, but not limited to, Grenadiers, Hagfish, Ratfish and unknown fish. Despite the wide variety of species, EM tended to over represent this group by 3.67 fish per average haul of 16. The bulk of this category was the ‘unknown fish’ group at close to 50% of the piece counts.

Observers and EM image viewers used slightly different categories for catch disposition when catch was not retained. Observers recorded non-retention disposition as ‘Released’, whereas viewers categorized non-retention either as ‘Released’ or ‘Drop-off’. The ‘Drop-off’ disposition was given to catch that dropped off the gear before the fisherman had taken control of that particular catch item. Due to the differing detail in non-retained catch, catch disposition was compared after grouping EM “drop off” and “released” catch. Observer data recorded 87% of the fish catch as retained. Catch disposition comparisons of EM and observer data for total fish catch per haul are shown in Figure 10. EM slightly over-represented retention and underrepresented non-retention. Most of the outliers in the non-retained graph correspond to non-target species that EM detected when it was brought onboard, but was not detected when discarded. The discrepancy between discarded numbers for EM and observers may be inflated visually by the scale of the second graph and readers should keep in mind that the overall piece count for all species and vessels only differed by 2%.

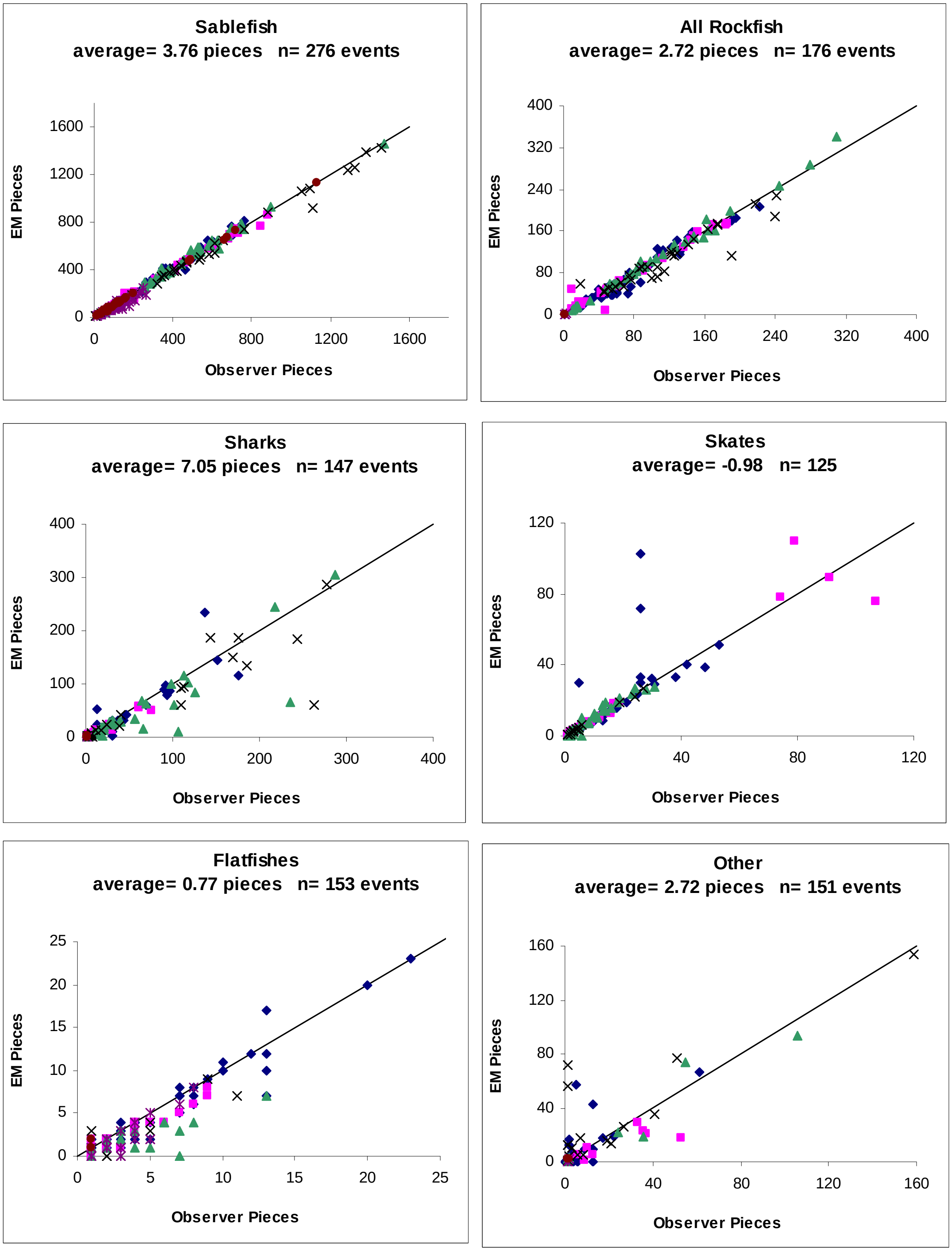


Figure 5. Scatter plots for EM data catch versus observer data total catch per fishing event for Sablefish, the most common target species, grouped rockfish and the most common bycatch species group. Each plot also shows the average observer minus EM piece difference and the total number of events compared for each species or species group. Legend for Vessel symbols is the same as Figure 4.

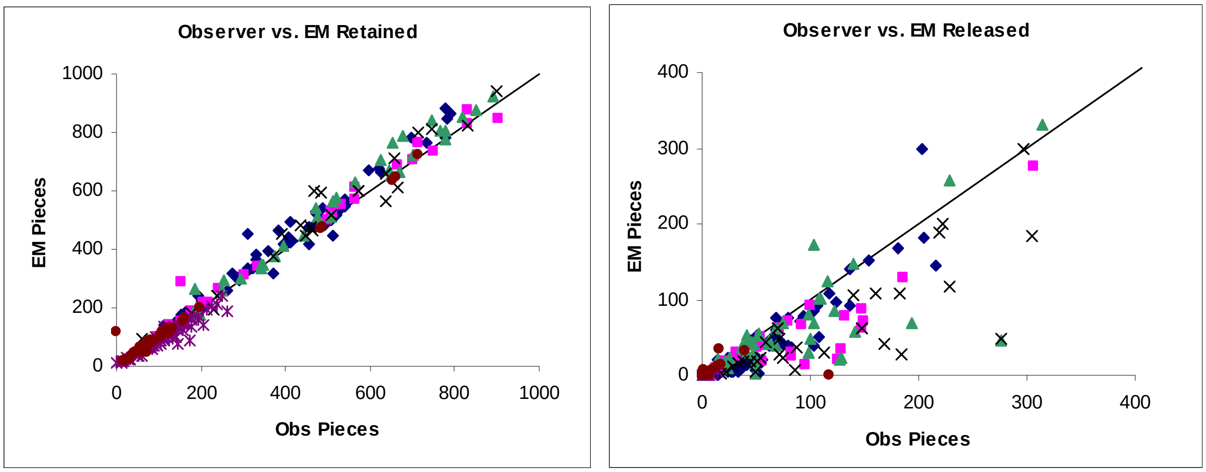


Figure 6. Scatter plot of retained and non-retained observer data total fish catch per haul versus EM data total catch per haul. The legend is the same as Figure 4.

Catch Comparison of EM and Fishing Log Observations

In the 328 events compared between EM and fishing log data, fishing logs categorized catch into 23 species, 1 genus, 7 families, 1 class and 1 unknown fish category. This was quite similar to the species list of the observer to EM comparison, except there were five fish species that observers speciated that fishers did not. The more general classifications by EM correspond to rockfish and flatfish species, while fishing log data assigned more general categories to bycatch species.

Table 8 shows the total piece comparison between EM and fishing log data (here it is calculated as 'EM – fishing log' since that is how an audit would work) by species or species category. Again the comparisons overall were good and fishing log data contained 0% different fish catch items and 1% more and 4% less items for sablefish and rockfishes respectively. Fishing log counts for flatfish, skates and sharks were less in line with EM counts, at 9% more, 13% less and 14% more respectively. Again, EM was not able to identify about 1% of the catch that was identified in the fishing log and grouped them to unidentified fish. While it is tempting to re-allocate those fish to the missed shark category, they could in fact be from any of the species listed.

Table 8. Summary table showing the comparison of fishing log and EM total catch by species or species group. (n= 328)

Species Name	FLog Percent Occurrence	EM Percent Occurrence	FLog Pieces	EM Pieces	Total Piece Difference	Percent Difference
Thornyheads *	51%	50%	11,908	12,074	166	**1%**
Blackgill Rockfish	8%	1%	666	43	-623	
Aurora Rockfish	7%	0%	98	0	-98	
Chilipepper Rockfish	0%	0%	1	0	-1	
Pinkrose Rockfish	0%	0%	1	0	-1	
Rosethorn Rockfish	0%	0%	1	0	-1	
Rockfish (unidentified)	0%	19%	0	1,117	1,117	
Total Rockfish			**12,675**	**13,234**	**559**	**4%**
Sablefish	100%	100%	**83,930**	**83,330**	**-600**	**-1%**
Dover Sole	42%	4%	506	55	-451	
Deepsea Sole	0%	0%	0	0	0	
Flatfish (unidentified)	0%	40%	0	408	408	
Total Flatfish			**506**	**463**	**-43**	**-9%**
Filetail Cat Shark	0%	0%	0	0	0	
Longnose Cat Shark	0%	0%	0	0	0	
Brown Cat Shark	0%	1%	0	166	166	
Cat Sharks	0%	39%	0	4,772	4,772	
Total Cat Sharks			*0*	*4,938*	*4,938*	
Spiny Dogfish Shark	13%	5%	759	28	-731	
Sharks (unidentified)	39%	9%	5,006	68	-4,938	
Blue Shark	0%	2%	0	6	6	
Pacific Sleeper Shark	0%	5%	0	20	20	
Total Other Sharks			*5,765*	*122*	*-5,643*	
Total Sharks			**5,765**	**5,060**	**-705**	**-14%**
Longnose Skate	0%	6%	0	215	215	
Black Skate	0%	0%	0	8	8	
Sandpaper Skate	0%	0%	0	0	0	
Skate (unidentified)	36%	35%	1,494	1,488	-6	
Total Skates			**1,494**	**1,711**	**217**	**13%**
Pacific Grenadier	3%	0%	377	0	-377	
Giant Grenadier	0%	1%	0	25	25	
Grenadier (unidentified)	15%	12%	383	681	298	
California Grenadier	0%	0%	0	0	0	
Popeye Grenadier	0%	1%	0	97	97	
Total Grenadiers			*760*	*803*	*43*	***5%***
Pacific Flatnose	0%	1%	0	18	18	
California Slickhead	5%	0%	260	0	-260	
Pacific Hagfish	0%	1%	0	3	3	
Hagfish (unidentified)	11%	3%	49	12	-37	
Pacific Pomfret	1%	0%	24	1	-23	
Spotted Ratfish	1%	1%	3	4	1	
Pacific Hake	0%	1%	0	20	20	
Unknown Fish	0%	38%	1	1,076	1,075	
Lamprey	0%	0%	0	1	1	
Total Other Fish			**1,097**	**1,938**	**841**	**43%**
Overall Totals			**105,467**	**105,736**	**269**	**0%**

* Thornyheads are grouped in this table as EM did not differentiate shortspine and longspine thornyheads.

Total catch by haul comparisons are shown in Figure 7. The average EM minus fishing log piece difference for all vessels is 0.16 pieces on or 0% of the average number pieces (322) per event. One outlier was identified in the total catch per event comparisons and was displayed with a red circle on Figure 7. This outlier corresponding to vessel C was the result of a haul total difference of 150 fish that were classified as 'unknown' by EM when none were recorded by the fishing log.

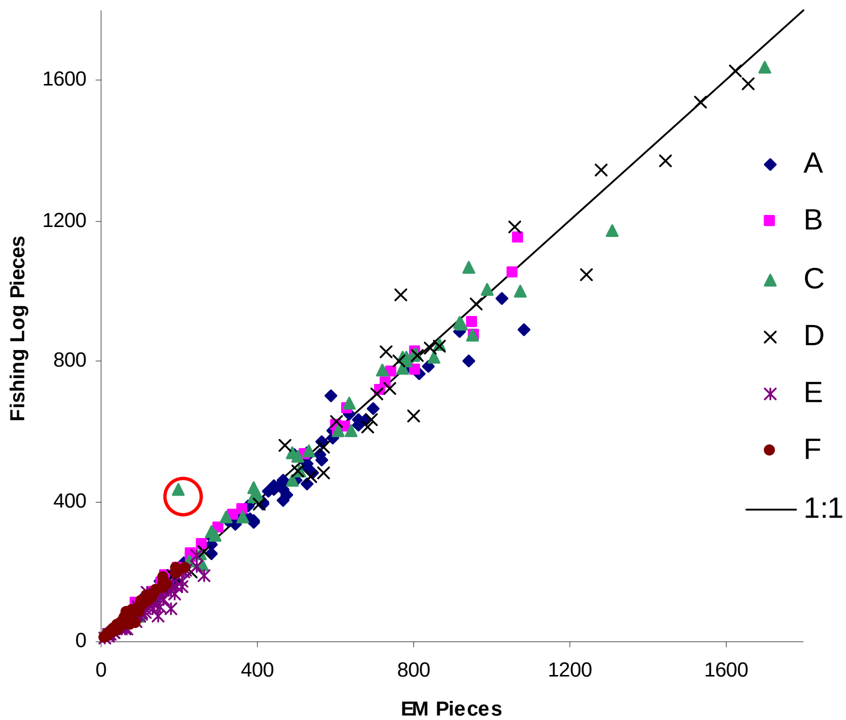


Figure 7. Scatter plot of EM versus fishing log data total catch per haul. Only fish species were considered for this analysis. Outliers displayed with a red circle are described in the text.

Similar to the EM to observer comparisons, piece count differences by species (Figure 8) for fishing logs to EM (EM – Flog) at the haul level also follow the trends seen in the total catch results. There was very high agreement between fishing log and EM piece counts for sablefish and rockfishes, with sablefish within 1% of the average number of pieces per set and rockfishes 3.23 pieces lower than the average haul size of 39. Sharks, skates and flatfishes were all very close, being 0.25 and 1.32 fish higher and 0.32 fish lower for an average haul respectively. While the panel for 'other' fish show a much larger difference between fishing logs and EM, the average difference of 4.68 pieces is greatly inflated by only a few hauls.

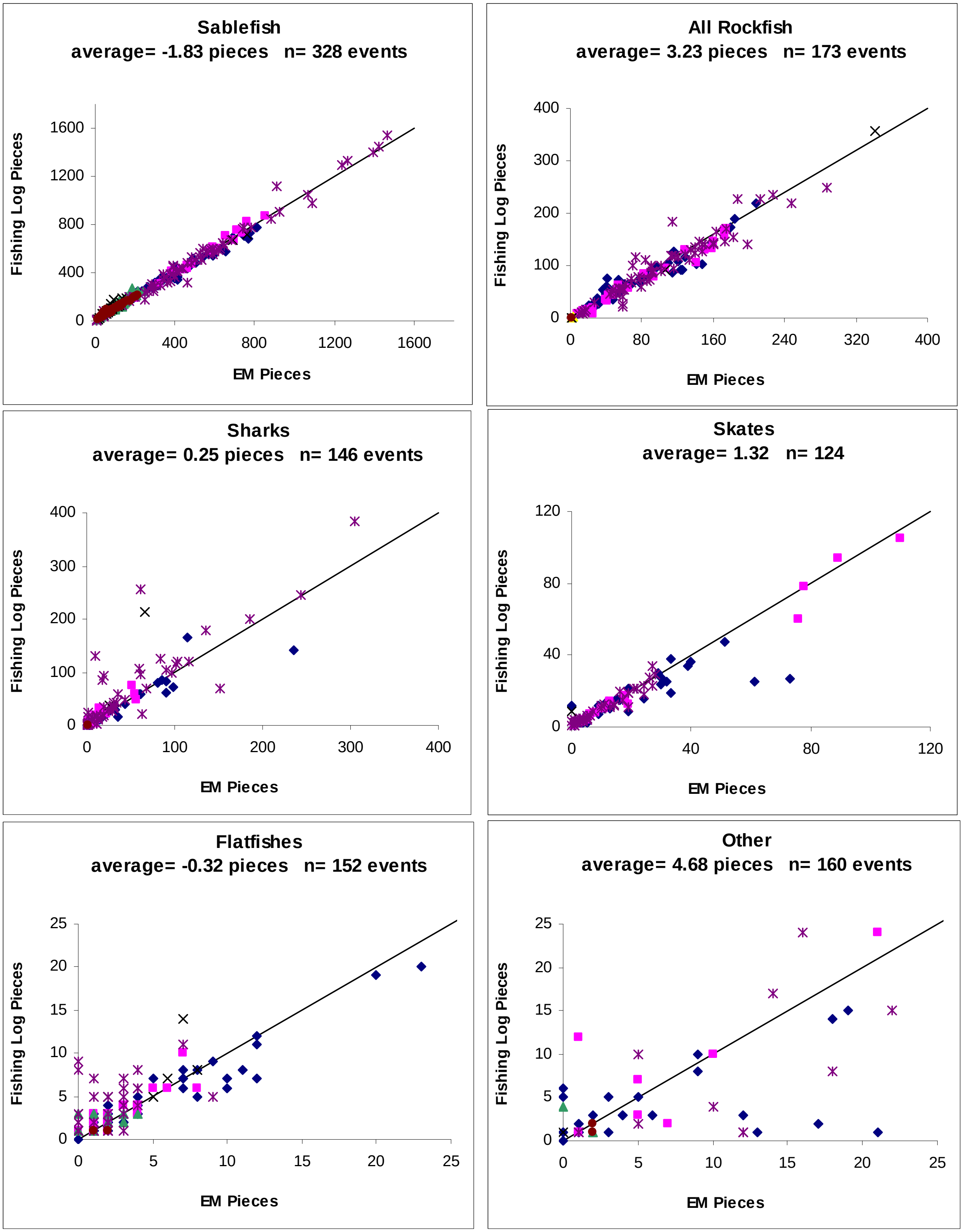
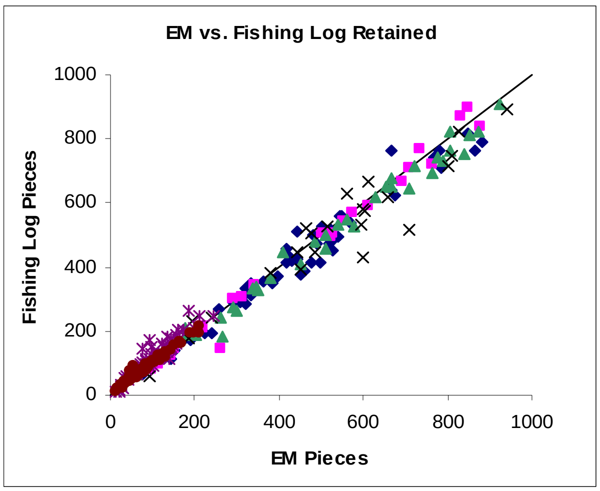


Figure 8. Scatter plots for fishing log data catch versus EM data total catch per fishing event for sablefish, grouped rockfish, and the most common bycatch species groups. Each plot also shows the average EM minus fishing log piece difference and the total number of events available for each comparison. The legend is the same as Figure 7.

Catch disposition comparisons of EM and fishing log data for total fish catch per haul are shown in Figure 9. Fishing log data recorded 90% of the fish catch as retained while EM recorded 91% as retained. EM slightly over-represented retention and underrepresented non-retention. Most of the scatter in the non-retained graph corresponded to bycatch that EM detected when it was brought onboard, but was not detected when discarded as it was discarded by observers outside of camera view. Discrepancies between discarded numbers for EM and fishing logs may be inflated visually by the scale of the second graph and readers should keep in mind that the overall piece count difference between EM and fishing logs for all species and Vessels was 0%.



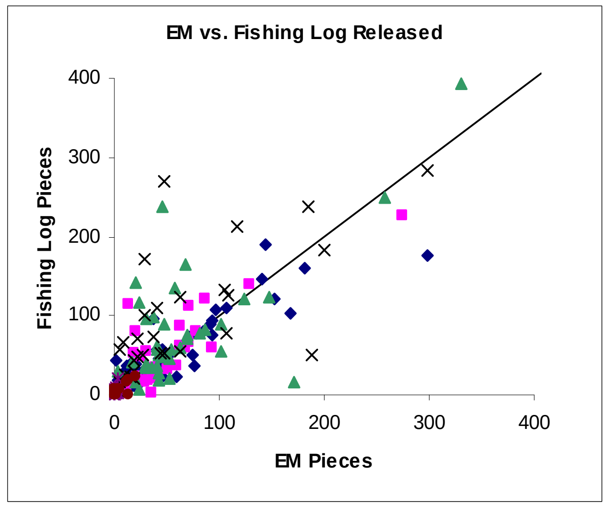


Figure 9. Scatter plot of retained and non-retained fishing log versus EM data for total fish catch per haul. The legend is the same as Figure 7.

Viewer Comparison and Quality Control

Twenty-six hauls were reviewed a second time by experienced viewers at Archipelago. Of that sample, only 1 was rated low quality for viewing. Two questions were asked when comparing the primary and secondary viewing data: 1) Compared to observer data, did secondary viewing improve on the data from that of primary viewing. Here we use 'improved' to mean that the difference between observer and secondary counts was smaller than the difference between observer and primary counts. 2) Were the secondary counts consistent with the primary counts. Here 'consistent' means that there was less than or equal to a 3% change in value between secondary and primary.

In the majority of cases, (Table 9) secondary viewing resulted in catch counts that were closer to the observer's count than primary. Of the 18 hauls where the counts were improved, 16 of them also had piece counts that were inconsistent with the primary viewing. This means that 16 of the 26 hauls recounted had piece counts that were closer to the observer's count and more than 3% different from the primary count.

Table 9. Comparing the catch count between primary and secondary viewers for 26 hauls stratified across all 6 participating vessels.

Event ID	Image Quality	Observer	Primary Viewing	Secondary Viewing	Consistent	Compared to Obs
1	M	409	467	456	Consistent	Improved
2	M	125	105	121	Inconsistent	Improved
3	M	183	149	181	Inconsistent	Improved
4	M	179	161	177	Inconsistent	Improved
5	M	985	876	965	Inconsistent	Improved
6	L	759	642	807	Inconsistent	Improved
7	M	246	197	225	Inconsistent	Improved
8	M	180	93	190	Inconsistent	Improved
9	M	58	35	58	Inconsistent	Improved
10	M	145	75	145	Inconsistent	Improved
11	H	74	46	70	Inconsistent	Improved
12	H	35	26	33	Inconsistent	Improved
13	H	61	47	61	Inconsistent	Improved
14	M	804	815	815	Consistent	Equal
15	M	1196	1181	1229	Inconsistent	Unimproved
16	M	793	798	816	Consistent	Unimproved
17	M	1022	1069	1069	Consistent	Equal
18	M	606	681	671	Consistent	Improved
19	H	517	538	546	Consistent	Unimproved
20	H	278	316	317	Consistent	Unimproved
21	M	290	436	450	Inconsistent	Unimproved
22	M	947	904	962	Inconsistent	Improved
23	M	946	875	973	Inconsistent	Improved
24	H	366	357	371	Inconsistent	Improved
25	M	815	823	827	Consistent	Unimproved
26	M	1263	1173	1345	Inconsistent	Improved

This points out an important aspect of both this project and any planned implementation of EM monitoring for fisheries management; proper training and ongoing QA/QC is an essential component of these programs. The catch comparisons by total count and species composition for the EM data used in this report were well aligned with observer results. However, these results were gathered by staff that had been recently trained to build local capacity and were only able to receive an amount of training appropriate to a pilot project. Continued work experience and additional time spent on training would improve these results.

4. Development of a Fishing Log Audit Methodology

EM data can be used as a stand alone at-sea monitoring system when catch is estimated by reviewing all fishing events. In this census-style program the resulting effort and catch data derived from EM would be directly used for quota management. An alternative use of EM data is with an audit-based monitoring program. Since EM data collection and data processing and analysis occur at different stages, the technology allows to for capture of all fishing activity at-sea without the need to engage in data interpretation for all of it. However, EM captures all of the fishing activity and it can be used to fully reconstruct a fishing trip in cases where the fishing log is not deemed accurate. Benefits of an audit-based monitoring program include (Stanley, in press):

- Cost and logistically efficient monitoring since 100% coverage is achieved but only a portion of the data needs to be interpreted and analyzed when no data quality issues are detected
- Compels fishers to be involved in data reporting resulting in higher industry engagement and incentivizes improving the quality of the data provided.
- Provides catch estimates that are transparent, intuitive, and trusted by fishers since they are derived from self-reported records.
- Provides motivation for compliance since random selection of events acts as a 'radar trap'.
- The random sample of EM data reviewed serves as a virtually independent and unbiased estimate of catch (Stanley et al., 2009).

Over the last six years, Archipelago Marine Research, Ltd. has been highly involved in the development and implementation of this type of audit program in the British Columbia, Canada hook-and-line and trap fishery. Based on this experience and the findings from the 2008 and 2010 Morro Bay EM pilot studies, we propose the following framework to serve as a starting point for developing an audit program for the Morro Bay fixed gear fishery in particular and the West Coast groundfish fishery in general.

The design of an audit depends largely on the objectives of the monitoring program. This audit framework is based on our perceived catch monitoring needs to:

- account for all catch by species (both retained and released) in the fishery;
- account for all fishing activity (time and location); and
- monitor compliance of full rockfish retention.

In addition to using EM data, we strongly suggest considering using dockside monitoring data to further validate the fishing log for retained catch, for example in terms of ensuring all catch recorded as retained in the fishing log are landed and confirming identification of similar species. For this reason we have included the use of dockside monitoring data in the proposed audit framework.

The audit would be composed of three different comparison categories (Figure 10). First, we recommend that all sensor data be interpreted to determine data completeness, EM system performance, and time and location for all fishing activity. Second, a certain proportion of fishing events would then be randomly selected to account for catch. The BC hook-and-line fishery, for example, selects 10% of fishing events per trip with a minimum of one event (i.e., if the total events are less than 14, one fishing event is reviewed; if the total events are between 15 and 24, two fishing events are reviewed, etc.). Finally, total pieces recorded as retained in the fishing log would be compared to piece counts from the dockside monitor data. An additional phase of verification involving prioritizing certain fishing events considered high risk or where rare events have been reported (e.g. fishing in closed areas) could also be added as the program matures.

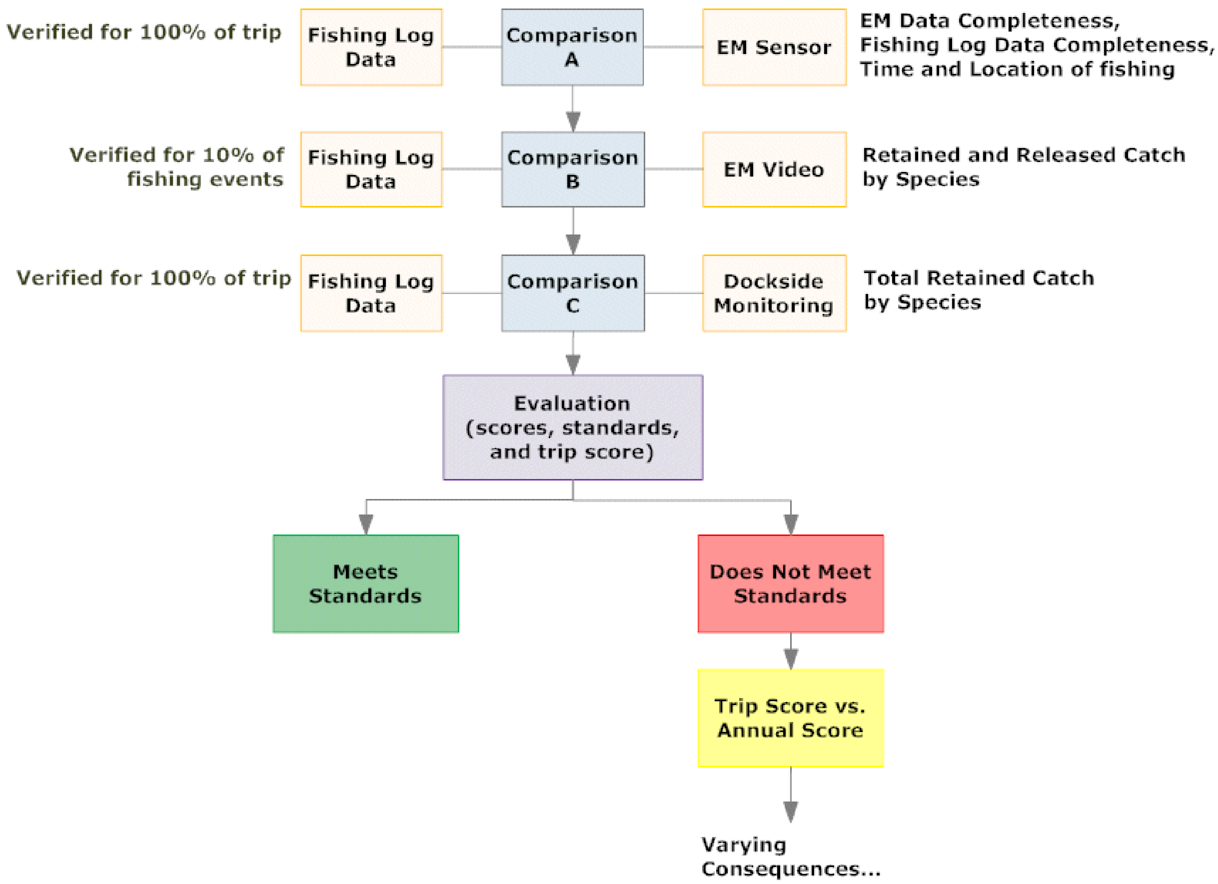


Figure 10. Conceptual audit model of the proposed comparisons to verify fishing log data.

To evaluate the data quality of logbooks against EM, the data would be put through several tests and we propose using the three different layers of evaluation methods described below. The tests shown in Table 10 are presently in use in BC and could be used as a starting point in designing the audit-based monitoring program validation for NOAA in the West Coast groundfish fishery. Further details on scores, standards and vessel history rules are described in Appendix III.

Catch evaluation is a primary focus of the monitoring program in the Morro Bay fixed gear fishery and the West Coast groundfish fishery in general and likely the most complex aspect of the audit system. This complexity is inherent in monitoring a mixed-species fishery, since there are several different species retained and/or released in a given haul and each of them has a different priority from a conservation and fisheries management perspective. The audit program must be sensitive to this level of complexity in the fishery. To start with, not all species need to be tested (even if catch information is still recorded for all), and of those tested, not all need to be tested to the same level of detail. A nested approach to testing catch would therefore be appropriate, i.e., some species may be tested separately while all catch items are pooled and tested at the haul or trip level.

Table 10. Suggested tests and evaluations to be performed in a fishing log audit using EM data.

Test	Evaluation Method	Score/Standard Example	Result
Fishery management issues			
Species / Species Groups by Utilization	Scoring; Standard met or not met; Score matrix.	Score based on piece counts for quota species (Table IV.1); Standard based on risk- further discussion needed	Feedback for first two years, then feedback and consequences.
Fishing time*	Standard met or not met	Within one hour	Feedback
Fishing location*	Standard met or not met	Within one nm	Feedback
Fishing management area*	Standard met or not met	Match	Feedback
Data Completeness issues			
EM data captured	Scoring; Standard met or not met; Score matrix.	Score based on amount of data lost and risk (e.g. transit vs. data loss at fishing grounds)	Feedback for first two years, then feedback and consequences.
All fishing events recorded in the Fishing Log	Scoring using dockside monitoring data; Standard met or not met	Score based on piece counts for quota species (Table IV.1); Match	
Fishery Rules issues			
Full retention of all rockfish	Standard met or not met	No rockfish species observed as discarded	Feedback for first two years, then feedback and consequences.

* Further discussion is needed to determine if both set and haul information would be required or just one or the other.

The structure of the proposed audit program is a series of steps that include collecting data, evaluating data, and providing feedback. Each stage of the program involves both fishers and managers, so that communication is ongoing. The structure of the program is outlined in a conceptual model (Figure 11). The process begins with a skipper completing a fishing trip, recording catch in the fishing logbook, and using EM equipment to collect data. Both the EM and fishing logbook data sets would then be used for processing, auditing and scoring of the trip.

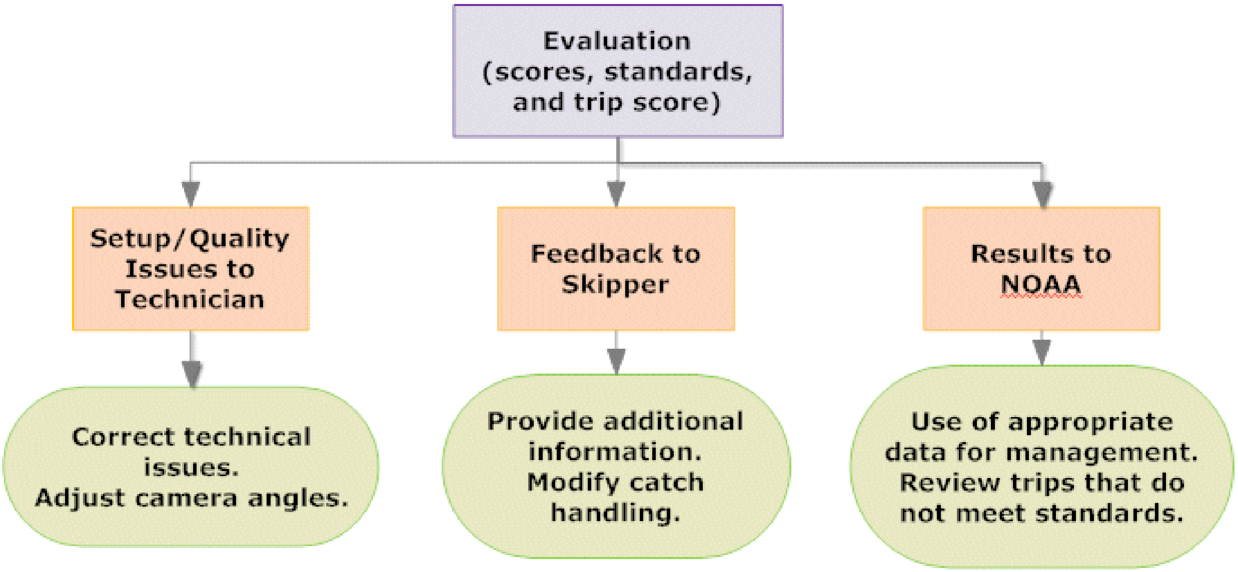


Figure 11. Conceptual model of the feedback that could be generated from the fishing log audit process to the different user groups.

Following review of the EM data, fishers and managers would be provided with a trip report summarizing the trip data and any comments on the logbook data quality. If the audit did not meet standards NOAA would make a decision on whether a full review of EM data was necessary for use in quota management. At the same time, the skipper would be given an opportunity to explain any discrepancies. If necessary, information would also be provided to the EM technician to make adjustments to the EM equipment onboard. The fisher then would take another fishing trip and the process begins again. The feedback loop allows fishers, and managers as required, the opportunity to get feedback on a continual basis and make adjustments so that data collection and quality improves.

Based on previous experiences with other similar fisheries, this feedback loop is integral to ensuring success of the program. We have seen that fisher logbooks can become a highly reliable source of data if the appropriate checks and feedback loops are put in place. The success of an EM audit-based monitoring program will be dependent on industry buy-in from an early stage, and the process and end result needs to be transparent so that all stakeholders will trust the resulting data. The collection of data for monitoring depends on fishermen completing forms, running equipment, adjusting certain catch handling behaviour, and reporting data. Findings from the 2010 Morro Bay EM Pilot Study show strong industry involvement in data collection: 100% compliance in filling out complete fishing logs, and high compliance in maintaining the EM equipment running (332 out of 338 hauls captured by EM and overall close comparisons of fishing log catch data per haul to EM).

It is advisable that an audit-based monitoring program be implemented in stages, and that during the first one or two years the emphasis is on providing feedback to industry, polishing the process and analyzing the information gathered to understand where most of the data quality issues or risks are. For the first year, scores and standards may be more like guidelines for each vessel, so that skippers are able to understand where their data records sit within the set out expectations. It would not be advisable to begin implementing consequences for poor data quality until the program is well understood by industry and vessels operators know where they sit in relation to the standards and within overall fleet performance. The goal of an audit-based program is to obtain good quality data from industry by setting challenging but realistic goals.

5. COST STRUCTURE CONSIDERATIONS FOR EM PROGRAMS

Many factors influence cost in a monitoring program (Table 11). Some of them are determined by how the fishery operates (external factors) and others are directly related to decisions made around how the program itself operates (internal factors). It is important to note that although the same factors would need to be considered when structuring costs for any monitoring program, observer or EM, different monitoring programs may have different degrees of sensitivity to a particular factor. For example, an EM program would be less impacted by highly erratic fishing schedules than an observer program due to the ability of ensuring an operational EM system at all times and little to no cost to the program in the case of a cancelled trip vs. ensuring observer availability at all times and the costs associated with cancellations. In contrast, an observer program would be less sensitive to higher requirements for service decentralization than an EM program due to the higher infrastructure requirements needed to service equipment and retrieve data. Most of the internal factors that would influence cost on an operational EM program for the Morro Bay fixed gear fishery remain to be defined.

The cost structure of the Morro Bay EM pilot study does not provide an accurate representation of monitoring costs as the pilot study was structured very differently than a mature operational EM program would. The cost of the pilot study should be much larger than the cost of an operational EM program for three main reasons. The first reason is that the current pilot study was staged from Canada and focused on building local capacity, which resulted in expensive travel and training costs as well as necessary duplication of labour between Tenera and Archipelago staff as both groups needed to be tracking the same information related to the management of the project. These capacity building costs are expected to be the highest during pilot studies and decrease noticeably as EM programs are implemented.

Table 11. Factors that influence the cost structure of an EM and observer program.

Factors	Examples
External	
Fishery activity	Number of vessels, landing, fishing events and seadays
Port use patterns	Temporal and spatial distribution of the fishery
Internal	
Analysis and reporting requirements	Data product delivered
Overall maturity of data model	Integration of data from different sources and flow of monitoring data to quota system
Degree of program centralization	Management of the program operations centralized vs. replication necessary at various levels
Cost recovery method	Division of cost responsibilities between government and industry as well as within industry
Program responsiveness	Reporting timelines
Feedback and outreach processes	Reports, meetings, one-on-one feedback
Performance tolerances	Data quality requirements. If audit-based: additional analysis required based on initial results
Audit method and coverage level *	Amount of data that requires interpretation as well as level of detail within interpreted data

* Only a factor for audit-based programs

Equipment costs are the second reason cost structures would be significantly different between a pilot study and an operational program. This project leased equipment for the entire duration of the study whereas in an operational program equipment is often purchased and, although upfront capital costs are high, the cost of equipment is amortized across the total seadays for the lifespan of the equipment. Given that EM systems have historically lasted for up to 10 years of operation, this amortization can be significant.

The third reason for differences in cost structure was that for this study, as is true for other pilot studies, reporting requirements were complex including the writing of an interim and a formal final report with ad hoc data analysis and summaries. Once reporting requirements for an operational EM program are defined, reporting is done in a standardized way for all trips. This has the added benefit of ensuring that trips with high quality data follow a streamlined process with little or no additional time needed for further investigation to provide feedback whereas trips with fair or poor data quality follow a different path in which additional time is needed for investigation or feedback and may cause a delay in reporting along with additional expenses for the fisherman in question.

The best insight into cost structure for an EM program comes from analyzing data from existing mature EM programs for which all inputs and outputs have been defined; such as the BC hook-and-line catch monitoring program (Table 12). The BC hook-and-line monitoring program is an audit-based EM program that delivers a finished data product for a yearly average cost per vessel of 194 $CDN (~200 $USD) per seaday or 3.2% of the landed catch value on average (median 4.7%) (Stanley *et al*., in press). Beyond EM monitoring, this cost also includes hail, fishing log and dockside programs as well as data editing and consolidation for all these separate programs. The monitoring program includes all data collection, interpretation and reporting to generate a finished data product, i.e. audit report and appropriate quota deductions. Some of the external and internal factors for this fishery are:

External

- 202 active vessels, 1,323 trips, 11,545 seadays and 23,192 fishing events per year
- Total landed weight of 11,789 tons with a value of 75 million Canadian dollars
- Operates out of six main ports but service is provided for a total of close to 30 ports across the BC coast.

Internal

- EM data must be retrieved after every fishing trip.
- Finished data product must be available to industry and fisheries managers within five days of landing, unless audit fails to meet standards.

Table 12. Summary of BC hook-and-line catch monitoring program costs for the 2009/2010 programme year, including funding from both industry and the Department of Fisheries and Oceans Canada and covering on average 3.2% of the landed catch value (median 4.7%) for each vessel. (Stanley *et al*., in press).

Monitoring programme	Average cost vessel^{-1} year^{-1} ($CDN)
Hail programme	$236
Logbooks	$312
Dockside monitoring	$2 890
EM equipment	$1 760
EM field services	$3 889
EM data services	$2 891
EM subtotal	$8 540
Total programme costs	$12 053
Cost per trip	$1 840
Cost per sea-day	$194
Cost per kg landed	$0.21

When all cost factors are equal, independent at-sea monitoring program options in order of lowest to highest cost are audit-based EM programs, EM census programs, and observer programs. The EM portion of the BC hook-and-line program accounts for ~70% or roughly a yearly average cost per vessel of 136 $CDN (~140 $USD) per seaday. Stanley *et al.* (2009) estimate that, using the same external and internal factors already defined in the BC hook-and-line catch monitoring program, if the audit-based program was substituted with an EM census program (i.e. 100% review of all video) the EM costs would increase to 274 $CDN (~280 $USD) per sea day, and logistical challenges and potential additional costs would be introduced in order to meet the five day turnaround timeline. The closest estimate we have as to what an observer program would cost for this fishery comes from the offshore trawl fishery in BC which is 580 $CDN (~597 $USD) per seaday (although the BC offshore trawl fishery operates with 50 vessels and 4,500 seadays per year). Although these numbers are estimates, they offer valuable insight on the differences that could be expected from considering these different methods.

6 . DISCUSSION

The findings involving fishing activity time and location interpretation, catch comparisons, image quality, and catch handling, are consistent with previous work done for the 2008 EFP. Our recommendations are geared towards implementing an audit-based monitoring program using EM in the Morro Bay fixed gear fishery in particular and the West Coast groundfish fishery in general.

6.1 TECHNICAL ASSESSMENT OF EM SYSTEM

The 2010 study successfully expanded the data collected in the 2008 study by deploying equipment on six vessels for a collective total of 97 fishing trips, over 124 days at sea of EM data, and a total of 332 fishing events detected by EM. Data collected in the 2010 study represents double of that collected in 2008 by number of vessels and fishing events. Overall sensor data capture success was about 91%, however, if the equipment had not been manually turned off at the beginning and end of some trips, the capture success could have been increased and that data lost is of low risk. Six hauls were not captured by EM due to power interruption to the system and five of those corresponded to the same trip in which the EM system was only powered for 1.4 hours at the fishing grounds.

System performance and data collection success from the 2008 and 2010 studies show that it is possible to achieve virtually complete data from fishing activity using EM (97% of hauls were complete and usable for comparisons in both studies and in 2010 EM was compared to 97% of hauls detected by observers or fishing logs). More rigorous checking of the system performance before a trip starts and during the trip can further decrease the likelihood of data loss. These checks can be achieved through adequate rules within an operational monitoring program.

A further expansion in the data collection for the 2010 study was the addition of two pot/trap gear vessels in addition of longline gear vessels. Although detecting hauls from EM data was straightforward for longline gear, pot/trap vessels proved to be more challenging for detecting gear setting and matching it to hauls. One of the vessels also proved to be much more challenging for catch assessment than the other pot/trap vessel and all of the longline ones. This was caused mostly by the way catch was handled (more than one person sorting catch out of the hopper simultaneously) and periods of time when the camera view of the hopper being partially blocked by a rope. This particular challenge illustrates that not only gear differences need to be taken into account when setting up EM equipment on a vessel, but that vessel specific deck layouts and the associated catch handling are key considerations.

EM interpretation of hauls was straightforward for both longline and pot/trap gear. Overall there were few issues detected around imagery quality and catch handling. The number of medium and low quality imagery was largely due to crew and observer behaviour and inadequate lighting during night hauls in one of the longline vessels, a problem that is easily addressed in operational EM monitoring systems by providing feedback to the fishermen and making proper lighting a requirement. In fact, EM was able to successfully determine individual hauls for pot/trap gear which was problematic for the skippers and observers at first. Based on EM data early in the study it was possible to adjust the methodology for recording pot/trap fishing events in the fishing log and correct some of the observer data records. Although hauls were easy to detect, sets were only consistently detected for longline gear but inconsistent for pot/traps. Difficulties for detecting pot trap setting were primarily due to gear being set in different trips from when it was hauled as well as the short duration of those sets (five minutes for Vessel F).

> **Recommendation #1:** We recommend developing an audit-based monitoring program structure with clear expectations for complete EM data collection (i.e. EM systems continually powered while the vessel is at sea). The program may require system checks before every fishing trip and for skippers to report any issues to the service provider. Rules around procedures in the case of system problems while the vessel is at-sea will need to be discussed.

> **Recommendation #2:** We recommend that a document be created for each vessel that details the EM system setup (including camera views), accepted catch handling procedures to ensure they are aligned with EM cameras, deck lighting, etc. This 'Vessel Monitoring Plan' would be based on the initial install interview with the skipper and would serve as the basis for any feedback from data processors. The document would be a valuable reference to the EM service provider and the fishermen.

> **Recommendation #3:** We recommend that the feedback mechanism between EM service providers and fishermen be based on the 'Vessel Monitoring Plan' and include information on amount of data collected per trip, catch handling procedures, and other items related to EM data quality that may affect interpretation.

> **Recommendation #4:** If EM detection of setting activity was deemed a necessary component of at-sea monitoring program, we recommend experimenting with the use of radio frequency identification (RFID) tags to mark each line of gear. This would allow video triggering during setting to confirm sensor data time and location of setting activity for pot trap vessels and would enable connecting set and hauls together, even across different trips.

6.2 Efficacy of EM for Catch Accounting

The basic study design to measure the accuracy of EM data used observer data as a benchmark. The assumption in this design was that observer data are currently the accepted standard in at-sea monitoring so the evaluation consisted of determining how well EM results would match observer data. However, a key problem with the method is that observer data also contain errors (Karp and McElderry, 1999). Observer error was not measured in this study but should be kept in mind in interpreting the results of this study. The lack of agreement between observer and EM catch results can be partly attributed to unknown amounts of observer error.

Both observers and EM recorded over 105,000 pieces of catch. Fish catch was lower in observer data than in EM data with a 2% overall piece difference. These results were consistent with other studies in longline fisheries in British Columbia (McElderry *et al*., 2003), Antarctic (McElderry *et al*., 2005), New England (McElderry *et al*., 2007), New Zealand (McElderry *et al*., 2008), Florida (Pria *et al*., 2008) and Hawaii (McElderry *et al*., 2010).

The two most important species groups were rockfishes, including thornyheads, and sablefish, for their conservation and market values respectively. EM was very successful at detecting both and identifying catch to species groups when compared to observer data. Rockfishes had an overall difference of -4% and sablefish 1% (observer-EM). In terms of rockfish identification, EM was not able to speciate thornyheads due to the similarities between the two species and classified them as a group. Non-retention of rockfish in this study was small, with 92% of the thornyhead catch retained according to observer data. EM data for this study only had 1% identified as drop offs as well, showing that this is not a very common occurrence.

> **Recommendation #5:** We recommend establishing a full rockfish retention rule as it was done in this study's EFP as it creates a situation where rockfish species identification can be done at the time of landing by a dockside observer since they have the advantage of handling the specimens to ensure proper identification. Rockfish discarding during transit back to port can be detected by comparing the total number of retained rockfish in the fishing log versus the number of rockfish counted at the dock. The verification of fishing log data using randomly selected EM events ensures that retained rockfish are properly accounted for at the fishing event level (mainly for area fishing information). Additionally, we recommend exploring the possibility of using depths associated with each fishing event to better determine rockfish species due to their vertical segregation in the water column.

Flatfishes and non target species also had high agreement at the species group level, but EM did not account for the full species diversity as compared to observer data. Flatfishes and bycatch also accounted for most of the discrepancies in catch disposition. Although total catch per haul had high agreement between observer and EM data, overall EM had more catch recorded as retained compared to observer data likely meaning that EM was able to detect the catch as it came on board but not its disposition. This was mainly due to catch handling procedures on deck as not all points of discard were in camera view and the observer often discarded catch en mass from a basket, not allowing for proper piece counting. The best way to deal with this problem would be through the development of more standardized catch handling procedures and modifying the camera positioning to best match these catch handling practices, or compare total catch from EM to dockside counts as the difference can be accounted to discarding. In a project setting where there is no observer on board, some of these problems would be also be eliminated as catch would not have to get put aside for sampling and the observer would not be trying to discard catch away from fishing operations to minimize obstruction.

> **Recommendation #6:** We recommend that a subset of trips without observers be considered for participating vessels. This will allow the examination of the effect that observers have on

EM catch accounting, catch handling behaviour and fishing log entries. This will be a highly important step in any transition to any fisheries management procedure using EM systems. It would be advisable to begin this with a lower-risk section of the fishery, for example vessels that are targeting deep water species and are less likely to encounter overfished rockfish species. Using these criteria, many of the trips monitored as part of this study could be selected for inclusion in this test.

Recommendation #7: Once EM is monitoring non-human observed trips, there will be a period for fishermen to establish consistent catch handling processes to facilitate catch disposition detection by EM, which would increase efficiency of the imagery review and could also improve efficiency of catch processing. Feedback from EM data processors will play a key part in achieving this as well as the documentation process for the Vessel Monitoring Plan.

6.3 Efficacy of EM for Auditing Fishing Log Data

An improvement seen from the 2008 study was that in the current study all fishing events were recorded by the fishing log. Although ensuring proper alignment between EM and fishing log data using date and time information was still challenging in some cases, all fishing events captured by EM were able to be aligned with fishing log records. In an audit-based monitoring program where fishermen are paying for at least part of the processing cost, there are economic incentives for providing data that facilitates adequate alignment with EM.

Recommendation #8: Improved data collection can be achieved by providing in season feedback to the fishermen using the audit framework proposed in this report. Alignment between the two data sets can also be aided through the proposed feedback from EM data processors, using the event marker function available in the EM system to mark sets and hauls in the EM data record, and the use of electronic fishing logs that facilitate data merging.

Fishing log data had very high agreement for target species catch records with EM, with fishing log underestimating both rockfish and sablefish pieces per set by 2% of the EM average piece counts. Another improvement from the 2008 study was better alignment in catch between EM and fishing logs, especially as it related to released catch. Even though there is room for fishermen to improve their data for released catch, modifications in the fishing log design since 2008 allowed for better records of discarded catch in the fishing log and are reflected in this study's results. This was most notably in the degree to which released catch was speciated in the fishing log but also in some improvement on the pieces recorded per species.

The audit framework proposed in this report is intended to act as a starting point in discussions as many details would still need be to worked out. Discussions around implementing an audit-based monitoring system

Recommendation #9: We recommend that further work towards implementing an audit-based monitoring program includes discussions about which species will be tested. Species with quotas and those with higher conservation risks should be considered. Other species may be incorporated into the audit evaluation as the program matures.

6.4 CONCLUSIONS

Implementing monitoring programs using EM technology with the fixed gear fishery in Morro Bay and other parts of West Coast should start with discussions between all stakeholders since the monitoring program must meet the needs of fisheries managers, while buy-in from industry is essential to the success of the program. An audit-based program to validate fishing log data using EM and dockside monitoring would be the most valuable approach for the reasons described above; including its potential for cost-effectiveness, providing transparent catch estimates, and engaging industry in the monitoring of their fishery. This project has led to two key conclusions for moving forward in developing an audit-based model of fishing log data:

1. Consistent with the findings of the 2008 study, EM has been demonstrated to be an effective tool for at sea monitoring, delivering fishing effort and catch data comparable to on-board observers. There is no need for continuing to concentrate future efforts on comparing EM data with observer data. Next steps should concentrate on developing a comprehensive monitoring program involving tools such as fisher logbooks, dockside monitoring, EM, and supplemental observers as necessary. Lower-risk parts of the fishery could be monitored with EM at first, such as trips where fishing activity is concentrated exclusively in deep waters.

2. Further work involving EM as an audit-tool should concentrate in continuing to define the audit. The audit framework described above should be used as a basis for discussion on how a program of this type would work in the Morro Bay fixed gear fishery and elsewhere in the West Coast. Fisheries managers would be required to establish the requirements of the program and fishermen would then be able to engage on how to achieve those requirements. Some of the questions that require an answer from fisheries managers include: which species should be tested, what is an appropriate turnaround time for audit results, what should the incentives and disincentives be to achieve the desired data quality from logbook data.

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APPENDIX I – EM TECHNICAL SPECIFICATIONS

Overview of the EM System

The EM systems operate on the ship's power to record imagery and sensor data during each fishing trip. The software can be set to automatically activate image recording based on preset indicators (e.g. hydraulic or winch threshold levels, geographic location, time of day,). The EM system automatically restarts and resumes program functions following power interruption, or if a software lockup is detected. The system components are described in the following sections.

Control Box

The heart of the electronic monitoring system is a metal tamper-resistant control box (approx. 15x10x8" = 0.7 cubic feet) that houses computer circuitry and data storage devices. The control box receives inputs from several sensors and up to four CCTV cameras. The control box is generally mounted in the vessel cabin and powered from the vessel electrical system (Figure I.1). The user interface provides live images of camera views as well as other information such as sensor data and EM system operational status. The interface has been designed to enable vessel personnel to monitor system performance. If the system is not functioning properly, technicians can usually troubleshoot the problem based on information presented in the screen display.

EM systems use high capacity video hard drives for storage of video imagery and sensor data. The locked drive tray is removable for ease in replacement. Depending upon the number of cameras, data recording rates, image compression, etc., data storage can range from a few weeks to several months. For example, using the standard recording rate of 5 frames per second, data storage requirements are 60-100 megabytes per hour, depending upon the image compression method. Using a four-camera set up and 500-gigabyte hard drive, the EM system would provide continuous recording for 52-86 days.

Figure I.1 EM control box and user interface installations on two different vessels.

EM Power Requirements

An EM control box should be continuously powered (24hr/day) while the vessel is at sea. The EM system can use either AC or DC electrical power, however, DC is recommended. In the case of AC power, the control box is generally fitted with a universal power supply (UPS), to ensure continuous power supply. The recommended circuit capacity for an EM system is 400 watts if using 110-volts AC, or 20 amps with 12-volts DC. The EM system amperage requirements vary from about 6 amps (at 12-volts DC) when all cameras are active, to less than 3 amps without cameras (sensors only), and about 20 milliamps during the 'sleep cycle'. The EM system continuously monitors the DC supply voltage and can be set to initiate a sleep cycle to save power when the vessel is idle and the engine is off, and shut off completely when vessel power drops below critical levels. During the sleep cycle the EM system box will turn on for 2 minutes every 30 minutes to check status and record sensor data. The EM system will resume functions when the engine re-starts.

CCTV Cameras

Waterproof armoured dome cameras are generally used (Figure I.2), as they have been proven reliable in extreme environmental conditions on long-term deployments on fishing vessels. The camera is lightweight, compact and quickly attaches to the vessel's standing structure with a universal stainless steel mount and band straps. In general, three or four cameras are required to cover fish and net handling activity and areas around the vessel. In some cases it is necessary to install a brace or davit structure in order to position cameras in the desired locations (Figure I.3).

Color cameras with 480 TV lines of resolution and low light capability (1.0 lux @ F2.0) are generally used. A choice of lenses is available to achieve the desired field of view and image resolution. The cameras have an electronic iris that adjusts automatically to reduce the effects of glare or low light levels on image quality. The output signal is composite video (NTSC) delivered by coaxial cable to the control box and converted to a digital image (480 x 640 pixel resolution). Electrical power (12 volt DC) is carried to the camera on conductors packaged in a single sheath with the coaxial cable.

Figure I.2 CCTV camera installations on three different fishing vessels. Each camera has a mounting bracket and stainless steel mounting straps.

Figure I.3 Installation showing a swing arm camera mount.

GPS Receiver

Each EM system carries an independent GPS, integrated receiver and antenna, which is wired directly to the control box (there is no attached display interface). The GPS receiver is fixed to a mount on top of the wheelhouse away from other vessel electronics (Figure I.4).

The GPS receiver is a 12 channel parallel receiver, meaning it can track up to 12 GPS satellites at once while using 4 satellites that have the best spatial geometry to develop the highest quality positional fix. The factory stated error for this GPS is less than 15 metres (Root Mean Square). This means that if the receiver is placed on a point with precisely known coordinates, a geodetic survey monument for example, 95% of its positional fixes will fall inside a circle of 15 metres radius centered on that point.

The GPS time code delivered with the positional data is accurate to within 2 seconds of the Universal Time Code (UTC = GMT). The EM control box software uses the GPS time to chronologically stamp data records and to update and correct the real time clock on the data-logging computer.

When 12 volts DC is applied the GPS delivers a digital data stream to the control box that provides an accurate time base as well as vessel position, speed, heading and positional error. Speed is recorded in nautical miles per hour (knots) to one decimal place and heading to the nearest degree.

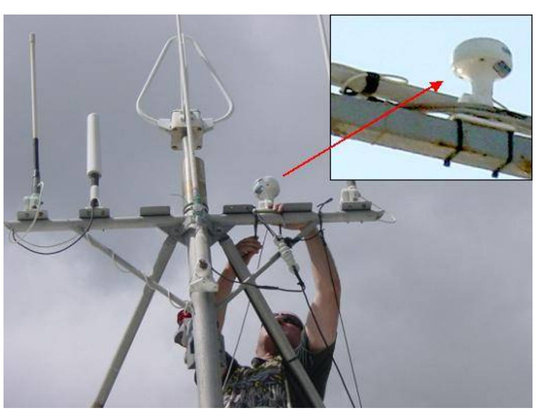


Figure I.4. GPS receiver installed in the rigging of a vessel and a close up photograph of the mounted GPS.

Hydraulic Pressure Transducer

An electronic pressure transducer is generally mounted into the vessel hydraulic system (Figure I.5 left image) to monitor the use of fishing gear (e.g., winches, line haulers, etc.). The sensor has a 0 to 2500 psi range, high enough for most small vessel systems, and a 15,000 psi burst rating. The sensor is fitted into a ¼ inch pipe thread gauge port or tee fitting on the pressure side of the hauler circuit. An increase in system pressure signals the start of fishing operations such as longline retrieval. When pressure readings exceed a threshold that is established during system tests at dockside, the control box software turns the digital video recorder on to initiate video data collection.

Drum Rotation Sensor

A photoelectric drum rotation sensor is generally mounted on either the warp winch or net drum to detect activity as vessels often deploy gear from these devices without hydraulics. The small waterproof sensor is aimed at a prismatic reflector mounted to the winch drum to record winch activity and act as a secondary video trigger. (Figure I.5 right image).

Figure I.5. A hydraulic pressure sensor installed on the supply line of a vessel line hauler (left). Drum rotation sensor (right) mounted on pelagic longline vessel, showing optical sensor and reflective surface.

APPENDIX II – EM DATA COLLECTED

Table II.1 EM data collected by Vessel, trip and haul. Departure is the date a trip started, Duration is the time from leaving port to returning in a trip, Time Gap is the amount (if any) of missing video data during a trip, Time Gap Category is the classification for the time interval that was missing (B-beginning, M- middle, E- end, N- none), Sensor Data collected should correspond to the number of hours in a trip and is also expressed as a percentage, Haul Imagery Collected reports the number of hours of video collected for that trip and the number of hauls that were recorded on video.

Vessel ID	Trip Number	Departure	Trip Duration (Hours)	Time Gap (Hours)	Time Gap Category	Sensor Data Collected (Hours)	Sensor Data Completeness (%)	Haul Imagery Collected (Hours)	Hauls Captured
A	1	12-Jul-10	20.4	0.00	N	20.4	100%	7.1	3
A	2	21-Jul-10	22.0	5.42	B	16.6	75%	7.8	3
A	3	23-Jul-10	19.9	0.00	N	19.9	100%	6.6	2
A	4	26-Jul-10	21.6	0.00	N	21.6	100%	7.1	2
A	5	28-Jul-10	23.9	0.00	N	23.9	100%	6.5	1
A	6	01-Aug-10	19.7	0.00	N	19.7	100%	7.3	2
A	7	06-Aug-10	18.9	0.03	M	18.9	100%	6.0	2
A	8	08-Aug-10	20.9	0.00	N	20.9	100%	7.2	2
A	9	24-Aug-10	42.3	0.03	M	42.3	100%	11.0	4
A	10	01-Sep-10	33.1	0.00	N	33.1	100%	7.8	3
A	11	06-Sep-10	27.1	0.00	N	27.1	100%	5.3	2
A	12	11-Sep-10	32.8	9.07	M	23.8	72%	6.2	3
A	13	24-Sep-10	25.3	0.00	N	25.3	100%	6.6	3
A	14	06-Oct-10	30.1	0.00	N	30.1	100%	7.0	3
A	15	12-Oct-10	27.3	0.00	N	27.3	100%	7.1	3
A	16	16-Oct-10	23.9	0.04	M	23.8	100%	6.4	3
A	17	20-Oct-10	5.3	0.00	N	5.3	100%	0.0	0
A	18	21-Oct-10	21.7	5.89	B	15.8	73%	7.0	2
A	19	31-Oct-10	17.9	4.36	B, M	13.6	76%	5.7	2
A	20	04-Nov-10	25.3	0.00	N	25.3	100%	8.5	2
A	21	15-Nov-10	31.6	0.00	N	31.6	100%	4.1	2
A	22	17-Nov-10	25.5	1.16	M	24.4	95%	6.9	2
A	23	26-Nov-10	27.2	0.03	M	27.2	100%	7.1	2
A	24	29-Nov-10	32.9	7.86	M	25.0	76%	7.1	2
A	25	02-Dec-10	25.8	0.03	M	25.7	100%	6.1	2
A	26	07-Dec-10	25.1	0.11	M	25.0	100%	6.2	2
A	27	15-Dec-10	18.5	0.00	N	18.5	100%	5.8	2
A	28	23-Dec-10	22.2	0.02	M	22.2	100%	4.7	2
Vessel Totals			**688.1**	**34.0**		**654.1**	**95%**	**182.2**	**63**

Vessel ID	Trip Number	Departure	Trip Duration (Hours)	Time Gap (Hours)	Time Gap Category	Sensor Data Collected (Hours)	Sensor Data Completeness (%)	Haul Imagery Collected (Hours)	Hauls Captured
B	1	21-Jul-10	20.5	7.50	B,E	13.0	63%	5.6	1
B	2	24-Jul-10	60.3	55.71	B,M,E	4.6	8%	1.0	1
B	3	28-Jul-10	23.8	0.62	M	23.2	97%	5.7	2
B	4	31-Jul-10	24.8	0.00	N	24.8	100%	7.2	2
B	5	06-Aug-10	24.7	0.00	N	24.7	100%	8.2	2
B	6	23-Aug-10	22.1	1.76	B	20.4	92%	6.3	2
B	7	25-Aug-10	21.7	0.00	N	21.7	100%	6.0	2
B	8	01-Sep-10	21.7	5.25	B,M	16.5	76%	5.7	1
B	9	03-Sep-10	22.7	0.00	N	22.7	100%	6.4	1
B	10	08-Sep-10	22.8	0.53	M	22.2	98%	6.8	1
B	11	14-Sep-10	23.1	0.05	M	23.1	100%	8.0	1
B	12	18-Sep-10	25.1	1.97	B	23.1	92%	7.7	2
B	13	20-Oct-10	23.6	0.00	N	23.6	100%	6.6	1
B	14	03-Nov-10	29.0	9.98	M	19.0	66%	7.2	1
B	15	05-Nov-10	23.2	4.18	B	19.0	82%	7.5	1
B	16	11-Nov-10	27.5	1.86	B	25.7	93%	7.6	1
B	17	15-Nov-10	25.4	0.00	N	25.4	100%	8.2	1
B	18	18-Nov-10	26.0	0.00	N	26.0	100%	9.3	1
B	19	22-Nov-10	15.6	0.00	N	15.6	100%	0.0	0
B	20	26-Nov-10	31.9	0.00	N	31.9	100%	9.3	1
B	21	01-Dec-10	30.5	0.00	N	30.5	100%	16.6	1
B	22	06-Dec-10	34.4	16.43	B,M	17.9	52%	8.0	1
B	23	14-Dec-10	29.3	2.97	B	26.3	90%	9.4	1
B	24	22-Dec-10	26.0	10.33	B	15.7	60%	7.0	1
Vessel Totals			**635.8**	**119.1**		**516.7**	**81%**	**171.3**	**29**

Vessel ID	Trip Number	Departure	Trip Duration (Hours)	Time Gap (Hours)	Time Gap Category	Sensor Data Collected (Hours)	Sensor Data Completeness (%)	Haul Imagery Collected (Hours)	Hauls Captured
C	1	07-Jul-10	32.0	0.00	N	32.0	100%	9.9	3
C	2	12-Jul-10	27.0	0.00	N	27.0	100%	9.0	2
C	3	20-Jul-10	34.2	0.05	M	34.2	100%	10.3	3
C	4	24-Jul-10	27.4	0.00	N	27.4	100%	10.1	2
C	5	10-Aug-10	34.1	0.00	N	34.1	100%	10.5	3
C	6	17-Aug-10	28.3	0.00	N	28.3	100%	10.4	2
C	7	01-Sep-10	38.5	0.00	N	38.5	100%	12.8	3
C	8	07-Sep-10	36.7	0.00	N	36.7	100%	13.1	3
C	9	12-Sep-10	35.8	0.00	N	35.8	100%	11.9	3
C	10	17-Sep-10	34.2	0.00	N	34.2	100%	11.3	4
C	11	29-Sep-10	32.8	0.00	N	32.8	100%	9.7	3
C	12	06-Oct-10	35.1	0.00	N	35.1	100%	12.7	3
C	13	13-Oct-10	32.6	0.00	N	32.6	100%	11.2	3
C	14	30-Oct-10	22.2	0.00	N	22.2	100%	7.8	2
Vessel Totals			**450.7**	**0.0**		**450.7**	**100%**	**150.8**	**39**

Vessel ID	Trip Number	Departure	Trip Duration (Hours)	Time Gap (Hours)	Time Gap Category	Sensor Data Collected (Hours)	Sensor Data Completeness (%)	Haul Imagery Collected (Hours)	Hauls Captured
D	1	14-Jul-10	24.7	0.00	N	24.7	100%	6.8	2
D	2	21-Jul-10	44.1	0.02	M	44.0	100%	11.0	3
D	3	25-Jul-10	32.4	0.05	M	32.3	100%	10.6	2
D	4	28-Jul-10	30.0	0.00	N	30.0	100%	10.2	2
D	5	08-Aug-10	27.4	0.00	N	27.4	100%	9.1	2
D	6	10-Aug-10	39.7	0.00	N	39.7	100%	11.6	2
D	7	17-Aug-10	31.6	0.00	N	31.6	100%	10.5	2
D	8	24-Aug-10	28.8	0.00	N	28.8	100%	8.9	2
D	9	02-Sep-10	34.9	0.00	N	34.9	100%	10.2	3
D	10	11-Sep-10	28.0	0.00	N	28.0	100%	10.3	3
D	11	14-Sep-10	26.1	0.00	N	26.1	100%	6.6	3
D	12	24-Sep-10	33.8	32.48	B,E	1.3	4%	0.0	0
D	13	29-Sep-10	43.0	18.16	B,E	24.8	58%	7.8	2
D	14	06-Oct-10	36.7	0.00	N	36.7	100%	10.6	2
Vessel Totals			**461.2**	**50.7**		**410.4**	**89%**	**124.2**	**30**

Vessel ID	Trip Number	Departure	Trip Duration (Hours)	Time Gap (Hours)	Time Gap Category	Sensor Data Collected (Hours)	Sensor Data Completeness (%)	Haul Imagery Collected (Hours)	Hauls Captured
E	1	26-Jul-10	15.8	0.00	N	15.8	100%	4.4	2
E	2	28-Jul-10	32.4	0.00	N	32.4	100%	0.0	0
E	3	31-Jul-10	44.4	0.00	N	44.4	100%	6.7	8
E	4	04-Aug-10	14.1	0.00	N	14.1	100%	0.0	0
E	5	09-Aug-10	61.0	0.00	N	61.0	100%	10.5	10
E	6	14-Aug-10	26.2	0.00	N	26.2	100%	5.5	6
E	7	17-Aug-10	29.3	0.00	N	29.3	100%	5.9	6
E	8	24-Aug-10	53.5	0.00	N	53.5	100%	9.5	10
E	9	12-Sep-10	72.3	7.49	B	64.8	90%	12.5	12
E	10	18-Sep-10	39.2	0.00	N	39.2	100%	6.0	7
E	11	25-Sep-10	22.0	3.46	B	18.5	84%	5.3	6
Vessel Totals			**410.2**	**10.9**		**399.3**	**97%**	**43.4**	**67**
F	1	14-Jul-10	57.0	5.38	M	51.6	91%	14.7	16
F	2	19-Jul-10	47.9	0.00	N	47.9	100%	10.2	12
F	3	31-Jul-10	53.0	9.64	M	43.4	82%	13.3	15
F	4	05-Aug-10	72.7	17.34	M	55.4	76%	21.2	25
F	5	12-Aug-10	55.2	0.00	N	55.2	100%	17.1	19
F	6	18-Aug-10	59.6	15.28	M	44.4	74%	14.4	17
Vessel Totals			**345.6**	**47.6**		**297.9**	**86%**	**90.9**	**104**
Overall Totals	**97**		**2991.6**	**262.5**		**2729.1**	**91%**	**762.7**	**332**

The duration of time gaps at the beginning or end of a trip were obtained from observer data.

APPENDIX III – SCIENTIFIC AND COMMON NAMES OF ENCOUNTERED SPECIES AND GROUPS

Table III.1 Scientific and common names for all fish species and groups recorded in the observer, fishing log and EM data sets.

Species Name	Scientific Name
Aurora Rockfish	*Sebastes aurora*
Black Skate	*Bathyraja trachura*
Blackgill Rockfish	*Sebastes melanostomus*
Blue Shark	*Prionace glauca*
Brown Cat Shark	*Apristurus brunneus*
California Grenadier	*Nezumia stelgidolepis*
California Slickhead	*Alepocephalus tenebrosus*
Cat Sharks	*Scyliorhinidae*
Chilipepper Rockfish	*Sebastes goodei*
Deepsea Sole	*Embassichthys bathybius*
Dover Sole	*Microstomus pacificus*
Filetail Cat Shark	*Parmaturus xaniurus*
Flatfish (unidentified)	*Pleuronectidae*
Giant Grenadier	*Albatrossia pectoralis*
Grenadier (unidentified)	*Macrouridae*
Hagfish (unidentified)	*Myxinidae*
Lamprey	*Petromyzontidae*
Longnose Cat Shark	*Apristurus kampae*
Longnose Skate	*Raja rhina*
Pacific Flatnose	*Antimora microlepis*
Pacific Grenadier	*Coryphaenoides acrolepis*
Pacific Hagfish	*Eptatretus stouti*
Pacific Hake	*Merluccius productus*
Pacific Pomfret	*Brama japonica*
Pacific Sleeper Shark	*Somniosus pacificus*
Pinkrose Rockfish	*Sebastes simulator*
Popeye Grenadier	*Corphaenoides cinereus*
Rockfish (unidentified)	*Sebastes/Sebastolobus*
Rosethorn Rockfish	*Sebastes helvomaculatus*
Sablefish	*Anoplopoma fimbria*
Sandpaper Skate	*Bathyraja kincaidii*
Sharks (unidentified)	*Chondrichthyes*
Skate (unidentified)	*Rajidae*
Spiny Dogfish Shark	*Squalus acanthias*
Spotted Ratfish	*Hydrolagus colliei*
Thornyheads	*Sebastolobus*

APPENDIX IV – DETAILS OF A PROPOSED FISHING LOG AUDIT METHODOLOGY

This appendix contains a description of three possible audit evaluation methods as well as the specific examples currently used in the British Columbia hook-and-line and trap fishery audit.

Scores: Scores are assigned to individual comparisons (e.g., retained piece differences between EM and fishing log for a specific species). Table IV.1 shows the scoring methodology for the BC hook-and-line fishery as an example. Results are calculated based on total piece differences or percentage of piece differences depending on the total number of pieces compared. Percentages are a powerful way of comparison when dealing with a large total number of pieces but become meaningless when comparing small numbers.

Table IV.1. Scoring scale used in the British Columbia hook-and-line audit-based catch monitoring program.

Score	Difference when Pieces < 30[*1]	Difference when Pieces ≥ 30[*1]
10	0 Pieces	0 - 2%
9	1 – 3 Pieces	2 - 10%
8	4 – 6 Pieces	10 - 20%
7	7 – 9 Pieces	20 - 30%
5	10 – 12 Pieces	30 - 40%
3	13 – 15 Pieces	40 - 50%
0	Over 15 Pieces	> 50%

[*1] *Where the number of pieces is determined by EM or Dockside Monitoring.*

Standards: Standards involve binary decisions (Table IV.2), i.e., met or not met. The standard itself can be based on a particular score, an average of scores, or some other comparison result (e.g., set starts need to be within one hour).

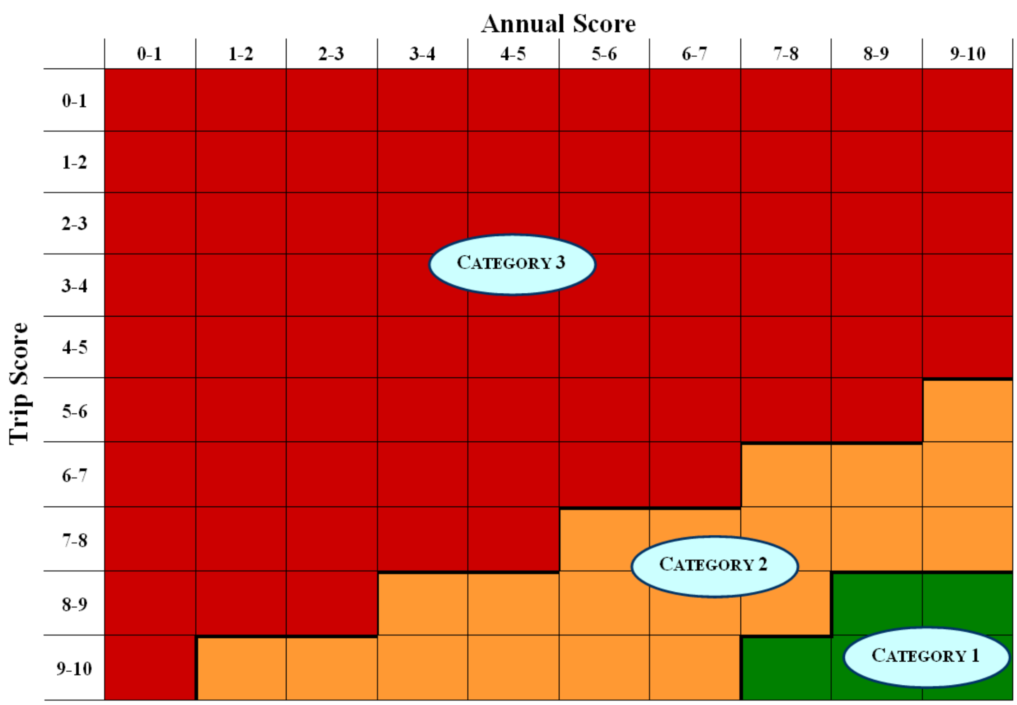
Table IV.2. Standards used in the British Columbia hook-and-line audit-based catch monitoring program.

Comparisons	Pass Value	Interpretation
DMP to Fishing Log	9	All of the tests must be 9 or better to obtain a "pass" in the audit
Video to Fishing Log (including rockfish)	8	The average score of video to fishing log pieces must be equal to or greater than 8 to obtain a "pass" in the audit
Video to Fishing Log Rockfish Scores	7	All of the scores for the video to fishing log rockfish pieces must be equal to or greater than 7 to obtain a "pass" in the audit
Management Area fished	Match	If these areas do not match, the EM area will be used for quota deductions.
Position of set start point	Within 1 nm	Informational only. No consequence.
Date/Time of set start point	Within 1 hour	Informational only. No consequence.

Score Matrix: A score matrix is the last layer in the evaluation methodology and is used in cases when the fishing log for a trip is deemed to have low data quality and failed to meet set standards. The premise is that a skipper that has consistently underperformed should have greater consequences than someone who has consistently provided good data but failed to on a single trip. A 'Trip Score' is obtained by averaging all scores (each score weighted based on number of pieces per test). This trip score is then compared to the vessel's history in the form of its average of all trip scores for the previous calendar year using a matrix such as the one shown in Figure IV.1. Depending on where a trip falls within the matrix, consequences may range from a warning to full review of all catch events in order to determine catch for the trip. Given that fishers pay for a portion of the reviewing costs, this incentivizes accurate logbook entries.

For a vessel history matrix to be meaningful and transparent it is necessary to gather a couple of years worth of data from the fleet, then plot a distribution of trip scores and decide what should the cut off for each of the categories be based on the overall performance and perceived risks.

Figure IV.1. Example of the score matrix used in the British Columbia hook-and-line audit-based catch monitoring program to rate trips based on vessel performance.



GoldenGate
Salmon Association

May 26, 2011

Dr. Gerald Meral
Deputy Secretary
California Natural Resources Agency
1416 Ninth Street
Sacramento, CA 95814

Ms. Karla Nemeth
BDCP Coordinator
California Natural Resources Agency
1416 Ninth Street
Sacramento, CA 95814

RE: BDCP Working Committees

Dear Dr. Meral and Ms. Nemeth:

On behalf of California's salmon fisheries we wish to thank Secretary Laird and the two of you for your invitation to our State's salmon fishery to participate in the development of a Bay-Delta Conservation Plan. Our goal is the same as yours, that the Plan comply with both the U.S. and California Endangered Species Acts as well as the recently enacted California law calling for the co-equal goal of restoring the Bay-Delta Estuary and its natural resources, including salmon, and development of a reliable water system for Californians who traditionally have depended on the Delta and its watershed as a source for water.

As you know, fishing interests were effectively "locked-out" of any meaningful participation in the development of the BDCP in the last administration. We welcome now the Brown Administration's decision to make development of the BDCP inclusive -- opening participation to, among others, fishing and Delta counties' representation, two of the major stakeholders -- in an open, transparent and science-based process.

We have reviewed the suggested Working Committees for the renewed development of the BDCP and are extremely concerned that none encompass the requirements for the protection and recovery of salmon resources. Not only is the Bay-Delta ecosystem, extending from the Sierra to the Gulf of the Farallones, the single most important estuary on the West Coast of both Americas, but it is also the migratory route for the second largest salmon runs in the lower 48 – four runs of chinook salmon emanating from the Sacramento and San Joaquin Rivers and their tributaries, along with Central Valley steelhead. This fishery is so important that it deserves and must have a working group dedicated to the protection, recovery and doubling (as required pursuant to both state and federal statute) of these magnificent fish whose economic importance is felt far beyond the rivers and estuary to the coast, including that of Oregon.

Although some of the working groups, we imagine, would touch on elements of salmon protection and recovery, none would provide the type of comprehensive approach necessary for ESA compliance. Nor, do we believe, would the sum of the effort of the current working groups, achieve the type of comprehensive and effective approach required by State and Federal law for development of, respectively, an acceptable NCCP or HCP. That is why a stand-alone salmon working group is essential.

We understand that approval for working groups may depend on water contractors who will be footing some of the bill. However, we would emphasize to them that absent a salmon working group, with knowledgeable salmon stakeholder participation, it will be difficult to develop a BDCP that, in fact, protects and recovers listed-salmon populations (as well as comply with State and Federal doubling requirements). The BDCP must encompass more than "window dressing habitat projects," paid for by the public intended to facilitate construction of a major new freshwater diversion project. It is important for the water contractors paying for portions of the BDCP, therefore, that the issues of salmon protection and recovery be effectively and comprehensively addressed, which calls for the establishment of a salmon working group.

To facilitate the establishment of a salmon working group, a number of the signatories below, are willing to participate, pursuant to your invitation for working group membership. Further, the Golden Gate Salmon Association has successfully raised funds necessary to support one individual who will be able to dedicate all of their time to this working group and BDCP development. The fishing groups are willing to carry their weight in the development of the BDCP.

We would appreciate your earliest response to this letter. The signatories here and the Golden Gate Salmon Association would like to submit names to you by your Friday deadline or as soon as the salmon working group is established. And, again, thank you for your kind invitation to participate; we most assuredly will.

Sincerely,

Dick Pool	Victor Gonella	Zeke Grader	Roger Thomas	Darrell Ticehurst
Water4Fish	GGSA	PCFFA	GGFA	Coastside Fishing Club

cc. Senator Fran Pavley – Chair, Senate Natural Resources and Water Committee
Assemblyman Wesley Chesbro – Chair, Joint Committee on Fisheries and Aquaculture
Assemblyman Jared Huffman – Chair Assembly Water Parks and Wildlife Committee
Secretary John Laird – California Secretary of Natural Resources.
Dr. Don McIsaac – Executive Director, Pacific Fishery Management Council

Pacific Coast Salmon 5-Year Review of Essential Fish Habitat

Final Report to the Pacific Fishery Management Council

Revised May 25, 2011

Pacific Coast Salmon 5-Year Review of Essential Fish Habitat

Final Report to the Pacific Fishery Management Council

John H. Stadler[1], Kerry F. Griffin[2], Eric J. Chavez[1], Brian C. Spence[1], Phil Roni[1], Charleen A. Gavette[1], Barbara A. Seekins[1], and Adam K. Obaza[1]

[1] National Marine Fisheries Service
[2] Pacific Fishery Management Council

Revised May 2, 2011

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EEZ	exclusive economic zone
EFH	essential fish habitat
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FERC	Federal Energy Regulatory Commission
FMC	Fishery Management Council
FMP	fisheries management plan
FMU	fishery management unit
GIS	geographic information system
HAPC	habitat area of particular concern
HU	hydrologic unit
IP	intrinsic potential
LNG	liquefied natural gas
LWD	large woody debris
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council
PFMC	Pacific Fishery Management Council
PS	Puget Sound
SAV	submerged aquatic vegetation
USGS	United States Geological Survey

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1. INTRODUCTION

The Magnuson-Stevens Fishery Conservation and Management Act (MSA)(16 USC 1801 et seq) defines essential fish habitat (EFH) as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity," and requires Fishery Management Councils (FMCs) to describe and identify EFH in fishery management plans (FMPs). The FMPs should identify EFH based on current distribution, habitat components, historical presence, or other factors; and should also identify habitat requirements at each life stage and research needs. FMPs must evaluate potential adverse impacts from both fishing and non-fishing activities, as well as minimize adverse effects of fishing to the extent practicable. FMPs should identify Habitat Areas of Particular Concern (HAPC) within EFH based on the habitat's ecological function, sensitivity to human-induced disturbance, rarity, or whether development activities may stress a particular habitat. The National Marine Fisheries Service (NMFS) has approval authority for the designations provided by the FMCs.

The Pacific Fishery Management Council (Council) has, in Appendix A to Amendment 14 of the Pacific Coast Salmon FMP (Amendment 14)(PFMC 1999), identified EFH for Pacific Coast salmon as all those streams, lakes, ponds, wetlands, and other currently viable water bodies and most of the habitat historically accessible to salmon in Washington, Oregon, Idaho, and California. In estuarine and marine areas, salmon EFH extends from the nearshore and tidal submerged environments within state territorial waters out to the full extent of the exclusive economic zone (EEZ) offshore of Washington, Oregon, and California north of Point Conception. Pacific Coast salmon EFH also includes those areas off Alaska designated as salmon EFH by the North Pacific Fishery Management Council (NPFMC). Exceptions in freshwater include cases in which certain man-made or naturally occurring barriers represent the current upstream extent of Pacific salmon access. The Council designated Pacific salmon EFH in 1999, and made minor revisions during the EFH codification process in 2008 (2008 Final Rule)(78 FR 60987).

This report summarizes the results of a review conducted by an oversight panel (Panel) made up of staff from the Council and NMFS (Table 1), of the EFH for Pacific Coast salmon. The report includes a description of the general requirements and elements of EFH, including guidance for periodic reviews; a summary of existing designations of EFH for Pacific Coast salmon; the currently available information on the distribution of Pacific Coast salmon in both fresh and marine waters; potential changes to the existing EFH designations; potential changes to the list of impassible dams that currently form the upstream extent of EFH; an inquiry into whether appropriate models exist to predict salmon distribution where data on distribution are lacking; a discussion of potential HAPCs; a brief summary of new information on the life history and habitat requirements of salmon; updated information on threats to EFH both from fishing and non-fishing activities; and identification of research needs to further refine EFH.

Essential Fish Habitat Consultation

Federal agencies must consult with the NMFS on activities that may adversely affect EFH, regardless of whether or not those activities occur within designated EFH. In other words, an activity can adversely affect EFH without occurring within EFH. An adverse effect means any impact that reduces either the quantity or quality of EFH (50 CFR 600.810). For those activities that would adversely affect EFH, NMFS then provides EFH conservation recommendations to the Federal agency to avoid, minimize, or offset those adverse effects. Fishery Management Councils may also comment on proposed actions that may adversely affect EFH, and is obligated to provide comments on any activity that is likely to substantially affect the habitat, including EFH, of an anadromous fishery resource under its authority. Although state agencies are not required to consult with NMFS on activities that may adversely affect EFH, NMFS is obligated to provide conservation recommendations to state agencies if NMFS receives information that an activity will adversely affect EFH. Whenever possible, NMFS utilizes existing coordination procedures to transmit EFH conservation recommendations.

Table 1. Members of the Oversight Panel.

Name	Affiliation
Chuck Tracy	Pacific Fishery Management Council
Kerry Griffin	Pacific Fishery Management Council
John Coon	Pacific Fishery Management Council
John Stadler – Chair	NMFS Northwest Region, Habitat Conservation Division
Barbara Seekins	NMFS Northwest Region, Protected Resources Division
Phil Roni	NMFS Northwest Fisheries Science Center
Eric Chavez	NMFS Southwest Region, Habitat Conservation Division
Adam Obaza	NMFS Southwest Region, Habitat Conservation Division
Bryant Chesney	NMFS Southwest Region, Habitat Conservation Division
Charleen Gavette	NMFS Southwest Region, Habitat Conservation Division
Brian Spence	NMFS Southwest Fisheries Science Center
Nancy Munn	NMFS Northwest Region, Habitat Conservation Division
Steve Copps	NMFS Northwest Region, Sustainable Fisheries Division

The designations and detailed descriptions of EFH in the FMPs are used during the EFH consultation process to determine where and for what species EFH has been designated in the project area. The analysis of the adverse effects from the proposed action, and potential conservation measures that avoid, minimize, or offset those effects, are informed by the information contained in the FMP.

Essential Fish Habitat Periodic Reviews

The regulatory guidelines for implementing the EFH provisions of the MSA state that Regional FMCs and NMFS should periodically review the EFH provisions of FMPs and revise or amend EFH provisions as warranted, based on available information (50 CFR 600.815(a)(10)). This review included evaluating published scientific literature and unpublished reports, soliciting input from interested parties, and searching for previously unavailable information on salmon stocks identified in the FMP. The Council may provide suggested changes to existing EFH to NMFS for their approval, if the information warrants changes. The regulatory guidance provides that a complete review should be conducted periodically, but at least once every five years. Pacific Coast salmon EFH was first designated in 1999 by the Council as part of Amendment 14 to the Pacific Coast Salmon FMP, and was codified in 2008 as a result of the Idaho County versus Commerce court case (Idaho County et al. v. Donald Evans et al., United States District Court for the District of Idaho, Case No. CV02-80-C-EJL). The current review was initiated in 2009.

Since EFH for Pacific Coast salmon was first designated in 1999, NMFS has taken steps to clarify the process for designating and refining EFH. In 2002, NMFS published final rules to implement the EFH provisions of the MSA (50 CFR Part 600), and, in 2006, issued a memo providing additional guidance to refine the description and identification of EFH (NMFS 2006). The 5-year review presented was guided by these two clarifying documents.

Methods/Approach

The Panel convened via conference call, on an intermittent basis, from June, 2009 through March, 2011.

Available information on salmon distribution in freshwater and marine habitats, impassible barriers in freshwater, salmon life history, and threats to EFH from fishing and non-fishing activities was compared to the information in Amendment 14 to the Pacific Coast Salmon FMP. Using these comparisons, the Panel evaluated potential modifications to EFH and identified potential changes to EFH where warranted. The information used was gathered from publicly available sources.

Chronology

- Early 2009 NMFS and the Council received $100k from NMFS Headquarters to provide support for the review and the Oversight Panel was established
- September 2009 – The Council Staff provided an informational report at the September Council meeting
- September 2009 – The Council hired Cramer Fish Sciences to compile new references and develop an annotated bibliography on the list of barriers, the habitats used by salmon at all life stages, and threats to EFH, as well as review and synthesize potential actions to avoid, minimize, or offset adverse impacts to EFH associated with the identified threats.
- June 2010 – Contract with Cramer Fish Sciences concludes; Oversight Panel begins developing draft report for September 2010 Council meeting
- September 2010 – Draft report presented to the Council
- October 2010 – December 2010 - Comments on draft report solicited by the Panel
- April 2011 – Final report delivered to the Council

2. CURRENT EFH DESIGNATIONS FOR PACIFIC COAST SALMON

This section summarizes existing EFH for Pacific salmon contained in Amendment 14 and the 2008 Final Rule.

In Amendment 14 to the Pacific Coast Salmon FMP (PFMC 1999), the Council chose a comprehensive approach to designate EFH for several reasons: salmon distribution varies spatially and temporally; there is very limited information regarding ocean distribution and migration; and there is an immense diversity of freshwater habitats. The comprehensive approach is manifested in the text descriptions and the associated maps provided to assist the user. The text descriptions are the legal definition of EFH and for Pacific salmon are written broadly. This means that the species-specific maps of the U.S. Geological Survey (USGS) 4^{th} field hydrologic units (HUs) across a large geographic area oblige the user to make a more refined determination as to whether a particular activity is within, or may adversely affect, Pacific Coast salmon EFH, within that HU. EFH identification based on USGS 4^{th} field HUs recognizes the diversity of habitats essential to the species through all life stages, considers the variability of environmental conditions, and reinforces linkages between aquatic and adjacent upslope areas (PFMC 1999).

In describing Pacific Coast salmon EFH, the Council chose to include Alaskan marine waters designated by the North Pacific FMC (NPFMC) as EFH for salmon. This highlights the importance of habitats in the North Pacific Ocean and recognizes the fact that many of the salmon stocks spawned in the contiguous West Coast states migrate north past British Columbia and into the waters of Alaska.

Pacific salmon EFH underwent minor revisions in 2008 as a result of the Idaho County v. Department of Commerce lawsuit (Case No. CV02–C–EJL), which required NMFS to issue the Pacific salmon EFH descriptions as a Final Rule. The 2008 rulemaking exercise addressed some issues (fixed typographical and nomenclature errors; consolidated the marine and freshwater definitions of salmon EFH), but did not constitute an MSA-required review.

This section presents a summary of existing EFH descriptions for the three species of Pacific salmon managed by the Council. More detailed information can be found in Amendment 14 to the Pacific Coast Salmon Plan (PFMC 1999) and the Final Rule that codified Pacific Coast salmon EFH in 2008 (73 FR 60987). It is important to bear in mind that the text descriptions of EFH are the legal definition. Maps are provided to assist the user in interpreting the spatial extent of salmon EFH, but should not be considered to absolutely depict the extent of EFH. It follows that due to various factors (new information, changes to presence/absence of salmon, etc) the maps and descriptions will be amended over time.

The 2008 Final Rule merged the marine and freshwater designations of EFH to simplify the description. It identifies EFH for Pacific Coast salmon as “all streams, estuaries, marine waters, and other water bodies occupied or historically accessible to salmon in Washington, Oregon, Idaho, and California” and adds caveats for impassible barriers and for Puget Sound pink salmon (see following sections).

Chinook salmon

Chinook salmon (*Oncorhynchus tshawytscha*) EFH, as currently designated, includes all streams, estuaries, marine waters, and other water bodies occupied or historically accessible to Chinook salmon in Washington, Oregon, Idaho, and California. Exceptions include cases in which long-standing naturally occurring barriers (e.g., waterfalls) or specifically identified man-made barriers (e.g., dams) represent the current upstream extent of Pacific salmon access. Chinook salmon EFH includes the marine areas off Alaska designated as salmon EFH by the NPFMC. Including marine EFH designated by the NPFMC serves to recognize the migratory patterns of Chinook salmon, and the importance of habitat during all life stages. Current marine EFH for Chinook salmon includes the entire exclusive economic zone (EEZ) around Alaska. The southern extent of Chinook salmon marine EFH extends to Point Conception, CA, which represents the approximate southern extent of the Chinook range.

The designation of EFH is based on distribution data available at the time of Amendment 14, and all U.S. Geologic Survey (USGS) 4th field HUs with known or historical Chinook salmon presence at the time of Amendment 14, with the exception of those above certain man-made barriers, are currently designated as EFH for this species (Figures 1-3).

Amendment 14 includes descriptions of relevant habitat parameters, including the four major components of Chinook salmon freshwater EFH: (1) spawning and incubation; (2) juvenile rearing; (3) juvenile migration corridors; and (4) adult migration corridors and adult holding habitat. It also includes a detailed description of the life history and habitat requirements at each life stage.

Coho salmon

Coho salmon (*O. kisutch*) EFH, as designated in Amendment 14, includes all streams, estuaries, marine waters, and other water bodies occupied or historically accessible to coho salmon in Washington, Oregon, Idaho, and California. Exceptions include cases in which long-standing naturally occurring barriers (e.g., waterfalls) or specifically identified man-made barriers (e.g., dams) represent the current upstream extent of Pacific salmon access. Coho salmon EFH includes the marine areas off Alaska designated as salmon EFH by the NPFMC. Including marine EFH designated by the NPFMC serves to recognize the migratory patterns of coho salmon, and the importance of habitat during all life stages. Current marine EFH for coho salmon includes the entire EEZ around Alaska. The southern extent of

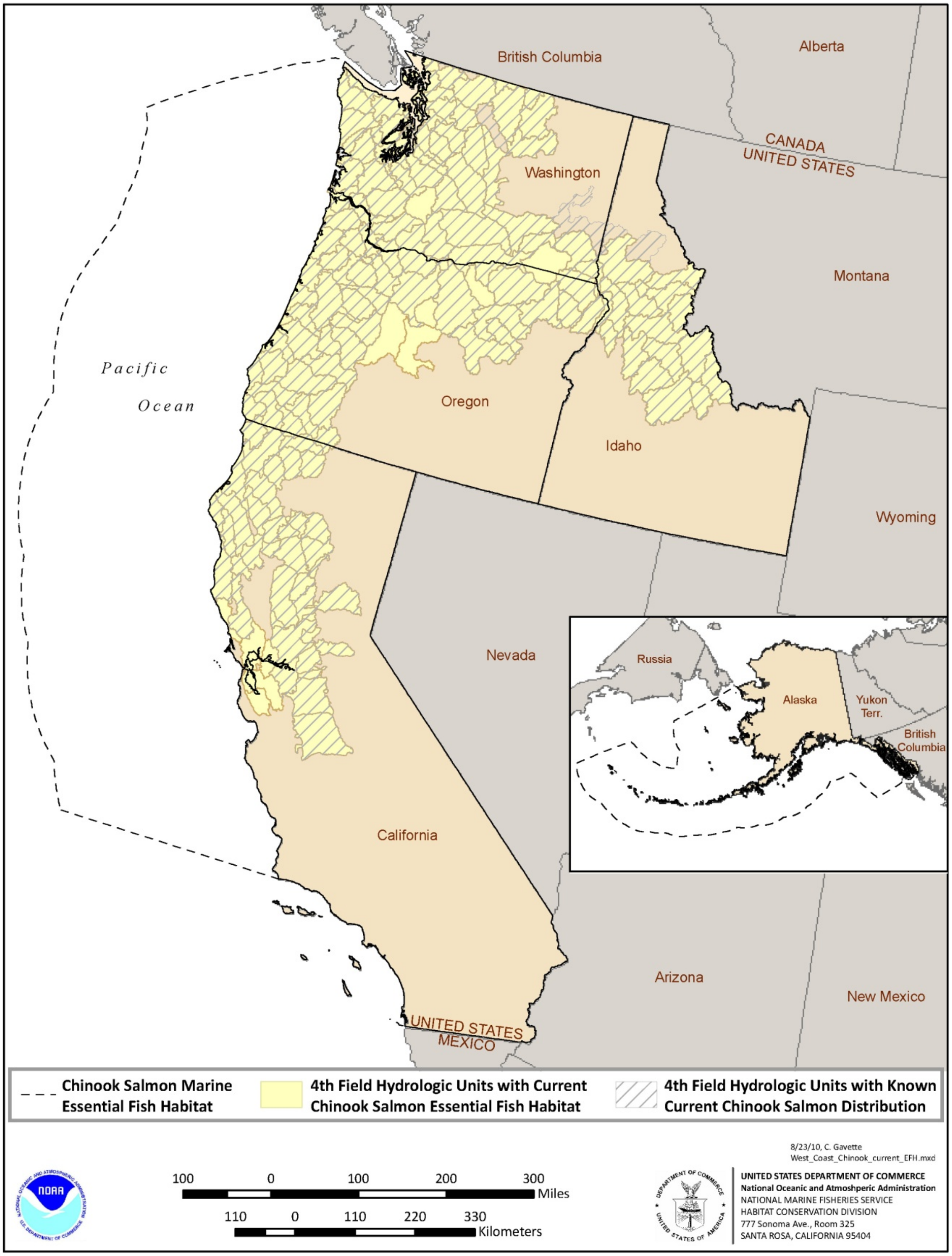

Figure 1. 4th field HUs and marine waters currently identified as EFH for Chinook salmon in relation to current Chinook salmon distribution for the U.S. West Coast and Alaska.

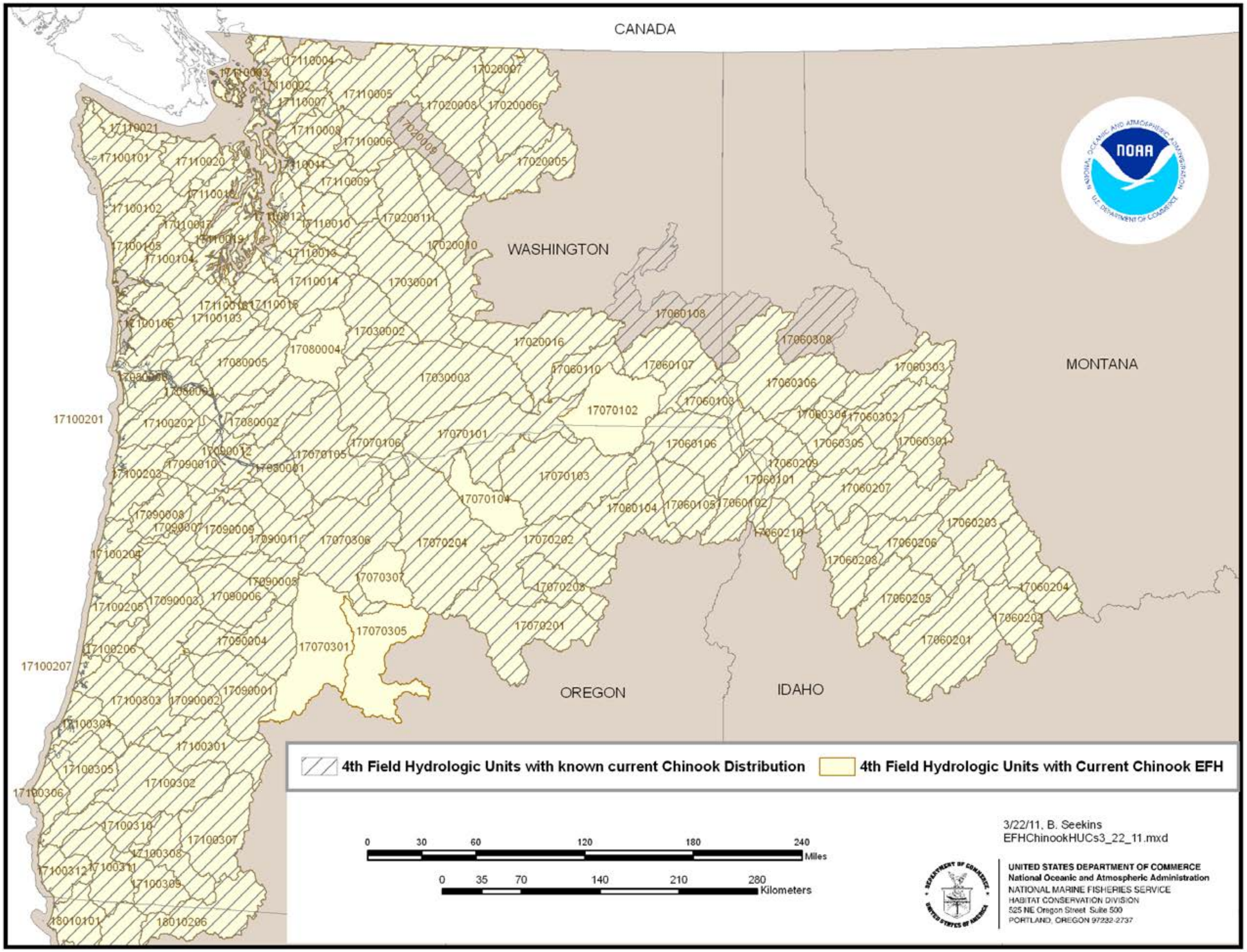

Figure 2. 4th field HUs currently identified as EFH for Chinook salmon in relation to current Chinook salmon distribution in Washington, Oregon, and Idaho.

Figure 3. 4th field HUs currently identified as EFH for Chinook salmon in relation to current Chinook salmon distribution in California.

coho salmon marine EFH is Point Conception, CA, which represents the approximate southern extent of the range of coho salmon.

The designation of EFH is based on distribution data available at the time of Amendment 14, and all U.S. Geologic Survey (USGS) 4th field HUs with known or historical coho salmon presence at the time of Amendment 14, with the exception of those above the identified man-made barriers, are currently designated as EFH for this species (Figures 4-6).

Amendment 14 includes descriptions of relevant habitat parameters, including the four major components of coho salmon freshwater EFH: (1) spawning and incubation; (2) juvenile rearing; (3) juvenile migration corridors; and (4) adult migration corridors. The current EFH for coho salmon does not include adult holding habitat. Amendment 14 also includes detailed description of the life history and the habitat requirements for each life stage.

Puget Sound Pink Salmon

Puget Sound (PS) pink salmon (*O. gorbuscha*) life history and migratory patterns are distinctly different than Chinook and coho salmon, and are described in Amendment 14. Puget Sound pink salmon EFH, as currently designated, includes all streams, estuaries, marine waters, and other water bodies occupied or historically accessible to pink salmon within Washington State. Exceptions include cases in which long-standing naturally occurring barriers (e.g., waterfalls) or specifically identified man-made barriers (e.g., dams) represent the current upstream extent of Pacific salmon access. EFH for PS pink salmon also includes marine waters north and east of Cape Flattery, Washington, including Puget Sound, the Strait of Juan de Fuca and Strait of Georgia. It is difficult to determine a western limit for pink salmon essential marine habitat because of limited information on their ocean distribution, but most PS pink salmon are typically found in Canadian, Alaskan, and international waters both within and outside the EEZ north of Cape Flattery, Washington.

The designation of EFH is based on distribution data available at the time of Amendment 14, and USGS 4th field HUs with known or historical PS pink salmon presence at the time of Amendment 14, with the exception of those above the identified man-made barriers, are currently designated as EFH for this species (Figure 7).

The four major components of freshwater PS pink salmon EFH are: (1) spawning and incubation; (2) juvenile rearing; (3) juvenile migration corridors; and (4) adult migration corridors. The current EFH description for PS pink salmon does not include adult holding habitat. Amendment 14 also includes a detailed description of the life history and the habitat requirements per life stage.

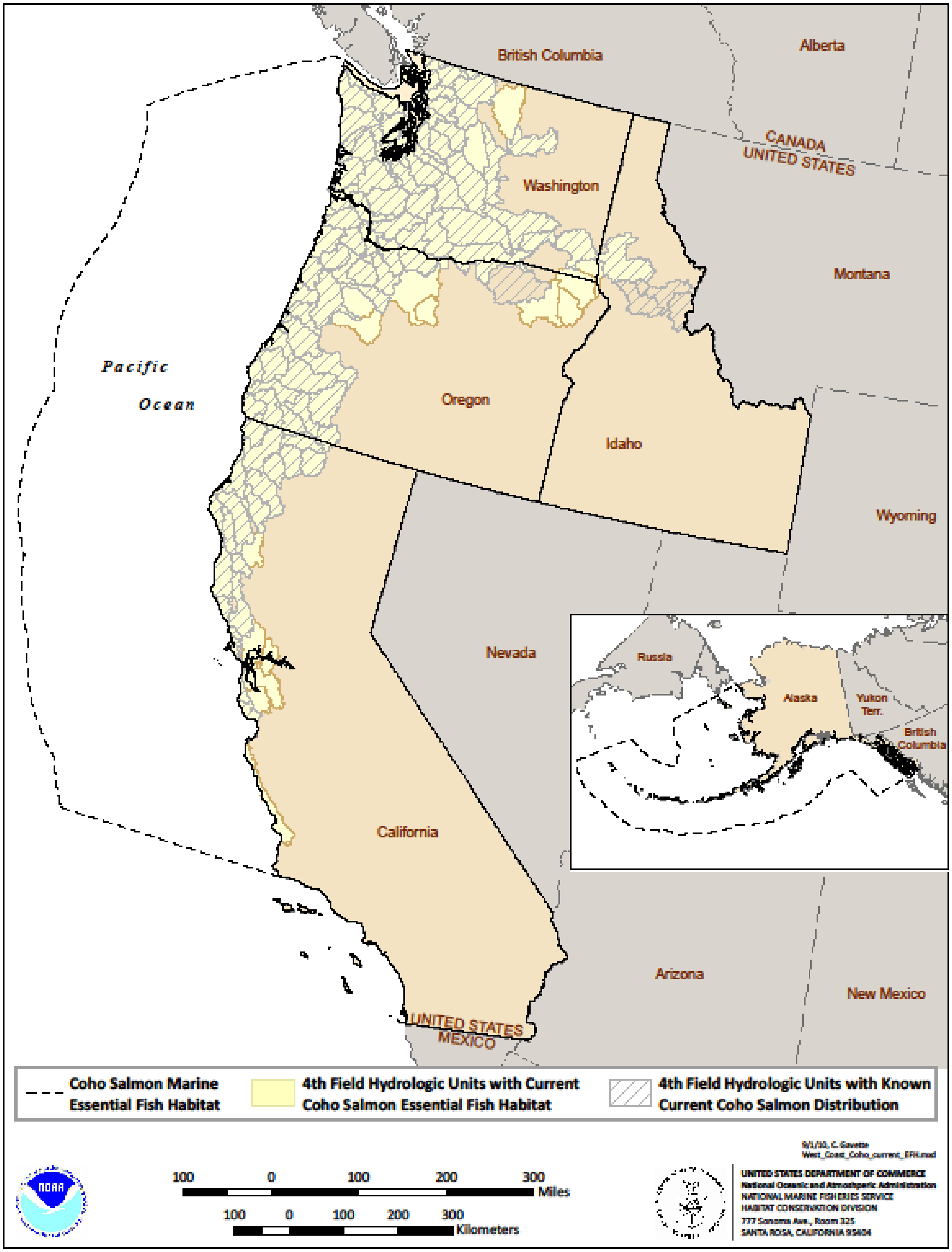

Figure 4. 4th field HUs and marine waters currently identified as EFH for coho salmon in relation to current coho salmon distribution in the U.S. West Coast and Alaska.

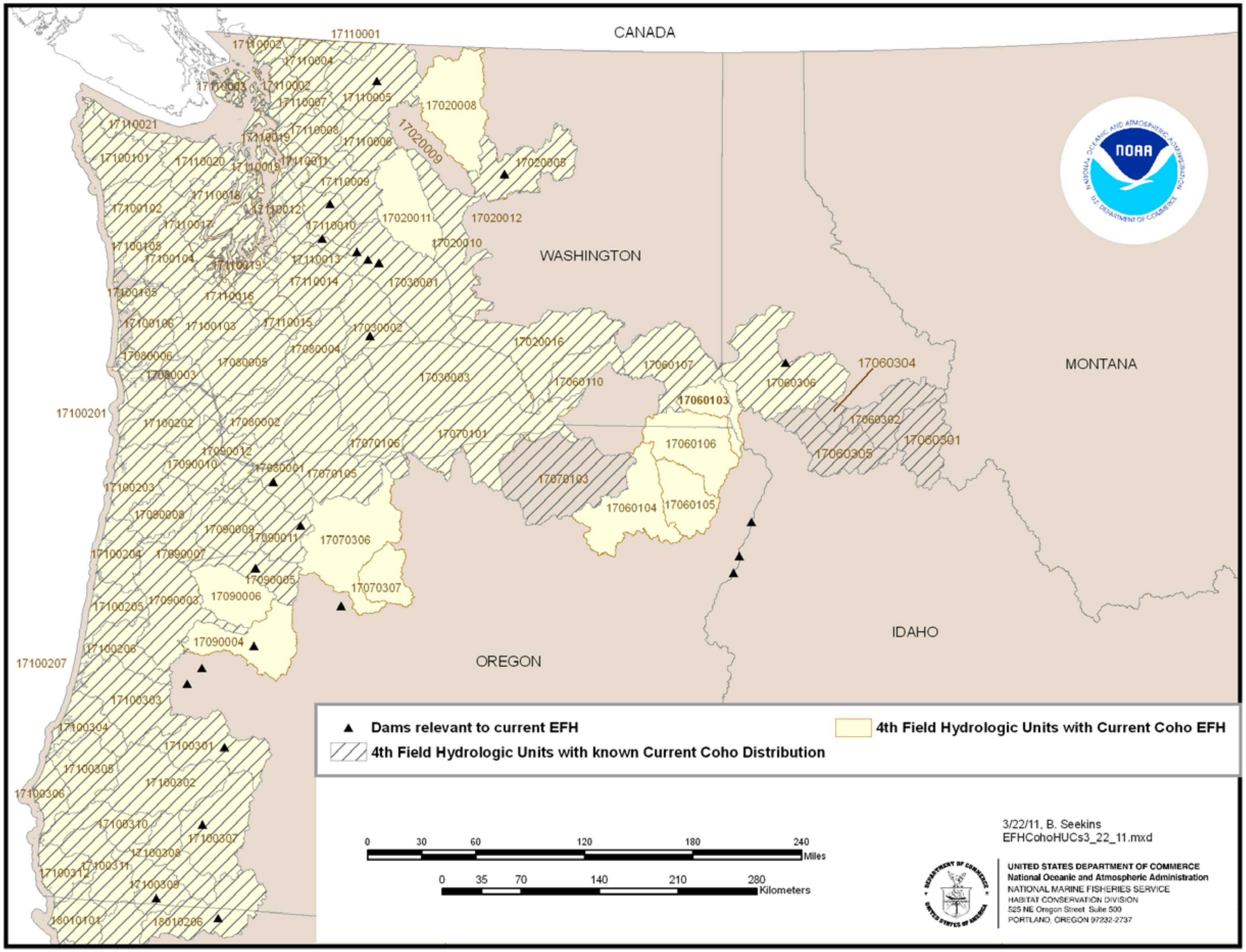

Figure 5. 4th field HUs currently identified as EFH for coho salmon in relation to current coho salmon distribution in Washington, Oregon, and Idaho.

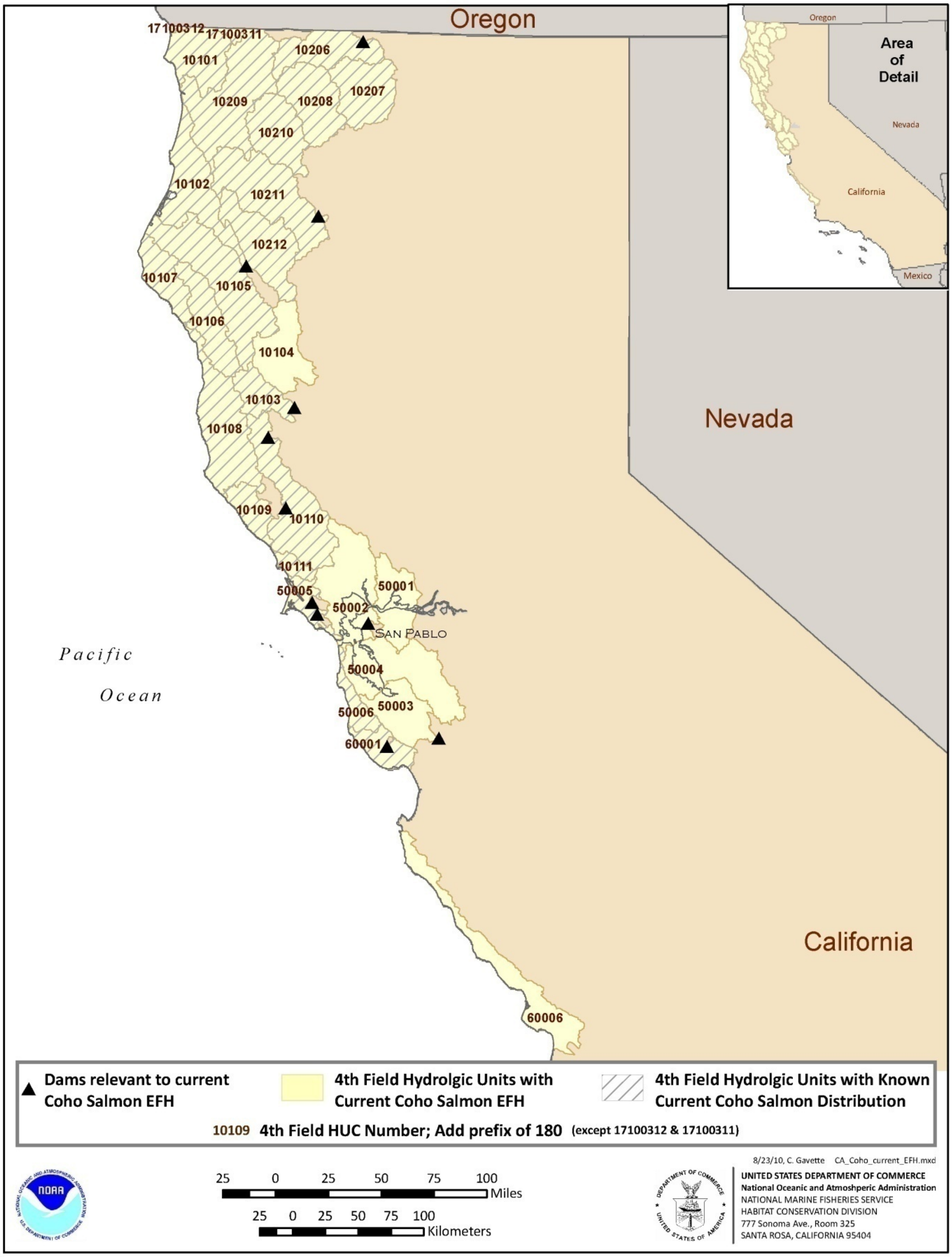

Figure 6. 4th field HUs currently identified as EFH for coho salmon in relation to coho salmon distribution in California.

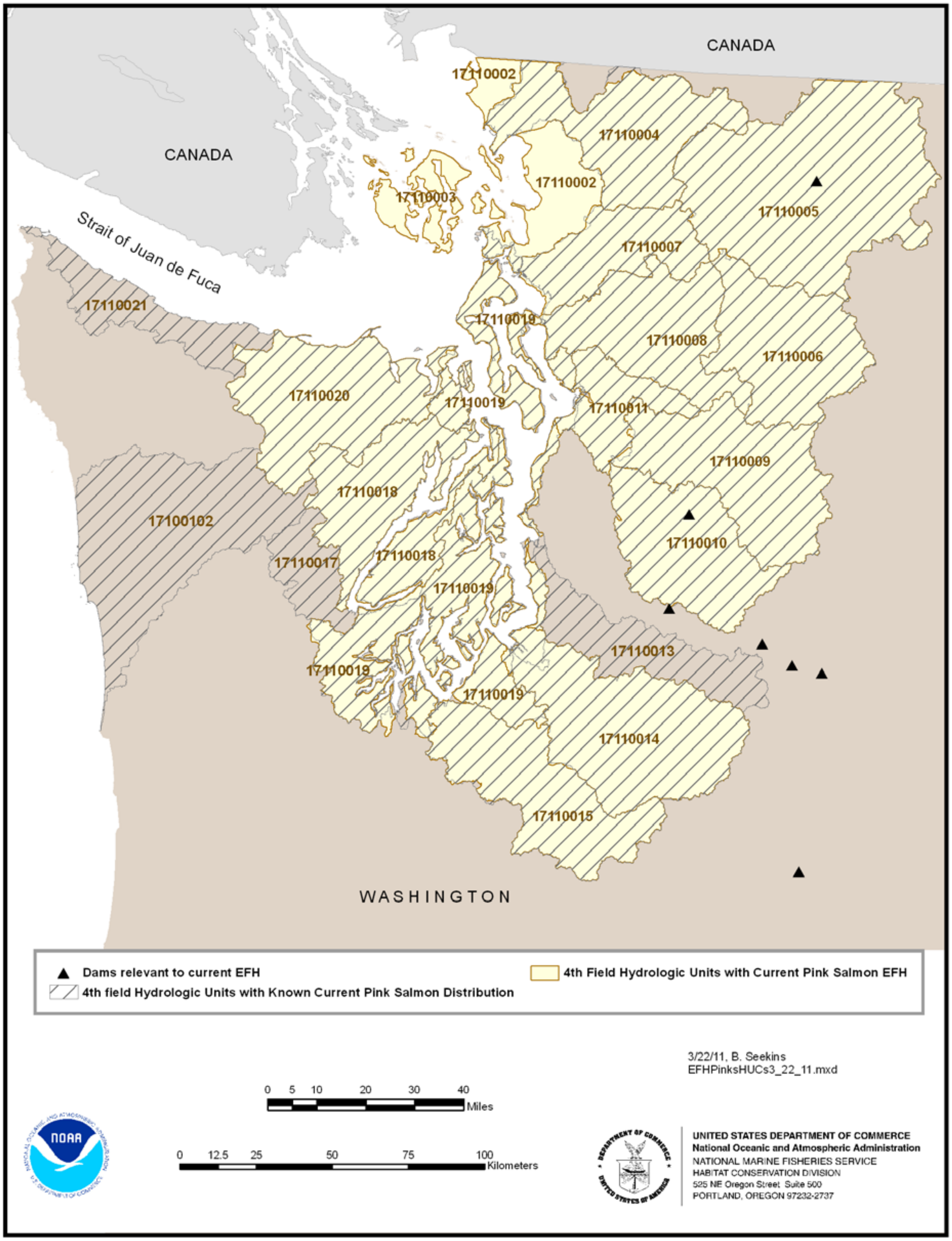

Figure 7. 4th field HUs currently identified as EFH for PS pink salmon in relation to current PS pink salmon distribution in western Washington.

3. REVIEW ESSENTIAL FISH HABITAT FOR PACIFIC COAST SALMON

A primary purpose of an EFH review is to examine new or newly-available information, especially as it relates to the information that was used as the basis for the original EFH designations. The regulatory guidance provides guidelines for organizing information. They recommend organizing the habitat information into one of four levels, and then suggest describing EFH based on the highest level of data (50 CFR 600.815(a)(1)(B)). These levels are:

Level 1: Distribution data are available for some or all portions of the geographic range of the species. At this level, only distribution data are available to describe the geographic range of a species (or life stage).

Level 2: Habitat-related densities of the species are available. At this level, quantitative data (i.e., density or relative abundance) are available for the habitats occupied by a species or life stage.

Level 3: Growth, reproduction, or survival rates within habitats are available. At this level, data are available on habitat-related growth, reproduction, and/or survival by life stage.

Level 4: Production rates by habitat are available. At this level, data are available that directly relate the production rates of a species or life stage to habitat type, quantity, quality, and location.

The available data on the habitat of Pacific Coast salmon includes some from all four levels. Pacific Coast salmon are distributed over a wide geographic range, with populations adapted to local habitat conditions that can vary widely across this range. Current distribution data (Level 1) is generally available across the entire geographic range. However, historical distribution data are lacking in certain parts of the range, and particularly in areas in which salmon populations have been extirpated. Information from the other levels, on the other hand, is generally not available across the entire range, and where available is usually limited to a smaller geographic area (i.e., a watershed or basin). Habitat-specific information from one location does not necessarily apply across the entire range. Therefore, it is appropriate to determine the geographic distribution of EFH for Pacific Coast salmon using Level 1 information, and incorporate information from the other levels, when possible, in the species- and life-stage-specific descriptions of EFH.

The Panel included two geographic information system (GIS) specialists who provided spatial information and maps to assist in identifying existing EFH and distribution information and determining whether new information warranted changes to the existing EFH maps. Updates, refinements, and revisions have occurred to both the hydrologic units and the salmon distribution data sets since the 1999 designation of EFH. The data used to create the 1999 designation was compared to recent data and NMFS GIS specialists provided potential updates to EFH where appropriate.

Historical and Current Distribution

The Panel recognizes that, as currently designated, EFH for Pacific Coast salmon is very broad, and includes virtually all freshwater habitats in those river systems that are currently or were historically occupied by salmon. However, the MSA defines EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.” The anadromous life history strategies of Pacific salmon rely on the connectedness of their habitats, from the rivers and streams downstream to the estuary and out to marine waters. Every habitat along this continuum serves a vital function in salmon life history, whether it is spawning, rearing, foraging, migrating, or a combination of these functions. Excluding any of these habitats from EFH would ignore the dependency that salmon have on this continuum and would conflict with the statutory definition of EFH. The Panel also recognized that within any river system, there is a limit on the upstream extent of habitats utilized by salmon, and that the three species will utilize the various habitats differently (e.g., coho salmon will spawn in smaller streams than either Chinook salmon or PS pink salmon). However, the data to allow for identification of EFH on a stream-by-stream basis are not available.

The Panel compared the current data on distribution of Pacific Coast salmon in freshwater and marine habitats with the current EFH designations. The freshwater and marine habitats are discussed separately because freshwater systems are classified by spatially-explicit HUs and marine waters are not. In addition, the physical nature of the habitats is different (e.g., freshwater systems have both natural and man-made barriers to salmon).

Freshwater Distribution

This section describes the various strategies that the Panel considered for determining the freshwater distribution of Pacific Coast salmon. The strategies included using current subbasin-scale distribution data and information on man-made impassible barriers (dams) to determine the current and historical distribution of salmon at the subbasin scale (4^{th} field HU) and modeling the freshwater habitat to estimate salmon distribution at a finer resolution (e.g., stream reach). The resulting salmon distribution data were then compared to the data used to designate EFH in Amendment 14. Finally, the Panel makes recommendations to the Council on where and at what spatial resolution EFH for Pacific Coast salmon should be designated.

Amendment 14 provided the following rationale for adopting a subbasin-based designation of EFH:

> *"Adopting an inclusive, watershed-based description of EFH using USGS HUCs is appropriate, because it (1) recognizes the species' use of diverse habitats and underscores the need to account for all of the habitat types supporting the species' freshwater and estuarine life stages, from small headwater streams to migration corridors and estuarine rearing areas; (2) considers the variability of freshwater habitat as affected by environmental conditions (droughts, floods, etc.) that make precise mapping difficult; and (3) reinforces important linkages between aquatic and adjacent upslope areas. Habitat available and utilized by salmon changes frequently in response to floods, landslides, woody debris inputs, sediment delivery, and other natural events. To expect the distribution of salmon within a stream, watershed, province, or region to remain static over time is unrealistic. Furthermore, this watershed-based approach is consistent with other Pacific salmon habitat conservation and recovery efforts such as those implemented under the Endangered Species Act (ESA). "*

The Panel agrees with this rationale, and used it for this review of EFH for Pacific Coast salmon.

Spatial Resolution of Salmon Distribution

Distribution data were obtained from the publicly available GIS data sets Streamnet (http://www.streamnet.org/) and Calfish (http://www.calfish.org/). These data were examined to determine whether it would be possible or practical to delineate EFH at finer spatial resolution.

Using USGS Hydrologic Units for EFH Designations

The current designations of freshwater EFH designations for the three species of Pacific Coast salmon are based on USGS 4^{th} field HUs. Defining EFH at a 4^{th} field HU level results in relatively coarse geographic descriptors. Geospatial mapping has improved significantly since the original Amendment

14, and USGS 5th or 6th field HUs are commonly used in many geospatial applications. One way to provide a more refined and precise interpretation of the text descriptions for Pacific Coast salmon EFH is to present historical and current distribution in smaller HUs. The resulting descriptions would provide a more precise spatial representation of EFH and would remove areas that are neither current nor historical salmon habitat from EFH.

However, several obstacles make this task difficult. First, and most significant, is the paucity of salmon distribution data for the 5th and 6th field HUs, where many of the HUs have no distribution data. Within the 174 4th field HUs that are currently designated as EFH, there are approximately 1052 5th field HUs and 5492 6th field HUs. Approximately 808 (77%) of the 5th field and 2990 (54%) 6th field HUs have known presence data. Figures 8 and 9 illustrate the extent of the 5th and 6th field HUs that lack distribution data. It is important to note that because neither Streamnet nor Calfish contain data on salmon absence, it is not reasonable to assume that all units without distribution data are unoccupied. Nor is current distribution information necessarily a good indicator of historical occupancy. The Panel concluded that the uncertainty associated with these smaller hydrologic units that lack distribution data, and the need to maintain a consistent approach across the geographic range of Pacific Coast salmon, precluded refining EFH down to the 5th or 6th field HU.

The second and less problematic issue is the magnitude of staff resources required to analyze all 5492 6th field HUs or 1052 5th field HUs. To ensure areas were not being erroneously omitted from, or included in, EFH designations, biologists with detailed knowledge of salmon distribution in a particular geographic region would need to evaluate these individual 5th or 6th field HUs. This task could not be completed during this review process. Therefore, the Panel concluded that designating EFH at the 4th field HU was both reasonable and appropriate at this time.

Mapping EFH at the 4th field HU may be seen as overly broad because it appears to incorporate not only the streams, but the upland areas as well. However, EFH can be designated only in aquatic habitats, so it is the streams in each HU that are designated as EFH, and not the uplands. Figure 10 illustrates how the extent of EFH is actually far less than the entire 4th field HU.

Designating at the 4th field level also may be seen as overly broad because it designates all streams, in their entirety, within that HU as EFH. However, the Panel recognizes that there will be portions of the streams in each 4th field HU that are not currently or historically utilized by salmon, especially in the upper reaches. Similar to the difficulty in designating EFH at the 6th field HU level, salmon distribution for each stream reach is not available across the entire geographic range of salmon. This apparent broadness can be reduced if the designations are modified in practice according to location and species-specific information. If, for example, a stream reach is upstream of the upper-most reach occupied, either currently or historically, by a particular species, then it should not be considered EFH for that species. Consulting biologists with a better understanding of salmon distribution in a particular region should be able to make this type of determination.

The 4th field HUs used to designate EFH in Amendment 14 were based on data created by the USGS in 1987. However, in 1999 the U.S. Department of Agriculture's Natural Resource Conservation Service published an updated GIS dataset that differs slightly from the 1987 data in the spatial extent, names, and codes of some of the HUs. These inconsistencies appear to be confined to the California Central Valley and the Puget Sound Region, where in some areas the subbasins have been more accurately

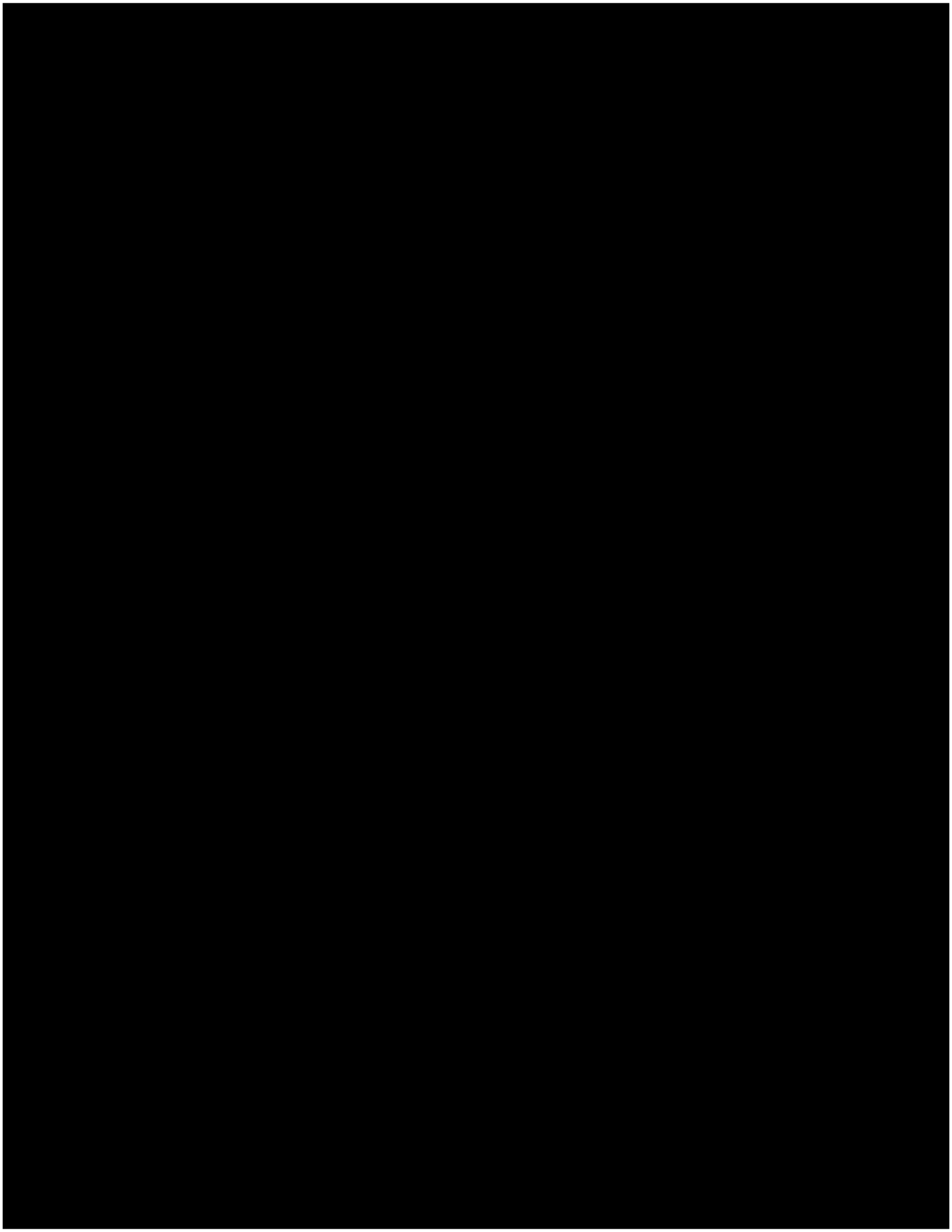

Figure 8. Example comparison of 6th field HUs with current or historical distribution data for coho salmon with those lacking distribution data.

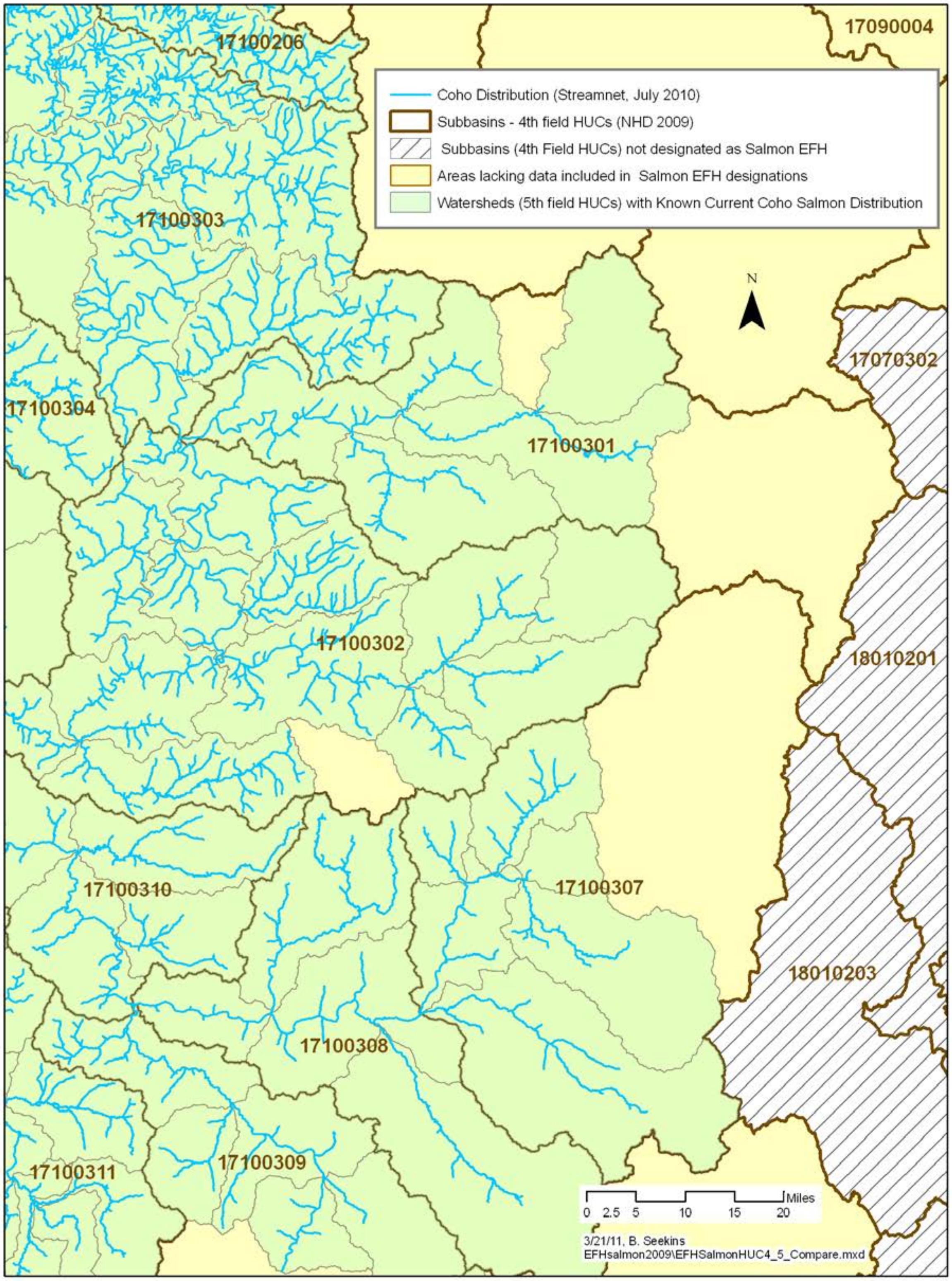

Figure 9. Example comparison of 5th field HUs with current or historical distribution data for coho salmon with those lacking distribution data.

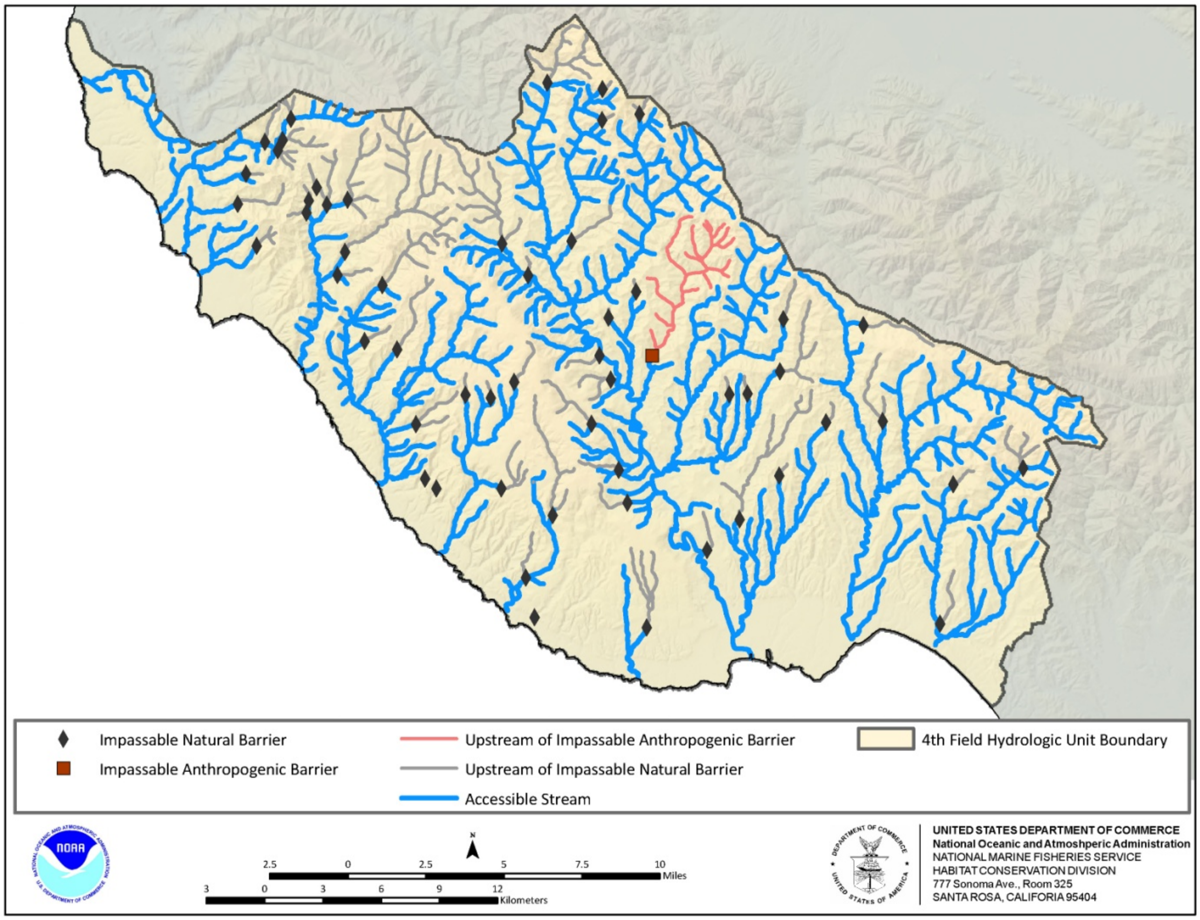

Figure 10. Example 4th field HU showing stream segments that are designated as EFH. Accessible stream reaches below anthropogenic and natural barriers that represent the upstream extent of EFH are shown.

delineated. The Panel determined that the updated GIS data is the most appropriate information to use for this review. Differences between these datasets, and the potential changes are noted in the tables where they affect the designation of EFH.

4th Field Distribution Data by Species

The Panel determined the current distribution, at the 4th field HU, of all three species of Pacific Coast salmon in Oregon, Washington, and Idaho using data on the presence of these species obtained from Streamnet (http://www.streamnet.org/), and in California from Calfish (http://www.calfish.org/). These data sets include data from stream surveys. However, because not all stream reaches are surveyed, Streamnet includes streams where, based on the best professional judgment of the state fisheries biologists, salmon are expected to occur. Additionally, Calfish represents only the known distribution based on where the species has been recently observed and reported. The majority of observations only indicate where the species was sampled for or otherwise observed. Because of this, the data likely underestimates the absolute geographic distribution of the species. And, as the species may not be found on an annual basis in all indicated reaches due to natural variations, the data does not verify that the species are currently present in a given stream. Conversely, the absence of distribution for a given stream does not necessarily indicate that the species does not occur in that stream. In addition, the Panel is aware of some current distribution data that are not reflected in the Calfish database (e.g., Leidy et al. 2007; Ettlinger et al. 2010).

Chinook Salmon
The current distribution data for Chinook salmon is depicted in Figures 1-3, which also compares these data with Amendment 14. There are 10 4th field HUs that are currently designated as EFH, but have no current distribution data for Chinook salmon (Table 2). In three cases, Amendment 14 indicates that these were either inaccessible historical habitat, or currently accessible but underutilized habitat. Therefore, they meet the general description of EFH and should retain their designation. These HUs are either currently accessible or were historically occupied by Chinook salmon, and therefore meet the designation criteria as described in Amendment 14. Of the remaining seven HUs, five were indicated in Amendment 14 as having data on presence in 1999, but that data was either not incorporated into the GIS databases used in this review or was found in the intervening years to be erroneous. The remaining two HUs are the San Juan Islands and Strait of Georgia, where Chinook salmon are known to occur in the marine waters, but not in the streams. Therefore, it is only the marine waters of these HUs that qualify as EFH for this species.

Four 4th field HUs have current Chinook salmon distribution data, but were not designated as EFH in Amendment 14 (Table 3). The presence of Chinook salmon in Lake Chelan (17020009) appears to be limited to the lower reaches, below a naturally impassible stream reach. Although Chinook salmon are present in the lake, these are non-anadromous fish, and are not likely to part of the FMU and therefore not managed by the Council. Another HU, Palouse (17060108) has current Chinook salmon distribution data but was not designated as EFH. The third, the lower north fork of the Clearwater River (17060308) had no data on presence in 1999, but now does. These data are from the relatively short portion of river that is below Dworshak Dam. The fourth HU is Tomales-Drakes Bay (18050005). Ettlinger et al (2010) reported that Chinook salmon have been observed in this subbasin (Lagunitas Creek) in 12 out of the last 15 years.

Although Calfish lacks Chinook salmon distribution data for Coyote Creek (18050003), an HU that is currently designated as EFH for this species, Leidy et al. (2007) report that Chinook salmon are present in this subbasin.

Using the most recent 4thfield HU GIS data produces potential alterations to the Chinook salmon EFH designation. Comparing the 1999 HUCs designated as EFH to the most recent data reveal several differences in HU numbers, names, and spatial extent, primarily in the California Central Valley. Figure 11 illustrates those differences. While some new areas may be designated as EFH, other areas that were previously designated as EFH may now be excluded. For example, the Fresno River is now defined as a separate subbasin where it was previously incorporated into the larger San Joaquin HU. The lack of historical or current Chinook salmon presence in the Fresno River precludes its inclusion in EFH. In the same way the area covered by the southwest corner of the current designation would no longer be included. This is due to the newer data more accurately defining the subbasin boundaries. Table 4 shows the 4th field HUs from Amendment 14 that should be removed from EFH for Chinook salmon because they no longer exist.

Recommendation

The Panel recommends consideration of updating EFH designations for Chinook salmon, based on the distribution information provided above and the potential changes indicated in Tables 4 and 5.

Table 2. 4th field HUs lacking current distribution data but designated as EFH in Amendment 14, and the reason they are included in Amendment 14. Species: CK = Chinook salmon, CO = coho salmon, PK = PS pink salmon. Basis for inclusion in Amendment 14: C = occupied in 1999; H = inaccessible historical habitat; H*= accessible as of 1999 but unutilized, NA = not indicated.

4th Field Hydrologic Unit	Tributary/Basin	State	Species	Basis for Inclusion in Amendment 14
17020008	Methow River	WA	CO	H*
17020011	Wenatchee River	WA	CO	C
17060103	Lower Snake – Asotin Creek	ID/WA	CO	H*
17060104	Upper Grande Ronde	OR	CO	H*
17060105	Wallowa River	OR	CO	H*
17060106	Lower Grande Ronde	OR/WA	CO	H*
17070102	Walla Walla River	OR/WA	CK	H*
17070301	Upper Deschutes River	OR	CK	H
17070305	Lower Crooked River	OR	CK	H
17070306	Lower Deschutes River	OR	CO	C
17070307	Willow Creek	OR	CK	H*
17070307	Trout Creek	OR	CK and CO	H*
17080004	Upper Cowlitz	WA	CK	C
17090004	McKenzie River	OR	CO	C
17090006	South Santiam	OR	CO	C
17110002	Strait of Georgia*	WA	CH and PK	NA
17110003	San Juan Islands*	WA	CK and PK	NA
18010104	Middle Fork Eel River	CA	CO	C
18010109	Gualala-Salmon River	CA	CK	C
18010111	Bodega Bay	CA	CK	C
18050001	Suisun Bay	CA	CK and CO	C
18050002	San Pablo Bay	CA	CK and CO	C
18050004	San Francisco Bay	CA	CK and CO	C
18060006	Central Coastal	CA	CO	H*

* These hydrologic units include marine waters, but no Chinook salmon or PS pink salmon distribution data in freshwater.

Table 3. 4th field HUs having current or historical distribution data but are not designated as EFH in Amendment 14. Ck=Chinook salmon; CO = coho salmon, PK = PS pink salmon.

4th Field hydrologic unit	Tributary/Basin	State	Species	Basis for Exclusion From Amendment 14
17020009	Lake Chelan	WA	CK	No data reported.
17060108	Palouse	ID/ WA	CH	No data reported
17060301	Upper Selway River	ID	CO	No data reported
17060302	Lower Selway River	ID	CO	No data reported
17060304	MF Clearwater River	ID	CO	No data reported
17060305	SF Middle Clearwater River	ID	CO	No data reported
17060308	Lower NF Clearwater River	ID	CH	No data reported
17070103	Umatilla River	OR	CO	No data reported
17110013	Duwamish River	WA	PK	No data reported, but recent large returns
17110017	Skokomish River	WA	PK	No data reported. Outside of FMU?
17110021	Hoko-Crescent	WA	PK	No data reported. Outside of FMU?
17100102	Queets-Quinault	WA	PK	No data reported. Outside of FMU?
18050005	Tomales-Drakes Bay	CA	CK	No data reported

Table 4. 4th field HUs in California that are currently designated as EFH for Chinook salmon in Amendment 14, but due to revisions in the HU codes and names, no longer exist.

USGS 4th Field Hydrologic Unit	Hydrologic Unit Name
18010111	Bodega Bay
18020101	Sac.–Lower Cow–Lower Clear
18020102	Lower Cottonwood Creek
18020103	Sacramento – Lower Thomes
18020105	Lower Butte Creek
18020106	Lower Feather River
18020107	Lower Yuba River
18020108	Lower Bear River
18020109	Lower Sacramento River
18020110	Lower Cache
18020112	Sacramento–Upper Clear
18020113	Cottonwood Headwaters
18020114	Upper Elder – Upper Thomas
18020118	Upper Cow – Battle Creek
18020119	Mill – Big Chico
18020120	Upper Butte Creek
18040004	L. Calaveras – Mormon Slough
18040005	L. Consumnes– L. Mokelumne

Figure 11. Comparison of the California Central Valley 4th field HUs designated as EFH in Amendment 14 with the newly defined HUs having current or historical Chinook salmon distribution data. Note that the spatial extent of EFH for Chinook salmon has expanded in some areas.

Coho Salmon

The current distribution data for coho salmon is depicted in Figures 4-6, which also compares these data with Amendment 14. There are 16 4th field HUs that are currently designated as EFH, but have no current distribution data for coho salmon (Table 2). Of these, Amendment 14 indicates that six were currently accessible but not occupied The remaining 10 were indicated in Amendment 14 as having data on presence in 1999, but that data was either not incorporated into the GIS databases used in this review or was found in the intervening years to be erroneous. These HUs are either currently accessible or were historically occupied by coho salmon, and therefore meet the designation criteria as described in Amendment 14.

Although Calfish lacks coho salmon distribution data for Coyote Creek (18050003) and San Pablo Bay (18050002), HUs that are currently designated as EFH for this species, Leidy et al. (2005, cited in Leidy et al. 2007)) found evidence for probable occurrence in these subbasins.

Seven 4th field HUs have current data on presence of coho salmon, but were not designated as EFH in Amendment 14 (Table 3).

Recommendation

The Panel recommends further consideration of the designation of EFH for coho salmon based on the distribution information provided above and the potential changes indicated in Table 5.

Puget Sound Pink Salmon

The current distribution of PS pink salmon is depicted in Figure 7, which also compares these data with Amendment 14. There are two 4th field HUs that are currently designated as EFH, but for which Streamnet has no distribution data (Table 2), and no distribution data are noted in Amendment 14. Although PS pink salmon utilize the adjacent marine waters, they are not known to occur in the streams of these hydrologic HUs. However, these two HUs also include marine waters that are assumed to support emigrating juveniles and returning adults. Therefore, despite the lack of PS pink salmon in the stream systems of these HUs, they do qualify as EFH, but only the marine waters. There are four 4th field HUs that have current data on the presence of pink salmon, but are not currently designated as EFH (Table 3). Of these, the Duwamish (17110013) has experienced dramatic returns of pink salmon in recent years. The Washington State Department of Fish and Wildlife estimates that up to 2.1 million pink salmon will return to the Duwamish system in 2011. Despite the lack of data on presence in the Duwamish in 1999, there is no question that pink salmon occupy this system.

The three remaining HUs, the Skokomish River (17110017), the Hoko-Crescent (17110021) and the Queets-Quinault (17110102) are shown in SteamNet as being occupied by pink salmon. However, their distribution in these systems is limited and they may have simply been missed by Amendment 14.

Another possible explanation for the exclusion of the Hoko-Crescent and Queets-Quinault pink salmon is that they are not part of the PS pink salmon fishery management unit (FMU). The PS pink salmon FMU is not clearly defined in the FMP and the western boundary is uncertain. The Elwha River is the westernmost subbasin that was designated as EFH for this species. This coincides with the westernmost populations of the pink salmon Evolutionarily Significant Unit (ESU) identified by NMFS in the 1996 status review (NMFS 1996). In this Status Review, two pink salmon ESUs (even-year and odd-year) were found to be distributed in the Elwha River and eastward. Whether or not the status review erroneously excluded the Hoko-Crescent and Queets-Quinault HUs is unknown, but it appears that the 1999 designation of EFH for PS pink salmon is based on the ESUs.

Recommendation

The Panel recommends further consideration of the designation of EFH for PS pink salmon based on the distribution information provided above and the potential changes indicated in Table 5.

Distribution Modeling

The Panel considered using new modeling applications that could be useful for assessing salmon habitat suitability. The desired outcome was to use a modeling approach to infer salmon distribution in areas that lack such information and to increase the precision of spatial distribution maps. To have utility, a model must be applicable across the entire geographic range of Pacific Coast salmon, yet be sufficiently precise to provide information on a relatively small spatial scale. Although many models to assess salmonid habitat are in use, most are applicable to a relatively limited geographic scope. Only Intrinsic Potential (IP) was considered to potentially be of use and was the only model explored past the discussion stage.

Intrinsic Potential

Intrinsic Potential models are intended to predict the historical (i.e., pre-anthropogenic disturbance) potential for a given stream reach to develop habitat characteristics suitable for a particular salmonid species and life stage based on a limited set of geomorphic and hydrologic characteristics. Most IP models convert values for stream gradient, valley width index, and mean annual discharge (landform, geomorphic, and hydrologic functions that interact to govern movement and deposition of sediment, large wood, and other structural elements along a river network) into separate suitability ratings scaled between 0 and 1. These individual suitability values are combined (typically as the geometric mean of these three suitability values) into the IP value for a particular reach. Additionally, some models may incorporate other environmental factors thought to limit the distribution or abundance of a particular species. For example, models of coho salmon intrinsic potential in California streams incorporate a mean August air temperature threshold as a method of masking out regions where water temperatures are too warm for coho salmon.

Intrinsic Potential models have potential application both in identifying EFH and in designating HAPCs. Specifically, the Panel explored using IP in areas that lack robust empirical information regarding salmonid presence/absence, either because they have not been surveyed or because populations have been extirpated. If a given hydrologic unit has never been surveyed and the paucity of valid information precludes definitively concluding current or historical presence, IP can be used to infer answers to those questions. IP models also typically include biophysical factors such as gradient that could be used to evaluate the relative suitability of different stream reaches, though such potential uses are confounded by the fact that IP models may be poor predictors of current habitat conditions, as none of the variables reflect habitat changes caused by anthropogenic activities. Figure 12 shows an example of how IP can be used to infer habitat suitability. In this example, stream reaches with suitable IP are highlighted and then colored to indicate stream reaches above currently impassible barriers. One barrier (Nicasio Dam) is being considered for fish passage while the other (Peters Dam) is not. Both dams, however, show IP above the barrier.

IP models have also been used extensively by salmon technical recovery teams to provide rough estimates of the relative habitat potential among different watersheds and subwatersheds. In these applications, the sum of all stream segment distances weighted by their IP values is calculated, a value termed IP-km. These estimates were used as proxies for relative habitat capacity in different hydrologic units.

Table 5. All 4th field HUs with current or historical distribution data for each species of Pacific Coast salmon and potential changes to the current EFH designations. C = currently designated as EFH; D = current or historical distribution data but not currently designated as EFH. The new HUs are from the updated dataset that overlap with the out-of-date HUs that are designated as EFH in Amendment 14.

USGS 4th Field Hydrologic Unit	State(s)	Hydrologic Unit Name	Species Distribution Data			Potential change
			Chinook	Coho	PS Pink	
17020005	WA	Columbia River	C	C		None
17020006	WA	Okanogan River	C			None
17020009	WA	Lake Chelan	D			Designate as EFH for Chinook salmon
17020007	WA	Similkameen	C			None
17020008	WA	Methow River	C	C		None
17020010	WA	Upper Columbia – Entiat River	C	C		None
17020011	WA	Wenatchee River	C	C		None
17020016	WA	Upper Columbia – Priest Rapids	C	C		None
17030001	WA	Upper Yakima River	C	C		None
17030002	WA	Naches River	C	C		None
17030003	WA	Lower Yakima River	C	C		None
17060101	OR/ID	Hells Canyon	C			None
17060102	OR	Imnaha River	C			None
17060103	OR/WA/ID	Lower Snake – Asotin Creek	C	C		None
17060104	OR	Upper Grande Ronde	C	C		None
17060105	OR	Wallowa River	C	C		None
17060106	OR/WA	Lower Grande Ronde	C	C		None
17060107	WA	Lower Snake – Tucannon River	C	C		None
17060110	WA	Lower Snake River	C	C		None
17060201	ID	Upper Salmon River	C			None
17060202	ID	Pahsimeroi River	C			None
17060203	ID	Mid. Salmon – Panther River	C			None
17060204	ID	Lemhi River	C			None
17060205	ID	Upper Middle Fork Salmon River	C			None
17060206	ID	Lower Middle Fork Salmon River	C			None
17060207	ID	Mid. Salmon – Chamberlain	C			None
17060208	ID	S.F. Salmon River	C			None
17060209	ID	Lower Salmon River	C			None

USGS 4th Field Hydrologic Unit	State(s)	Hydrologic Unit Name	Species Distribution Data			Potential change
			Chinook	Coho	PS Pink	
17060210	ID	Little Salmon River	C			None
17060301	ID	Upper Selway River	C	D		Designate as EFH for coho salmon
17060302	ID	Lower Selway River	C	D		Designate as EFH for coho salmon
17060304	ID	M.F. Clearwater River	C	D		Designate as EFH for coho salmon
17060305	ID	S.F. Clearwater River	C	D		Designate as EFH for coho salmon
17060306	WA/ID	Clearwater River	C	C		None
17060308	ID	Lower NF Clearwater River	D	D		Designate as EFH for Chinook salmon and coho salmon
17070101	OR/WA	Mid. Columbia – Lake Wallula	C	C		None
17070102	OR/WA	Walla Walla River	C			None
17070103	OR	Umatilla River	C	D		Designate as EFH for coho salmon
17070104	OR	Willow	C			None
17070105	OR/WA	Mid. Columbia – Hood	C	C		None
17070106	WA	Klickitat River	C	C		None
17070201	OR	Upper John Day River	C			None
17070202	OR	North Fork John Day River	C			None
17070203	OR	Middle Fork John Day River	C			None
17070204	OR	Lower John Day River	C			None
17070301	OR	Upper Deschutes River	C			None
17070305	OR	Lower Crooked River	C			None
17070306	OR	Lower Deschutes River	C	C		None
17070307	OR	Trout Creek	C	C		None
17080001	OR/WA	Lower Columbia–Sandy River	C	C		None
17080002	WA	Lewis River	C	C		None
17080003	OR/WA	Lower Columbia – Clatskanie River	C	C		None
17080004	WA	Upper Cowlitz River	C	C		None
17080005	WA	Cowlitz River	C	C		None
17080006	OR/WA	Lower Columbia	C	C		None
17090001	OR	Middle Fork Willamette River	C			None
17090002	OR	Coast Fork Willamette River	C			None
17090003	OR	Upper Willamette River	C	C		None
17090004	OR	McKenzie River	C	C		None

USGS 4th Field Hydrologic Unit	State(s)	Hydrologic Unit Name	Species Distribution Data			Potential change
			Chinook	Coho	PS Pink	
17090005	OR	N. Santiam River	C	C		None
17090006	OR	S. Santiam River	C	C		None
17090007	OR	Mid. Willamette River	C	C		None
17090008	OR	Yamhill River	C	C		None
17090009	OR	Molalla – Pudding River	C	C		None
17090010	OR	Tualatin River	C	C		None
17090011	OR	Clackamas River	C	C		None
17090012	OR	Lower Willamette River	C	C		None
17100101	WA	Hoh – Quillayute	C	C		None
17100102	WA	Queets – Quinault	C	C	D	Designate as EFH for PS pink salmon
17100103	WA	Upper Chehalis River	C	C		None
17100104	WA	Lower Chehalis River	C	C		None
17100105	WA	Grays Harbor	C	C		None
17100106	WA	Willapa Bay	C	C		None
17100201	OR	Necanicum River	C	C		None
17100202	OR	Nehalem River	C	C		None
17100203	OR	Wilson – Trask – Nestucca	C	C		None
17100204	OR	Siletz–Yaquina River	C	C		None
17100205	OR	Alsea River	C	C		None
17100206	OR	Siuslaw River	C	C		None
17100207	OR	Siltcoos River	C	C		None
17100301	OR	N. Umpqua River	C	C		None
17100302	OR	S. Umpqua River	C	C		None
17100303	OR	Umpqua River	C	C		None
17100304	OR	Coos River	C	C		None
17100305	OR	Coquille River	C	C		None
17100306	OR	Sixes River	C	C		None
17100307	OR	Upper Rogue River	C	C		None
17100308	OR	Middle Rogue River	C	C		None
17100309	CA/OR	Applegate River	C	C		None
17100310	OR	Lower Rogue River	C	C		None

USGS 4th Field Hydrologic Unit	State(s)	Hydrologic Unit Name	Species Distribution Data			Potential change
			Chinook	Coho	PS Pink	
17100311	CA/OR	Illinois River	C	C		None
17100312	CA/OR	Chetco River	C	C		None
17110001	WA	Fraser (Whatcom)		C		None
17110002	WA	Strait of Georgia†	C	C	C	None
17110003	WA	San Juan Islands†	C	C	C	None
17110004	WA	Nooksack River	C	C	C	None
17110005	WA	Upper Skagit	C	C	C	None
17110006	WA	Sauk River	C	C	C	None
17110007	WA	Lower Skagit River	C	C	C	None
17110008	WA	Stillaguamish River	C	C	C	None
17110009	WA	Skykomish River	C	C	C	None
17110010	WA	Snoqualmie River	C	C	C	None
17110011	WA	Snohomish River	C	C	C	None
17110012	WA	Lake Washington	C	C		None
17110013	WA	Duwamish River	C	C	D	Designate as EFH for PS pink salmon
17110014	WA	Puyallup River	C	C	C	None
17110015	WA	Nisqually River	C	C	C	None
17110016	WA	Deschutes River	C	C		None
17110017	WA	Skokomish River	C	C	D	Designate as EFH for PS pink salmon
17110018	WA	Hood Canal†	C	C	C	None
17110019	WA	Puget Sound†	C	C	C	None
17110020	WA	Dungeness – Elwha†	C	C	C	None
17110021	WA	Hoko – Crescent	C	C	D	Designate as EFH for PS pink salmon
18010101	CA/OR	Smith River	C	C		None
18010102	CA	Mad–Redwood	C	C		None
18010103	CA	Upper Eel River	C	C		None
18010104	CA	Middle Fork Eel River	C	C		None
18010105	CA	Lower Eel River	C	C		None
18010106	CA	South Fork Eel River	C	C		None
18010107	CA	Mattole River	C	C		None
18010108	CA	Big – Navarro – Garcia	C	C		None

USGS 4th Field Hydrologic Unit	State(s)	Hydrologic Unit Name	Species Distribution Data			Potential change
			Chinook	Coho	PS Pink	
18010109	CA	Gualala – Salmon Creek	C	C		None
18010110	CA	Russian River	C	C		None
18010206	CA/OR	Upper Klamath River	C	C		None
18010207	CA	Shasta River	C	C		None
18010208	CA	Scott River	C	C		None
18010209	CA/OR	Lower Klamath River	C	C		None
18010210	CA	Salmon River	C	C		None
18010211	CA	Trinity River	C	C		None
18010212	CA	S.F. Trinity River	C	C		None
18020104	CA	Sacramento – Stone Corral	C			None
18020111	CA	Lower American River	C			None
18020115	CA	Upper Stony	C			Designate as EFH due to the new HU dataset
18020116	CA	Upper Cache	C			Designate as EFH due to the new HU dataset
18020125	CA	Upper Yuba	C			None
18020126	CA	Upper Bear	C			Designate as EFH due to the new HU dataset
18020151	CA	Cow Creek	C			Designate as EFH due to the new HU dataset
18020152	CA	Cottonwood Creek	C			Designate as EFH due to the new HU dataset
18020153	CA	Battle Creek	C			Designate as EFH due to the new HU dataset
18020154	CA	Clear Creek-Sacramento River	C			Designate as EFH due to the new HU dataset
18020155	CA	Paynes Creek-Sacramento River	C			Designate as EFH due to the new HU dataset
18020156	CA	Thomes Creek-Sacramento River	C			Designate as EFH due to the new HU dataset
18020157	CA	Big Chico Creek-Sacramento River	C			Designate as EFH due to the new HU dataset
18020158	CA	Butte Creek	C			Designate as EFH due to the new HU dataset
18020159	CA	Honcut Headwaters-Lower Feather	C			Designate as EFH due to the new HU dataset
18020161	CA	Upper Coon-Upper Auburn	C			Designate as EFH due to the new HU dataset
18020162	CA	Upper Putah	C			Designate as EFH due to the new HU dataset
18020163	CA	Lower Sacramento	C			Designate as EFH due to the new HU dataset
18040001	CA	Middle San Joaquin– LowerChowchilla	C			None
18040002	CA	LowerSan Joaquin	C			None
18040003	CA	San Joaquin Delta	C			None
18040008	CA	Upper Merced	C			Designate as EFH due to the new HU dataset

USGS 4th Field Hydrologic Unit	State(s)	Hydrologic Unit Name	Species Distribution Data			Potential change
			Chinook	Coho	PS Pink	
18040009	CA	Upper Tuolumne	C			Designate as EFH due to the new HU dataset
18040010	CA	Upper Stanislaus	C			None
18040011	CA	Upper Calveras	C			None
18040012	CA	Upper Mokelumne	C			Designate as EFH due to the new HU dataset
18040013	CA	Upper Cosumnes	C			None
18040051	CA	Rock Creek-French Camp Slough	C			Designate as EFH due to the new HU dataset
18050001	CA	Suisun Bay	C	C		None
18050002	CA	San Pablo Bay	C	C		None
18050003	CA	Coyote Creek	C	C		None
18050004	CA	San Francisco Bay	C	C		None
18050005	CA	Tomales–Drakes Bay	D	C		Designate as EFH for Chinook salmon
18050006	CA	San Francisco–Coastal South		C		None
18060001	CA	San Lorenzo–Soquel		C		None
18060006	CA	Central Coastal		C		None

A workshop on Salmon Intrinsic Potential was held in Portland, OR on Nov. 19-20, 2008. A resultant product of that workshop is a paper titled "Development & Management of Fish Intrinsic Potential Data and Methodologies: State of the IP 2008 Summary Report" (Sheer et al. 2009). An excerpt from the report reads "IP models have been developed for some salmon and steelhead ESUs listed under the ESA, and model results have been incorporated into recovery planning activities. However, currently, there is no standard methodology for developing geospatial datasets needed for IP models nor are there peer-reviewed species preference curves for many resident and anadromous species in the Pacific Northwest."

Figure 12. Example of how Intrinsic Potential can help identify potentially suitable habitats for Pacific Coast salmon.

To date, IP models have been limited to several ESUs of Pacific salmon that are listed under the ESA. Although ESUs are not directly relevant to the MSA and EFH, the Panel assumed that IP models for ESA-listed salmon are applicable to all managed salmon of the same species in that area. These ESUs include:

Lower Columbia coho salmon
Lower Columbia Chinook salmon
Oregon Coast coho salmon
Willamette Chinook salmon
Puget Sound Chinook salmon
Snake River spring/ summer Chinook salmon
Upper Columbia River spring-run Chinook salmon
Southern Oregon/Northern California Coast coho salmon
Central California Coast coho salmon
California Coastal Chinook salmon

No GIS data for Snake River fall Chinook salmon are available, and the Panel is not aware of any IP models that have been developed for pink salmon. The NMFS Southwest Region GIS staff currently have resultant GIS data for the IP model work done in that region. However, individual data files do not exist for each hydrologic unit making any desired analysis fairly time-consuming. The NMFS Northwest Region GIS staff do not currently have GIS data for the IP models and would need to obtain it to use IP to infer EFH for particular hydrologic units.

Before IP modeling can be utilized to refine EFH for any of the species of Pacific Coast salmon managed under the FMP there must be regionally based models that that lead to similar spatial resolution of salmon habitat. Those models must, when taken together, cover the entire geographic range of that species. It is clear that IP modeling is inconsistent, at best, covering only a relatively small portion of the geographic range of any species. These gaps preclude the use of IP models in EFH designations, and will require significant time and effort to fill. However, the Panel also recognizes that in some cases of sparse information, existing IP can be used as a tool to investigate the likelihood of suitable salmonid habitat on a site- by-site basis for the purposes of EFH consultation.

Impassible Dams Designated as the Upstream Extent of EFH

Numerous dams block access to historical salmon habitat and/or alter the hydrography of downstream river reaches. In identifying EFH in Amendment 14, the Council considered dams that completely blocked fish passage, and used four criteria to determine whether a particular dam should represent the upstream extent of EFH:

1. *Is the dam federally owned or operated, licensed by the Federal Energy Regulatory Commission (FERC), state licensed, or subject to state dam safety supervision?* This criterion assures the dam is of sufficient size, permanence, impassibility, and legal identity to warrant consideration for inclusion in this list;

2. *Is the dam upstream of any other impassible dam?* This criterion provides for a continuous boundary of designated habitat;

3. *Is fish passage to upstream areas under consideration, or are fish passage facilities in the design or construction phase?* There is no currently, or soon to be, accessible freshwater salmon habitat that is expendable. All such habitat is key to the conservation of these species and needs the special considerations for protection and restoration incumbent with designation; and

4. *Has NMFS determined that the dam does not block access to habitat that is key for the conservation of the species?* This criterion provides for designation of habitat upstream of, and exclusion of, otherwise listed dams when NMFS is able to determine restoration of passage and conservation of such habitat is necessary for long-term survival of the species and sustainability of the fishery.

As a result, EFH was designated above a number of impassible dams that met one or more of these criteria, including Elwha Dam, Merwin Dam, Landsburg Dam, Howard Hanson Dam, Condit Dam, Cushman Dam, Mayfield Dam, Foster Dam, Pelton Dam, and Englebright Dam. Justification for designating EFH above impassable barriers has been provided in both the EFH regulations and Amendment 14 to the FMP. The regulatory text at 50 CFR §600.815(a)(1)(iv)(F) states:

> *"If degraded or inaccessible aquatic habitat has contributed to reduced yields of a species or assemblage and if, in the judgment of the Secretary and the appropriate Council(s), the degraded conditions can be reversed through such actions as improved fish passage techniques (for stream or river blockages), improved water quality measures (removal of contaminants or*

increasing flows), and similar measures that are technologically and economically feasible, EFH should include those habitats that would be necessary to the species to obtain increased yields."

Amendment 14 included the following language regarding habitat needed to support a sustainable fishery and the identification of such habitat through other processes and analyses:

"While available information is not sufficient to conclude that currently accessible habitat is sufficient for supporting sustainable salmon fisheries and a healthy ecosystem, subsequent analyses (e.g., in recovery planning, ESA consultations, or hydropower proceedings) may conclude that inaccessible habitat should be made available to the species."

Amendment 14 then focused specifically on the importance of considering the need to restore fish passage to historically accessible areas through the FERC relicensing process noting:

"Even though habitat above such barriers may not currently be designated as EFH, this conclusion does not diminish the potential importance of restoring access to these areas. Therefore, a determination on a case-by-case basis during FERC relicensing proceedings whether fish passage facilities will be required to provide access to habitat above currently impassible barriers will be necessary. Should salmon access or reintroduction above any of the dams listed in Table A-2 become feasible, the Council will remove them from the list, and the areas above the barriers would be designated as salmon EFH."

The EFH provisions of the MSA are intended to ensure conservation and protection of EFH to promote a sustainable fishery, which requires a more robust population than necessary to ensure persistence of the population or ESU. Therefore, the Panel determined that if the habitat may be necessary for the persistence of the population or ESU, it is clearly necessary to promote a sustainable fishery. As demonstrated in both the EFH regulations and Amendment 14 to the FMP, designating EFH above impassable dams is appropriate under certain conditions and has been done in the past. The Panel agreed that the four criteria identified in Amendment 14 were still applicable and further elaborated on the interpretation of criterion 4. Specifically, habitats that may be necessary to contribute to the conservation or recovery of a species, as identified in a document such as a biological opinion, recovery plan, critical habitat designation, or FERC/Federal Power Act fish passage prescriptions, are clearly necessary to support a sustainable fishery. When available, economic analyses regarding the cost of providing fish passage should also be taken into consideration. Recovery plans must identify priority actions necessary for population recovery. In some cases, recovery plans specifically identify habitat upstream of existing dams that are on the list of impassible dams marking the upstream extent of EFH, thereby providing support for designating EFH above those dams. Consultation under the ESA typically includes issuance of a biological opinion (Opinion), which includes mandatory actions to protect the species and/or its designated critical habitat. These actions may include fish passage above dams on the list of impassable dams marking the upstream extent of EFH, again providing support for designating EFH above those dams. Another example is that of fish passage "prescriptions" issued under Section 18 of the Federal Power Act, in which NMFS may require fish passage installation and/or upgrades to existing facilities to address the impacts of a hydropower project and expand access to historical and currently suitable habitat above dams to contribute to the conservation of the species. In such cases, habitat above the dam should be designated as EFH and a new upstream extent of EFH should be identified.

The Panel applied the selection criteria to the dams that were previously determined to be the upstream extent of EFH, as published in the 2008 Final Rule that codified the EFH descriptions for Pacific Coast salmon, along with two others that were recommended to NMFS by the Bureau of Reclamation in 2007. Table 5 lists all the dams that were considered, the potential changes to the dams that are designated as the upstream extent of EFH, and the rationale behind those changes. Designation of the habitat above any of these dams as EFH would mean that consultation would be required for any Federal action that may adversely affect EFH in those areas. Designating EFH above a dam would also require that the upstream habitats be examined to see what, if any, impassible dams there are further upstream and any additional 4th field HUs that would become accessible. In areas where EFH may be designated above impassable dams, the Panel did not investigate the dams located further upstream to determine the new extent of EFH.

The potential changes to the dams that are designated as the upstream extent of EFH fall into 4 broad categories and several subcategories, as follows:

1 Corrections to the 2008 Final Rule, where a dam was designated as the upstream extent of EFH in Amendment 14, but was inadvertently omitted from 2008 Final Rule;
2 Update HU name and code to match those published by the USDA in 1999;
3 Delete a dam from the list and designate the habitat upstream as EFH because:
   - a Fish passage is now occurring or passage facilities are under construction;
   - b Fish passage at the dam is in the planning stage;
   - c Fish passage at the dam is being considered;
   - d Critical habitat has been designated above this dam;
   - e Habitat above this dam has been identified in a document as habitat that may be necessary to contribute to the conservation or recovery of a species; or
   - f The dam is upstream of another impassible barrier, either natural or man-made;
4 Designate a dam as the upstream extent of EFH because it was investigated due to a comment by a Federal agency and found to meet the criteria.

Not all of these changes are as strongly supported as others. Some, such as corrections to the final rule, updating HU names and codes, and designating the habitat above a dam as EFH because fish are now being passed, are not seen by the Panel as being controversial and can be easily implemented. However, designating habitat above a dam as EFH because passage is being considered or that it "may be essential to" or "is necessary for" the conservation of the species has broader implications, with the potential for significantly expanding EFH. Such changes will require careful consideration by the Council. In doing so, the Council should consider several factors, including, but not limited to, the strength of the information that supports the changes, the likelihood that passage will be possible in the foreseeable future, and the extent of EFH that will be designated above the dam. For these reasons, the Panel is not making specific recommendations for revising this list.

The results from this evaluation process, including potential changes to the list of dams that form the upstream extent of EFH and the rationale behind those potential changes, are shown in Table 5. The Panel notes that recovery plans for a number of ESA-listed salmon ESUs are in draft form and have not been finalized. Consequently, there are uncertainties regarding which populations will be targeted in recovery scenarios and which of these populations may require passage above currently impassable dams in order to achieve recovery goals. Assessments regarding both the necessity of above-dam habitats for recovery and the feasibility of providing passage are currently underway. In some cases, it is clearly evident in draft recovery plans that passage will be required above specified dams to achieve recovery criteria for a particular ESU. In others, passage will almost certainly be required above one or more dams in order for recovery criteria to be met; however, the specific dams to be targeted for passage have not yet been explicitly identified. In the former case, we believe there is strong justification for designating the habit above identified dams as EFH. In the latter cases, we have noted the dams under consideration for passage in Table 5, but acknowledge that the justification for designating EFH upstream of these dams is not as straightforward. These specific cases will need to be revisited in a future EFH review.

Because of the changes to the 4th field HUs in the California Central Valley, areas that were not previously designated as EFH may become EFH. This may mean that additional dams may need to be designated as the upstream extent of EFH. One example is the Monticello Dam on Putah Creek.

Recommendations

The Panel recommends that the Council consider updating the list of impassible dams that mark the upstream extent of EFH based on the information provided in Table 5. The habitat above dams that are deleted from the list would then be designated as EFH for the appropriate species. The next natural or manmade barrier(s) upstream would then represent the new upstream extent of EFH

Marine Distribution

As currently designated, the geographic extent of marine EFH for Chinook salmon and coho salmon includes all marine waters within the EEZ north of Point Conception, California to the U.S. - Canada border and the marine areas off Alaska designated as salmon EFH by the NPFMC. For PS pink salmon, marine EFH is currently designated to include all nearshore marine waters north and east of Cape Flattery, Washington, including Puget Sound, the Strait of Juan de Fuca, and the Strait of Georgia. It is difficult to determine a western limit for pink salmon essential marine habitat because of limited information on their ocean distribution, but it is clear that the vast majority are found in Canadian, Alaskan, and international waters both within and outside the EEZ north of Cape Flattery, Washington. The current designation of marine EFH for PS pink salmon is based on the Elwha River being the western most extent of the FMU. However, if pink salmon from the Hoko-Crescent and Queets-Quinault systems were included in the FMU, some portion of the marine waters off the coast of Washington, from Cape Flattery, south to the Queets-Quinault should be considered EFH.

The current marine EFH designations are necessarily broad due to insufficient data in 1999 to more narrowly define EFH. In recent years, additional data have been collected on the marine distribution of Pacific Coast salmon (e.g., Bi et al. 2008; Peterson et al. 2010; Pool et al. *in prep*.). However, the Panel concluded that it would be better to wait to refine marine EFH until an effort to model marine distribution of salmon in Alaskan waters is complete. Similar to the PFMC, when the NPFMC designated EFH for salmon, the lack of data and resources resulted in designations that included the entire EEZ off the coast of Alaska. To address this issue, the NPFMC and the Alaska Region of NMFS are developing a model to predict marine distribution for each life-stage of five species of Pacific Coast salmon (Chinook salmon, coho salmon, pink salmon, sockeye salmon and chum salmon) in Alaskan waters. The model uses fish catch and hydrographical data compiled from multiple research efforts conducted within the Alaskan EEZ using systematic surface and midwater trawls at designated survey stations. Data sets include those obtained from NMFS and its Alaskan Fisheries Science Center, U.S. Global Ocean Ecosystem Dynamics program, the University of Alaska Fairbanks, the Department of Fisheries and Oceans Canada, and the International North Pacific Fisheries Commission. This model is expected to significantly reduce the extent of salmon EFH in Alaskan waters and can provide a basis for future refinement of marine EFH for the three species of Pacific Coast salmon managed by the Council.

The effort by the NPFMC to refine marine EFH for salmon would also have direct implications on the EFH designations for salmon managed by the Council. As described above, the EFH designations in Amendment 14 included Alaskan marine waters designated by the NPFMC as EFH for salmon. This was intended to highlight the importance of habitats around the North Pacific Ocean, as well as the far-ranging migrations that many stocks exhibit. Because the salmon managed by the Council rely heavily

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Table 6. Potential changes to the impassible dams representing the upstream extent of EFH. Note that an impassible barrier limits EFH extent only above that particular barrier. The remainder of the HU would still be considered EFH.

4th field Hydrologic Unit	State(s)	Hydrologic Unit Name	Impassible Man-made Barrier (from 2008 F.R.)	Supporting information	Potential Change
17020005	WA	Columbia River	Chief Joseph Dam	N/A	N/A
17030001	WA	Upper Yakima River	Keechelus Dam Kachess Dam (Kachess R.)	Bureau of Reclamation has conducted preliminary assessment of passage at Keechelus and Kachess Dams (BOR 2008; 2010), but is not moving forward with additional study until after passage is provided at Cle Elum and Bumping Dams.	Designate habitat above Keechelus and Kachess Dams as EFH
17030001	WA	Upper Yakima River	Cle Elum Dam (Cle Elum R.)	Bureau of Reclamation is in the process of planning passage for salmonids at Cle Elum Dam (BOR 2010).	Designate habitat above Cle Elum Dam as EFH.
17030002	WA	Naches River	Rimrock Dam (Tieton R.)	Bureau of Reclamation has conducted preliminary assessment of passage at Rimrock (Tieton) Dam (BOR 2008; 2010), but is not moving forward with additional study until after passage is provided at Cle Elum and Bumping Dams.	Designate habitat above Rimrock Dam as EFH.
17060101	OR/ID	Hells Canyon	Hells Canyon Complex (Hells Canyon, Oxbow, and Brownlee Dams)	Oxbow and Brownlee Dams are upstream of Hells Canyon Dam.	Change to Hells Canyon Dam, and delete Oxbow and Brownlee Dams
17060306	WA/ID	Clearwater River	Dworshak Dam (at border of HUCs 17060306 and 17060308)	N/A	N/A
17070103	OR	Umatilla	McKay Dam (McKay Creek)	Bureau of Reclamation (BOR 2007) proposed that McKay Dam be designated as upstream extent of EFH. NMFS staff subsequently verified that this dam meets the selection criteria for upstream extent of EFH.	Designate McKay Dam as the upstream extent of EFH (on McKay Creek only)
17070305	OR	Lower Crooked River	Opal Springs Dam	According to Scot Carlon, Hydro Division, NWR, a settlement agreement is possible to provide passage for Willamette River spring-run Chinook salmon at Opal Springs Dam.	Designate habitat above Opal Springs Dam as EFH for Chinook salmon
17080001	OR/WA	Lower Columbia-Sandy River	Impassable man-made barrier	The name of the impassible dam on the Bull Run River was inadvertently omitted from the 2008 Final Rule. It is Bull Run Dam #2. The CHART final report (NMFS 2005a) noted that habitat above the Bull Run Dam complex "may be essential" to the conservation of LCR Chinook salmon.	Two possible recommendations: (1) Designate habitat above as EFH for Chinook only; or (2) Keep the dam and properly identify as Bull Run Dam #2.

4th field Hydrologic Unit	State(s)	Hydrologic Unit Name	Impassible Man-made Barrier (from 2008 F.R.)	Supporting information	Potential Change
17090001	OR	Middle Fork Willamette River	Dexter Dam	Critical Habitat has been designated above Dexter Dam (70 FR 52630, September 2, 2005). In addition, spring-run Chinook salmon are currently being trapped and hauled above Dexter Dam. EFH above Dexter should be for Chinook only.	Designate habitat above Dexter Dam as EFH for Chinook
17090002	OR	Coast Fork Willamette River	Dorena Dam	N/A	N/A
17090004	OR	McKenzie River	Cougar Dam	N/A	N/A
17090005	OR	N. Santiam River	Big Cliff Dam	The CHART final report (NMFS 2005a) maintained that areas above the North Santiam dams "may be essential" for the conservation of Upper Willamette Chinook salmon and agreed that the Technical Recovery Team's viability assessment (McElhany et al., 2003) strongly suggests that these areas may warrant designation. In addition, the reintroduction of Upper Willamette Chinook salmon is underway, via trucking around the dams.	Designate habitat above Big Cliff Dam as EFH for Chinook salmon (coho salmon are not trucked around the dams)
17090011	OR	Clackamas River	Oak Grove Dam	According to the CH designations (70 FR 52630, September 2, 2005) and Google Earth, CH stops about 1 mile downstream of Oak Grove Dam. There may be a naturally-impassible waterfalls below this dam.	Delete Oak Grove Dam from list if a falls that is downstream of the dam is a natural barrier.
17100301	OR	N. Umpqua River	Soda Springs Dam	PacifiCorp is in process of constructing fish passage facility, with construction scheduled for completion in 2012 (http://www.pacificorp.com/about/newsroom/ 2010nrl/ptbwossfpp.html)	Designate habitat above Soda Springs Dam as EFH
17100307	OR	Upper Rogue River	Lost Creek Dam	N/A	N/A
17100308	OR	Middle Rogue	Emigrant Dam	Bureau of Reclamation (BOR 2007) proposed that Emigrant Dam be designated as upstream extent of EFH. NMFS staff subsequently verified that this dam meets the four selection criteria for upstream extent of EFH.	Designate Emigrant Dam as the upstream extent of EFH
17100309	CA/OR	Applegate	Applegate Dam	N/A	N/A
17110005	WA	Upper Skagit	Gorge Lake Dam	N/A	N/A
17110010	WA	Snoqualmie	Tolt Dam (S. Fork Tolt R.)	N/A	N/A
17110012	WA	Lake Washington	Cedar Falls (Masonry) Dam (Cedar R.)	N/A	N/A
18010102	CA	Mad-Redwood	Robert W. Matthews dam	N/A	N/A

4th field Hydrologic Unit	State(s)	Hydrologic Unit Name	Impassible Man-made Barrier (from 2008 F.R.)	Supporting information	Potential Change
18010103	CA	Upper Eel	Scott Dam	N/A	N/A
18010110	CA	Russian	Coyote Valley Dam (E. Fork Russian R.)\Warm Springs Dam (Dry Cr.)	N/A	N/A
18010206	CA/OR	Upper Klamath	Iron Gate Dam	NMFS/USFWS jointly filed final FPA prescriptions for fishways for the Klamath Hydroelectric Project (NMFS 2007b) , which withstood the trial-type hearing challenging the scientific basis. This led to the Klamath Hydropower Settlement Agreement process, which is ongoing and would provide for the removal of four dams on the mainstem Klamath River. NMFS Klamath Opinion on Operation of the Klamath Project between 2010 and 2018 (2010B) notes that the loss of historical habitat above Iron Gate Dam, combined with other factors (e.g., hatchery practices, land management activities, water withdrawals), "have contributed to the high risk of extinction of this population".	Designate habitat above Iron Gate Dam as EFH for coho and Chinook
18010207	CA	Shasta	None	This dam was mistakenly deleted from the 2008 F.R.	Re-designate Dwinnell Dam as the upstream extent of EFH
18010211	CA	Trinity	Lewiston Dam	N/A	N/A
18020111	CA	Lower American	Nimbus Dam	Public Draft CV Recovery Plan (NMFS 2009c) notes areas upstream of Nimbus and Folsom dams (NF, MF, and SF American River) are being considered for re-introduction of spring-run Chinook salmon	The designation of EFH above Nimbus and Folsom Dams warrants special consideration in a future EFH review and/or as new information becomes available. EFH designation above Nimbus and Folsom Dams warrant special consideration in a future EFH review and/or as new information becomes available.
18020115	CA	Upper Stony		This dam was mistakenly deleted from the 2008 F.R.	Designate Black Butte Dam as the upstream extent of EFH
18020126	CA	Upper Bear		This dam was mistakenly deleted from the 2008 F.R.	Add Camp Far West Dam

4th field Hydrologic Unit	State(s)	Hydrologic Unit Name	Impassible Man-made Barrier (from 2008 F.R.)	Supporting information	Potential Change
18020154	CA	Clear Creek-Sacramento River	Keswick Dam (Sacramento R.) Whiskeytown Dam (Clear Cr.)	Keswick Dam should have remained on the list of impassible dams in 2008 Final Rule. However, as noted below, based on newly available information, there is strong support for designating EFH above Keswick Dam and Shasta Dam NMFS Opinion on the Long-term Operations of the Central Valley Project and State Water Project (NMFS 2009a) includes long-term passage prescriptions at Shasta Dam and re-introduction of winter-run into its native habitat above the dam Public Draft CV Recovery Plan (NMFS 2009c) identifies the re-establishment of viable winter-run Chinook populations in both the Little Sacramento and McCloud rivers as critical to recovery of the Central Valley winter-run Chinook ESU. Public Draft CV Recovery Plan (NMFS 2009c) identifies the re-establishment of viable spring-run populations in the Little Sacramento and McCloud rivers as critical to recovery of the Basalt and Porous Lava Diversity Group within the Central Valley spring-run Chinook ESU.	Leave Whiskeytown Dam as the upstream extent of EFH Designate habitat above Keswick Dam and Shasta Dam as EFH for Chinook. Correct 4th field HUC. Listed in Amendment 14 as 18020112
18020159	CA	Honcut Headwaters-Lower Feather	None	Oroville Dam was listed in Amendment 14 as the upstream extent of EFH, but mistakenly was deleted from the 2008 F.R. NMFS staff recommended at that time to add the Feather River Fish Barrier Dam because that dam (approx 1.5 miles downstream of Oroville Dam) more logically defines the upstream extent for EFH on the Feather River. No fish pass this dam, and there is yet another impassible dam between Oroville and the Fish Barrier Dams. Public Draft CV Recovery Plan (NMFS 2009c) notes the area upstream of Oroville Dam (NF Feather River) is being considered for re-introduction of spring-run Chinook salmon	Designate Feather River Fish Barrier Dam as the upstream extent of EFH The designation of EFH above Feather River Fish Barrier Dam and Oroville Dam warrants special consideration in a future EFH review and/or as new information becomes available Correct 4th field HUC. Listed in Amendment 14 as 18020121 &18020123
18040006	CA	Upper San Joaquin		This dam was mistakenly deleted from the 2008 F.R.	Designate Friant Dam as the upstream extent of EFH

4th field Hydrologic Unit	State(s)	Hydrologic Unit Name	Impassible Man-made Barrier (from 2008 F.R.)	Supporting information	Potential Change
18040008	CA	Upper Merced	Crocker Diversion Dam	This dam was mistakenly deleted from the 2008 F.R. Public Draft CV Recovery Plan (NMFS 2009c) identifies areas upstream of Crocker Diversion and New Exchequer dams (Merced River) among three above-dam alternatives to be considered for re-introduction of spring-run Chinook salmon in the Southern Sierra Diversity Group; the establishment of a viable spring-run population in one of these three alternatives (i.e., upper Stanislaus, upper Tuolumne, or upper Merced) is identified as critical to recovery of the Central Valley spring-run Chinook ESU	Designate Crocker Diversion Dam as the upstream extent of EFH The designation of EFH above Crocker Diversion and New Exchequer Dams warrants special consideration in a future EFH review and/or as new information becomes available
18040009	CA	Upper Tuolumne	La Grange Dam (Tuolumne R.)	Public Draft CV Recovery Plan (NMFS 2009c) identifies areas upstream of LaGrange and Don Pedro dams (Tuolumne River) among three above-dam alternatives to be considered for re-introduction of spring-run Chinook salmon in the Southern Sierra Diversity Group; the establishment of a viable spring-run population in one of these three alternatives (i.e., upper Stanislaus, upper Tuolumne, or upper Merced) is identified as critical to recovery of the Central Valley spring-run Chinook ESU	The designation of EFH above La Grange and Don Pedro Dams warrants special consideration in a future EFH review and/or as new information becomes available Correct 4th field HUC. Listed in Amendment 14 as 18040002
18040010	CA	Upper Stanislaus	Goodwin Dam	Public Draft CV Recovery Plan (NMFS 2009c) identifies areas upstream of Goodwin, Tulloch, and New Melones dams (NF Stanislaus River) among three above-dam alternatives to be considered for re-introduction of spring-run Chinook salmon in the Southern Sierra Diversity Group; the establishment of a viable spring-run population in one of these three alternatives (i.e., upper Stanislaus, upper Tuolumne, or upper Merced) is identified as critical to recovery of the Central Valley spring-run Chinook ESU	The designation of EFH above Goodwin, Tullock and New Melones Dams warrants special consideration in a future EFH review and/or as new information becomes available
18040011	CA	Upper Calaveras California	New Hogan Dam	N/A	N/A

4th field Hydrologic Unit	State(s)	Hydrologic Unit Name	Impassible Man-made Barrier (from 2008 F.R.)	Supporting information	Potential Change
18040012	CA	Upper. Mokelumne	Camanche Dam	Public Draft CV Recovery Plan (NMFS 2009c) identifies areas upstream of Camanche and Pardee dams (Upper Mokelumne River) to be considered for re-introduction of spring-run Chinook salmon	The designation of EFH above Camanche and Pardee Dams warrants special consideration in a future EFH review and/or as new information becomes available Correct 4^{th} field HUC. Listed in Amendment 14 as 18040005
18050002	CA	San Pablo Bay	San Pablo Dam (San Pablo Cr.)	N/A	N/A
18050003	CA	Coyote	LeRoy Anderson Dam	N/A	N/A
18050005	CA	Tomales-Drake Bays	Nicasio Dam (Nicasio Cr.)/Peters Dam (Lagunitas Cr.)	N/A	N/A
18060001	CA	San Lorenzo-Soquel	Newell Dam (Newell Cr.)	N/A	NA

on habitats in Alaskan waters, maintaining these waters as EFH is justifiable. However, it is unclear to the Panel whether changes to EFH in Alaskan waters made by the NPFMC would automatically result in changes to EFH for Council-managed stocks, or whether the Council would need to take action to adopt these changes.

Recommendation

The Panel recommends further consideration of the designation of marine EFH and better definition of the FMU for coho salmon and PS pink salmon, based on the available information provided on marine distribution of Pacific Coast Salmon.

Essential Fish Habitat Descriptions

Pursuant to the EFH guidelines (50 CFR 600), FMPs should summarize the life history information necessary to understand each species' relationship to or dependence on its various habitats, using text, tables, and figures, as appropriate. A major part of the periodic EFH review process is aimed at updating the descriptions of EFH, which provide detailed information on the habitats used by Council-managed species.

Existing EFH Descriptions

Amendment 14 provides descriptions of EFH for each species and life stage that were developed through an extensive review and synthesis of the literature available in 1999. They provide a review of life history for each species, text descriptions, and tables that summarize, for each species, the habitats used by each life history stage and the important features of those habitats.

New Information

The Council enlisted Cramer Fish Sciences to develop an annotated bibliography (Bergman 2010) of relevant information that could inform and update the library of information relative to the habitat requirements of Pacific Coast salmon (Appendix A). The literature on salmon is very rich, and the Panel recognized that it did not have the necessary resources to compile an annotated bibliography of all recent and relevant information. Instead, the bibliography was intended to present a representative sample of the recent literature. Bergman (2010) includes about 100 references in the annotated bibliography, which presents literature for Chinook salmon, coho salmon, and PS pink salmon. The bibliography divides the literature into five distinct life stages: eggs and spawning, freshwater juveniles, estuarine juveniles, marine juveniles, and adults. For each life stage, the annotated bibliography presents several key or representative references. Because Pacific Coast salmon have been extensively studied for more than 100 years, especially in the freshwater environment, the Panel expects that the new information would help to refine the EFH descriptions.

This section highlights some of the literature that can be used to supplement the habitat descriptions in Amendment 14. The literature cited here provides information, such as use of a specific type of habitat not discussed in Amendment 14, and demonstrates that the descriptions should be revised to be more comprehensive.

Chinook Salmon

Eggs and Spawning
Chinook salmon have been shown to spawn in stream reaches characterized as low-gradient pool-riffle reaches (Montgomery et al. 1999). Chinook salmon redds were associated with large woody debris (LWD) in the Lower Mokelumne River (Merz 2001), where substrate was smaller and the mean depth of

the redds was greater. The study concluded that the presence of LWD improves otherwise lower-quality habitat, making it more suitable for spawning, and may allow greater concentration of redds on suitable sites.

Juveniles -Freshwater
In low-gradient alluvial valleys of the upper Columbia River basin, juvenile Chinook salmon are most often associated with streams that contain LWD and pools (UCSRB 2007). In higher-gradient fluvial valleys, large boulders provide habitat complexity.

Recent studies provide new insight into the importance of floodplain habitat to juvenile Chinook salmon. Floodplain and other seasonally inundated habitats provide better rearing habitat, with higher growth rates, for juvenile Chinook salmon than the adjacent river (Sommer et al. 2001; Jeffres 2006). Sommer et al. (2001) attributed the higher growth rates in inundated floodplains to significantly greater abundance of drift invertebrates. Inundated floodplains also appear to be better migration habitat than the adjacent river.

Effects of river flows on juvenile migration were investigated by Brandes and McLain (2001) and Sykes et al. (2009). Brandes and McLain (2001) found that more juveniles enter the Sacramento-San Joaquin Delta as fry during wet years and overall juvenile production leaving the delta is higher in wet years. Fry survival appears lower in delta than upriver in higher-flow years. This speaks to the diversity of the habitats used by salmonids, and this diversity maintains production under changing environmental conditions. Sykes et al. (2009) found that flow manipulations that change the timing, duration, and magnitude of temperature and flow in the spring could affect the migration of juvenile Chinook salmon.

Juveniles - Estuaries
Estuaries are important rearing, foraging, and migration habitat for juvenile Chinook salmon. Bottom et al. (2005) found that fry and fingerlings make extensive use of marsh habitats in the Salmon River estuary. A study by Semmens (2008) found that juvenile Chinook salmon have a strong preference for native eelgrass. No such preference was found for other structured benthic habitats such as oyster beds, non-native eelgrass, or non-native cordgrass. Ehinger et al. (2007) found that certain types of delta habitat, distributary channels and wetlands in particular, may have a major role in juvenile Chinook salmon productivity.

Juveniles – marine
Juvenile Chinook salmon migrate from the estuary to the surf zone, where they feed for up to two summer months before migrating offshore (Jarrin et al. 2009). When in the surf zone, they had growth rates of 0.6 mm per day. Smaller fish fed on amphipods but switched to a piscivorous diet as they grew.

Several studies have investigated the growth and survival of juvenile Chinook salmon in the marine environment. Analyzing the growth rings on scales of adults returning to the Yukon and Kuskokwim Rivers, Ruggerone et al. (2009) found a positive correlation between growth during the first year of marine residence and growth during the freshwater phases, and that growth during each year of marine residence was positively correlated with growth during the previous year. The authors related this correlation to the piscivorous diet and foraging benefits of larger size.

Coastal upwelling is a strong determinant of year class strength (Scheuerell and Williams 2005). Upwelling increases near-shore ocean productivity, and leads to increased growth and survival of juveniles, while reduced upwelling leads to reduced growth and survival of juvenile salmon.

Adults
Elevated water temperature has been shown to affect the upstream migration of adults. Spring run Chinook salmon in Sacramento river basin hold in pools that have moderate water velocities and cover

and preferred temperatures between 3 and 13°C (CDFG 1998). Lindley et al. (2004) found that upstream migration of Central Valley Chinook salmon was blocked at 21°C, with fish becoming stressed as temperatures approached 20°C. Similarly, Goniea et al. (2006) reported that migration rates for upriver bright Chinook salmon in the lower Columbia River slowed when water temperature exceeds 20°C. This slowed migration was associated with temporary use of tributaries that averaged 2-7°C cooler than the mainstem.

Central Valley spring-run Chinook salmon utilize mid- to high-elevation streams that provide appropriate temperatures and sufficient flow, cover, and pool depth as over-summering habitat (Yoshiyama et al. 1998). Thermal patchiness in streams provides habitat for Chinook salmon at the margin of their temperature tolerance (Torgensen et al. 1999).

Coho Salmon

Juveniles – freshwater

Flooded riparian vegetation and oxbow channels associated with beaver ponds are critical to winter and summer survival of juvenile coho salmon in Klamath River (CDFG 2004). Juvenile coho salmon make substantial use of off-channel habitat within non-natal tributaries of Klamath estuary (NMFS 2007a). Displaced fish display high fidelity with regard to this non-natal habitat, as well as greater fitness at the smolt stage compared to fish that overwintered in natal tributary. Coho salmon juveniles have been found to move into non-natal tributaries in fall and winter and exhibit higher winter growth and survival than fish that stay in mainstem areas (Ebersole et al. 2006; Ebersole et al. 2009).

Although tributary rearing habitat is widely recognized as important to young-of-the-year coho salmon, the mainstem habitats may also play a critical role in their survival in rivers such as Klamath where tributary conditions are particularly hostile (NRC 2002).

Koski (2009), describe several studies and observations that have recently provided new insights into the fate of "nomads", juvenile coho salmon that move downstream between the time of emergence and October, and the role of the stream-estuary ecotone and estuary in developing this life history strategy that promotes coho salmon resilience. Nomad coho salmon can acclimate to brackish water, survive, and grow well in the stream-estuary ecotone and estuary, and then return upstream into freshwater to overwinter before migrating to the ocean as smolts. Nomads may enter the estuarine environment from natal or non-natal streams, rear there throughout the summer, and then immigrate to a non-natal stream for overwintering and smolting in the spring. These estuarine and overwintering habitats have enabled coho salmon to develop this unique nomad life history strategy that may help to ensure their resilience.

Juveniles - Estuaries

Pink salmon

Juveniles – marine

Moss et al. (2007) found that juvenile pink salmon were concentrated in nearshore habitats, but had lower growth rates relative to other habitats. This lower survival was attributed to density-dependent factors.

Salmon – General

Juveniles – estuarine

River plumes are important foraging habitat for juvenile salmon. Juvenile salmon tend to be abundant in the frontal and plume regions compared to more marine shelf waters (Robertis et al. 2005), but stomach fullness is higher in marine waters than the front or plume areas. The Columbia River plume is important juvenile salmon habitat, particularly during first month or two of ocean residence (NMFS 2008c).

Juveniles - Marine
Ocean conditions play a critical role in the growth and survival of juvenile Pacific salmon. The first few months of ocean residency is the period of critical climatic influences on survival, suggesting that coastal and estuarine environments are key areas of biological interactions (Francis and Mantua 2003). Wind-driven upwelling in the ocean replenishes nutrients in surface waters and promotes productivity at the base of the food chain (NWF 2007). Warm water conditions negatively impact salmon in California Current and also affect migration patterns of salmon predators for a top-down effect (Peterson et al. 2006). Pacific Decadal Oscillation (PDO) and El Nino Southern Oscillation events appear to have significant influence on survival and migratory patterns (Shared Strategy 2007) with Pacific salmon size being negatively correlated with El Nino events (Wells et al. 2006). Predatory and forage fish distributions respond to ocean temperatures, predator/prey interactions and possibly turbidity (Emmett et al. 2006).

Wells et al. (2008) found that salmon rely heavily on krill and rockfish during early and later life stages.

The literature cited above identifies relevant information pertaining to specific habitats and habitat features, for each species, that were not discussed in Amendment 14. These habitats include tributaries, floodplains, oxbows and other offchannel areas, thermal refugia, river plumes, estuaries, eelgrass, surf-zone and general marine habitats. The literature identifies a number of important habitat features that contribute to the growth, survival, and productivity of Pacific Coast salmon, such as large woody debris, water temperature, stream flow, prey availability, and ocean upwelling. This information should be used to revise and refine the descriptions of EFH for each species and life stage.

Recommendation

The Panel recommends further consideration by the Council of the descriptions of EFH contained in the Pacific Coast salmon FMP, based on the information described above.

The Panel also recommends that the Council consider incorporating the additional information cited in this report into the annotated bibliography.

Habitat Areas of Particular Concern

The implementing regulations for the EFH provisions of the MSA (50 CFR part 600) recommend that the FMPs include specific types or areas of habitat within EFH as "habitat areas of particular concern" (HAPC) based on one or more of the following considerations: (1) the importance of the ecological function provided by the habitat; (2) the extent to which the habitat is sensitive to human-induced environmental degradation; (3) whether, and to what extent, development activities are, or will be, stressing the habitat type; and (4) the rarity of the habitat type. The intended goal of identifying such habitats as HAPCs is to provide additional focus for conservation efforts. While the HAPC designation does not add any specific regulatory process, it highlights certain habitat types that are of high ecological importance. This designation is manifested in EFH consultations, in which NMFS can call attention to a HAPC and recommend that the Federal action agency make an extra effort to protect these important habitats.

The Council designated HAPCs in Amendment 19 to the Pacific Coast Groundfish FMP (seagrasses, canopy kelp, estuaries, rocky reefs, and a number of clearly defined areas of interest), but not in its three other FMPs. Amendment 14 discusses HAPCs for each species but stops short of establishing HAPCs, citing lack of sufficient data on which to base HAPCs.

Several FMCs have designated discrete habitat areas as HAPCs, while others broadly designated all areas of a specific habitat type as HAPCs. The "areas of interest" and estuaries designated by the Council in the Pacific Coast Groundfish FMP are examples of discrete HAPCs, while the seagrass, canopy kelp, and rocky reef HAPCs are examples of the broadly defined HAPCs that are not mapped, but are based on a description of the habitat. Some FMCs designated HAPCs for all of the managed species in their jurisdictions, and others only designated HAPCs for particular species or life stages. HAPCs, like EFH generally, are subject to periodic reviews and are therefore subject to being modified over time.

As part of this 5-year review, the Panel developed five potential HAPCs. Habitat types were initially identified using the best available information and the collective professional knowledge and experience gained by the Panel through scientific research and conducting EFH and ESA consultations. These habitats were then evaluated according to the four considerations listed above. The five potential HAPCs for Pacific Coast salmon are discussed below.

Complex channels and floodplain habitats: meandering, island-braided, pool-riffle and forced pool-riffle channels. Complex floodplain habitats, including wetlands, oxbows, side channels, sloughs and beaver ponds, and steeper, more constrained channels with high levels of LWD, provide valuable habitat for all Pacific salmon species. The densities of both spawning and rearing salmon are highest in areas of high quality naturally functioning floodplain habitat and in areas with LWD than in anthropogenically modified floodplains (Brown and Hartman 1988; Chapman and Knudsen 1980; Brown and Hartman 1988; Montgomery et al. 1999). These important habitats are typically found within complex floodplain channels defined as meandering or island-braided channel patterns and in pool-riffle or forced-pool mountain river systems (see Montgomery and Buffington 1998 and Beechie et al. 2006 for detailed description of these channel types). Complex floodplain habitats are dynamic systems that change over time. As such, the habitat-forming processes that create and maintain these habitats (e.g., erosion and aggradation, channel avulsion, input of large wood from riparian forests) should be considered as integral to the habitat.

An important component of these habitats is large wood, which typically occurs in the form of logjams in floodplains and larger rivers and accumulations of single or multiple logs in smaller mountain channels. Large woody debris helps create complex channels and floodplain habitats and important spawning and rearing habitat by trapping sediment, nutrients, and organic matter, creating pools, sorting gravels, providing cover and hydrologic heterogeneity, and creating important spawning and rearing areas for salmon (Harmon et al. 1986; Abbe and Montgomery 1996; Bilby and Bisson 1998). Complex channels, floodplain habitat, and large woody debris are very sensitive to land, riparian, or river management. These areas also provide pools, off-channel areas, shade, cooler temperatures, and thermal refugia during both summer and winter (Crispin et al. 1993).

Complex channels and floodplain habitat and the HAPC considerations.

1. *The importance of the ecological function provided by the habitat.* Complex floodplains habitats, including wetlands, oxbows, side channels, sloughs, and beaver ponds, have been shown to be important habitats for salmonids. Juvenile coho salmon frequently move from main-channel habitats to off-channel habitats during the winter months, presumably to seek refuge from high winter flows (Cederholm and Scarlett 1982; Peterson 1982). Juvenile coho salmon inhabiting beaver ponds and other off-channel ponds exhibit higher densities, higher growth rates, and higher overwinter survival rates than coho salmon inhabiting other main-channel and side-channel habitats (Bustard and Narver 1975; Swales et al. 1986; Swales and Levings 1989).

Side channels are important spawning habitat for Chinook salmon as well as coho salmon, and complex floodplain habitat and associated channels have higher densities of spawning fish than modified or constrained habitats (Vronskiy 1972; Drucker 2006; NOAA unpublished data).

In higher-gradient reaches with more confined channels, large wood plays a major role in creating deep, complex pools that provide winter refuge where off-channel habitats are not available. Densities of juvenile coho salmon and other salmonids are often substantially higher in stream reaches with higher wood volumes compared to streams with little wood (reviewed in Bilby and Bisson 1998).

2. *The extent to which the habitat is sensitive to human-induced environmental degradation.* In most river systems throughout the Pacific Northwest and California, complex floodplain habitats have been subject to a high degree of direct anthropogenic modification. Floodplain areas have been cleared of woodland vegetation, drained, and filled to allow agricultural, residential, and urban development (Pess et al. 2002, 2003). Channelization and diking of rivers has effectively separated rivers from many off-channel habitats once available to salmonids (Beechie et al. 1994; Reeves et al. 1998). Clearing of large wood accumulations in rivers was commonplace to both improve navigation and facilitate transport of logs from upstream forest to mill sites downstream (Bilby and Bisson 1998). Active removal of beaver ponds or isolation of beaver ponds by levees has resulted in substantial losses of these habitats in many Pacific Northwest rivers (Beechie et al. 1994; 2001).

   Low-gradient, unconstrained reaches that typify where complex floodplain habitats are expressed are also highly responsive to disturbances that happen higher up in the watershed. For example, sediments generated by land-use and road-building practices are typically routed through higher-gradient, transport reaches and are deposited in low-gradient reaches. This can lead to widening and shallowing of the river channel, filling in of pool habitats, and reductions in the average particle size of the substrate (Montgomery and Buffington 1998). These changes, in turn, diminish the quality of spawning and rearing habitats for salmon, as well the capacity of affected reached to produce invertebrates that salmonids depend on for food.

   In moderate-gradient stream reaches, historical land-use practices including logging of riparian forests, splash damming, and active removal of wood from the stream channel to facilitate fish passage and protect local infrastructure has fundamentally altered the structure and function of salmon habitats. Despite improvements in riparian forest management that have occurred in the last 40-50 years, the legacy of early practices remains apparent in diminished sources for recruitment of large wood (particularly of coniferous origin), decreased quantities of large wood in stream channels, and a shift in composition of large wood pieces from large-diameter pieces of coniferous origin to smaller diameter pieces of hardwood origin, which decompose at a much faster rate (Bilby and Bisson 1998).

3. *Whether, and to what extent, development activities are, or will be, stressing the habitat type*. Many areas that historically were part of complex floodplain habitats have been permanently lost to urban development. Restoration of other such habitats would require major shifts in land-use practices including abandonment of agricultural lands and removal of dikes and levees. Consequently, maintaining those few relatively intact floodplain habitats that remain on the landscape should be a high priority in salmon conservation.

   Conditions in riparian forests along more confined channels are likely to improve over the long-term in response to forest practice rules; however, the time lag between establishment of these rules and expected attainment of instream benefits is long (100-200 years). Consequently, ensuring protection of stream reaches that are characterized by intact, coniferous riparian stands and/or that currently have high amounts of inchannel wood is a high priority to bridge this gap.

4. *The rarity of the habitat type*. Historically, neither complex floodplain habitats nor mid-gradient channels with large quantities of inchannel wood were inherently rare within forested landscapes of the Pacific Northwest and California, but they have become increasingly so in response to human alterations of the landscape. For example, in the Skagit and Stillaguamish River watersheds, agricultural and urban development in floodplain areas has led to a 50% loss of side-channel sloughs habitats, and roughly 90% of beaver ponds have been isolated from main channel habitats (Beechie et al. 1994, 2001). As a consequence of intensive forest management on the vast majority of landscape within the Pacific Coastal Ecoregion, streams throughout the region have experienced reductions in the quantity and average size of in-channel large wood, as well as loss of wood recruitment potential from adjacent riparian zones (Bilby and Bisson 1998).

The location and extent of these complex habitats can vary over space and time, and maps or spatial descriptions may not be reliable from year to year. As such, this HAPC should rely on detailed text that describes the general attributes of these habitats, rather than spatially explicit descriptions or maps.

Thermal Refugia. Areas to escape high temperatures are critical to salmon survival, especially during hot, dry summers in California and eastern Oregon and Washington. Thermal refugia provide important holding and rearing habitat for adults and juveniles (Goniea et al. 2006; Sutton et al. 2007). Important thermal refugia often exist higher in hydrologic units and are most susceptible to blockage by artificial barriers (Yoshiyama et al. 1998). Reduced flows that are either anthropogenic, natural or climate-change induced can also reduce or eliminate access to refugia (Battin et al. 2007; Riley et al. 2009). Loss of structural elements such as large wood can also influence the formation of thermal refugia. Thermal refugia typically include coolwater tributaries, lateral seeps, side channels, tributary junctions, deep pools, areas of groundwater upwelling and other mainstem river habitats that are cooler than surrounding waters (≥2° C cooler) (Torgersen et al. 1999; Ebersole et al. 2003). As such, refugia can occur at spatial scales ranging from entire tributaries (e.g., spring-fed streams), to stream reaches (e.g., alluvial reaches with high hyporheic flow), to highly localized pockets of water only a few square meters in size embedded within larger rivers.

Thermal refugia and the HAPC considerations.

1. *The importance of the ecological function provided by the habitat.* Studies have shown that salmon increase their use of thermal refugia (e.g., cool water tributaries) when exposed to elevated water temperatures (Sutton et al. 2007), which can significantly reduce migration rates and suggests these areas provide crucial habitat in warm years (Goniea et al. 2006). Torgersen et al. (1999) state that the ability for cold water fish such as salmon to persist in warm water environments (>25°C) that experience elevated summer temperatures and seasonal low flows may be attributed to thermal refugia because even relatively minor differences in temperature are ecologically relevant for fish. In addition, climate change is expected to cause a rise in freshwater temperatures and a reduction in snowpack, which would lead to lower flows in the summer and fall (Battin et al. 2007; Mote et al. 2003; Stewart et al. 2004). These impacts would likely result in a reduction in the quantity and quality of fresh water salmon habitat, making thermal refugia even more important in the future.

2. *The extent to which the habitat is sensitive to human-induced environmental degradation.* Artificial barriers can block access to thermal refugia, which are often located at higher elevations. These barriers can also restrict flows, potentially increasing downstream temperatures (Yoshiyama et al. 1998). In addition, human-induced climate change is anticipated to lead to increased freshwater

temperatures, thereby degrading or eliminating thermal refugia that currently exist (Battin et al. 2007).

3. *Whether, and to what extent, development activities are, or will be, stressing the habitat type.* As noted previously, artificial barriers can block access to thermal refugia, especially those located higher up in the watershed, and cause increased temperatures downstream (Yoshiyama et al. 1998). Land-use practices and resource extraction (e.g., agricultural and forestry practices) can affect riverine habitat and alter thermal spatial structure leading to elevated temperatures and reduced cool water habitat (Torgersen et al. 1999). Climate change is expected to exacerbate these impacts (ISAB 2007; Miles et al. 2000; Stewart et al. 2004).

4. *The rarity of the habitat type.* The abundance of cool water habitat features can vary substantially depending upon many factors including geographic location, flow characteristics and time of year. However, in certain areas with hot, dry summers (e.g., lower Sacramento River); it is likely that little, if any, suitable holding habitat exists for salmon to take refuge from elevated water temperatures (NMFS 2009a). Moreover, because climate change is expected to cause an increase in freshwater temperatures and prolonged summer drought periods (Battin et al. 2007; Mote et al. 2003; Stewart et al. 2004), these habitat types can be expected to become more rare (ISAB 2007).

Spawning habitat. Spawning habitat has an extremely high ecological importance, and it is especially sensitive to stress and degradation by a number of land- and water-use activities that affect the quality, quantity and stability of spawning habitat (e.g., sediment deposition from land disturbance, streambank armoring, water withdrawals) (Independent Scientific Group 2000; Snake River Salmon Recovery Board 2006). Salmon spawning habitat is typically defined as low gradient stream reaches (<3%), containing clean gravel with low levels of fine sediment and high inter gravel flow. Many spawning areas have been well defined by historical and current spawner surveys and detailed maps exist for some hydrologic units.

1. *The importance of the ecological function provided by the habitat. S*pawning is a particularly important element of the life history of any species of fish. Adverse effects to salmon spawning habitat can be caused by natural conditions such as drought, as well as from human activities. Regardless of potential impacts, the selection of suitable habitat and successful spawning can mean the difference between a successful recruitment year and a poor one.

2. *The extent to which the habitat is sensitive to human-induced environmental degradation.* Spawning habitat consists of the combination of gravel, depth, flow, temperature, and dissolved oxygen, among others. Impacts to any of these factors can make the difference between a successful spawning event and failure. Several anthropogenic activities are known to impact various physical, chemical, or biological features of spawning habitat, including road construction, timber harvest, agriculture, and residential development among others.

3. *Whether, and to what extent, development activities are, or will be, stressing the habitat type.* Although there are modest differences in spawning preferences between the species, all salmon require cold, highly oxygenated, flowing water as suitable spawning habitat. Many human activities and natural occurrences can affect spawning habitat, including road building, culvert construction, forestry activities, agriculture, dams, and others. The population of the contiguous U.S. west coast grew nearly 27% between 1990 and 2009 (U.S. Census 2010). This represents about 10 million people who need housing, transportation, and other infrastructure. As population growth continues to spur development, stresses to salmon habitat are inevitable.

4. *The rarity of the habitat type.* Chinook salmon spawn in a broad range of habitats. Depths can range from a few centimeters to several meters deep, and in small tributaries to large river systems

(PFMC 1999). Coho salmon typically spawn in smaller tributaries than Chinook salmon, but are known to also spawn in larger rivers and occasionally lakes. Puget Sound pink salmon tend to spawn in larger rivers, but can also spawn in a variety of niche habitats including the lower reaches of rivers and even the intertidal zone (Quinn 2005). But as with other salmon species, pink salmon require high dissolved oxygen and adequate temperatures. Although salmon do require suitable habitat for successful spawning, such habitat is generally available and therefore not considered rare.

The location and extent of spawning habitat can vary over space and time, and maps or spatial descriptions may not be reliable from year to year. As such, this HAPC should rely on detailed text that describes the general attributes of these habitats, rather than spatially explicit descriptions or maps.

Estuaries. Estuaries can be defined as "waters that are semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, and in which seawater is at least occasionally diluted by freshwater runoff from land" (Dethier 1990), and include nearshore areas such as bays, sounds, inlets, river mouths and deltas, pocket estuaries, and lagoons influenced by ocean and freshwater. Because of tidal cycles and freshwater runoff, salinity varies within estuaries and results in great diversity, offering freshwater, brackish and marine habitats within close proximity (Haertel and Osterberg 1967). Such areas tend to be shallow, protected, nutrient rich, and are biologically productive, providing important habitat for marine organisms, including salmon.

The inland extent of the estuary HAPC is defined as the mean higher high water tidal level, or the upriver extent of saltwater intrusion, defined as upstream and landward to where ocean-derived salts measure less than 0.5 parts per thousand during the period of average annual low flow. The seaward extent is an imaginary line closing the mouth of a river, bay, or sound; and to the seaward limit of wetland emergents, shrubs, or trees occurring beyond the lines closing rivers, bays, or sounds. This HAPC also includes those estuary-influenced offshore areas of continuously diluted seawater. This definition is based on Cowardin, et al. (1979).

Estuaries were designated as a HAPC in Amendment 19 to the Pacific Coast Groundfish FMP (PFMC 2005).

Estuaries and HAPC considerations.

1. *The importance of the ecological function provided by the habitat.* Estuaries are complex systems that encompass a number of habitat types in a relatively small area, including sand and gravel beaches, mudflats, tidal creeks, shallow nearshore waters, pocket estuaries, and mixing zones, that are vital to the growth and survival of salmon, primarily during their juvenile phase. These systems provide protected habitat for juvenile salmon before entering the marine environment (Macdonald et al. 1988; Miller and Sadro 2003; Blackmon et al. 2006). Juvenile salmon are thought to utilize estuaries for three distinct purposes: (1) as a rich nursery area capable of sustaining increased growth rates; (2) to gain temporary refuge from marine predators; and (3) as a physiological transition zone where juveniles can gradually acclimate to saltwater (Bottom et al. 2005). Chinook salmon are well known for utilizing natal river tidal deltas, non-natal "pocket estuaries" (nearshore lagoons and marshes), and other estuarine habitats for rearing during outmigration (Ehinger et al. 2007). In the larger, deeper estuaries of the west coast of North America (e.g., Puget Sound, Columbia River, and San Francisco Bay), the shallow nearshore habitats of estuaries are especially important to juvenile salmon. For example, in Puget Sound, pink salmon and some ocean-type Chinook salmon enter the estuary at a very small size and rear in the shallow nearshore waters (<3 m deep) until they reach 70 mm in length, when they then move offshore. These shallow waters provide access to benthic prey and protection from predators. Functional estuaries also promote a diversity of life history types in salmon populations, with variation in estuarine use and residence

time of juveniles contributing to variations in the timing and size of fish at ocean entry (Bottom et al. 2005). This diversity buffers populations from extreme events in the freshwater or marine environments, and may increase resilience of populations following such disturbances (Bottom et al. 2005).

2. *The extent to which the habitat is sensitive to human-induced environmental degradation.* Estuaries are highly sensitive to anthropogenic activities (Johnston 1994). A number of human activities (e.g., diking, dredging and filling, shoreline armoring, stormwater and wastewater discharge, industrialization, removal of riparian vegetation and large wood), including those that occur upstream in the rivers that flow into an estuary, can reduce both the quality and quantity of estuarine habitat that is available to salmon.

3. *Whether, and to what extent, development activities are, or will be, stressing the habitat type.* Degradation and loss of these sensitive habitats has been shown to have a detrimental effect on salmon populations (Magnusson and Hilborn 2003), and much estuarine habitat has been lost along the Pacific Coast. A number of human activities (e.g., diking, dredging and filling, shoreline armoring, stormwater and wastewater discharge, industrialization, removal of riparian vegetation and large wood), including those that occur upstream in the rivers that flow into an estuary, can reduce both the quality and quantity of estuarine habitat that is available to salmon. In Puget Sound alone, more than one third of the shoreline has been armored, with significant alteration of the shallow nearshore habitat (Shipman 2009). Shipping ports are often located in estuaries because they provide protected harbors. Development of port facilities (e.g., dredging and filling, armoring, overwater structures) has resulted in extensive loss of estuarine habitats along the West Coast. Although the effects of water withdrawals and control structures are little studied (Good 2000), there is evidence that they can alter the estuarine mixing zone (Jay and Simenstad 1996). Population growth is expected to increase water withdrawals from streams, which will reduce freshwater inflow to estuaries and lead to reduced flushing capacity for wastes, changes in habitat types and distribution, and other unknown risks to these ecosystems (Good 2000). Many estuaries have been converted to agriculture and urban land uses. For example, the Duwamish River has lost more than 99% of its tidal delta habitat (Simenstad et al. 1982), while the Skagit River, which contains the largest tidal delta in Puget Sound, has lost 80-90% of its aquatic habitat area (Collins et al. 2003).

4. *The rarity of the habitat type.* Estuaries are not especially rare, although many have been reduced in size through diking, draining, filling, dredging, and other human activities. Therefore, much of the historical estuarine habitat has been lost and much of the remaining habitat is often severely degraded.

Marine and estuarine submerged aquatic vegetation. Submerged aquatic vegetation (SAV) includes the kelps and eelgrass. These habitats have been shown to have some of the highest primary productivity in the marine environment (Foster and Schiel 1985; Herke and Rogers 1993; Hoss and Thayer 1993) and provide a significant contribution to the marine and estuarine food webs (see reviews by Fresh 2006 and Mumford 2007).

The kelps are brown macroalgae and include those that float to form canopies and those that do not, such as *Laminaria* spp. Canopy-forming kelps of the eastern Pacific Coast are dominated by two species, giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis leutkeana*). Kelp plants, besides requiring moderate to high water movement and energy levels, are most likely limited by the availability of suitable substrate (Mumford 2007).

Eelgrasses (Zostera *marina*) form dense beds of leafy shoots year-round in the soft sediments of the lower intertidal and shallow subtidal zone, and they form a three-dimensional structure in an otherwise two-dimensional (sand or mud) environment (Mumford 2007).

Both kelps (canopy-forming) and eelgrass (seagrasses) were designated as HAPCs in Amendment 19 to the Pacific Coast Groundfish FMP (PFMC 2005)

Marine and estuarine SAV and HAPC considerations

1. *The importance of the ecological function provided by the habitat.* These habitats provide important nurseries, feeding grounds, and shelter to a variety of fish species, including salmon (Shaffer 2002; Mumford 2007), as well as spawning substrate to Pacific herring (*Clupea pallasii*), an important prey species for all marine life stages of Pacific salmon. Juvenile salmon utilize eelgrass beds as migratory corridors as they transition to the open ocean, and the beds provide both refuge from predators and an abundant food supply (see reviews by Fresh 2006 and Mumford 2007).

2. *The extent to which the habitat is sensitive to human-induced environmental degradation.* Both kelp and eelgrass are highly sensitive to human activities. Stressors include those that affect the amount of light available to the plant, and the direct and indirect effects of high or low nutrient levels, toxins, and physical disturbance (Mumford 2007). Activities that produce such stressors include shoreline development (bulkheads, docks and piers, etc.), dredging, faulty septic systems, and stormwater discharge. These activities can alter shoreline erosion and sediment transport, alter depth profiles, generate turbidity plumes, and impair water quality, all of which can degrade eelgrass habitat (Fresh 2006) and, presumably, kelp habitat as well. Vessels can directly damage SAV through prop scour, groundings, and anchoring (Nightingale and Simenstad 2001). Eelgrass beds near ferry terminals are often heavily impacted by the propwash from these large vessels, and those near recreational facilities often show clear propeller damage. A number of studies (e.g., Walker et al. 1989; Hastings et al. 1995) have shown that anchor chains, especially those anchoring a mooring buoy, can scour a sizable area of seagrass when they drag across the bottom.

3. *Whether, and to what extent, development activities are, or will be, stressing the habitat type.* Short et al. (2006) noted a world-wide decline in seagrass habitats, many of which were attributable to anthropogenic activities. Development has altered a significant portion of the estuarine and marine shores along the West Coast, and is expected to increase in the future.

4. *The rarity of the habitat type.* Although marine and estuarine SAV are not especially rare across the geographic range of Pacific Coast salmon, they can be locally rare. In Puget Sound, for example, only 11 % of the shoreline has kelp, while up to 34% of the shoreline has eelgrass (Mumford, 2007).

The location and size of both kelp and seagrass beds vary over space and time, and maps or spatial descriptions may not be reliable from year to year. As such, this HAPC should rely on detailed text that describes the general attributes of these habitats, rather than spatially explicit descriptions or maps.

In addition to the five HAPCs discussed above, the Panel considered the potential for designating migratory corridors as a HAPC. Given the life history strategies of salmon, migratory corridors have extremely high ecological value and are often at risk of degradation due to human activities (e.g., impassible culverts). However, the migratory corridors of salmon extend from the spawning habitats, downstream to the estuary, and through marine waters. While HAPCs are intended to be a subset of EFH, a HAPC based on the migratory corridors would include all habitats used by salmon, and, therefore, all of EFH. As such, migratory corridors do not meet the intent of the HAPC provisions in the implementing regulations, and the Panel did not pursue it further.

Recommendation

The Panel recommends further consideration of designation of HAPCs based on the information provided on the value to salmon of channels and floodplains; thermal refugia; spawning habitat; estuaries; and marine and estuarine submerged aquatic vegetation.

4. THREATS TO EFH

Fishing Activities That May Affect EFH

The MSA requires FMCs for each FMP to identify fishing activities that may adversely affect EFH and to minimize adverse effects of those activities to the extent practicable. Fishing activities should include those regulated under the Pacific salmon FMP that affect EFH identified under any FMPs, as well as those fishing activities regulated under other FMPs that affect EFH designated under the Pacific salmon FMP. The fishing activities that have the potential to adversely affect EFH for Pacific Coast salmon are shown in Table 6. These include fishing activities not managed under the MSA that may adversely affect salmon EFH.

Fishing activities, derelict gear, harvest of prey species, and the removal of salmon carcasses and their nutrients from streams are identified as fishing-related activities that can affect Pacific Coast salmon EFH. Some of these activities are controlled by the Council and some are not.

Although it is unlikely that any potential effects to Pacific salmon EFH from commercial and recreational fishing activities have increases substantially since 1999, the activities identified in Amendment 14 warrant a more thorough review and description. In addition, the Panel identified marine debris (and derelict fishing gear, separately) as a potential adverse affect. Although minor changes in location may have occurred, it is unlikely that these would have a substantial effect on impacts to EFH for Pacific salmon. Further, it is likely that any changes to overall fishing activities have remained level or have decreased since 1999.

Table 7. Summary of fishing activities that potentially affect to EFH. CK=Chinook salmon ; CO=coho salmon; P=PS pink salmon.

	Habitat Type		
Fishing Activity	**Freshwater**	**Estuarine**	**Marine**
Roundhaul gear		CK, CO, P	CK
Pot/trap		CK, CO, P	CK
Bottom trawl			CK
Mid-water trawl			CK
Long lines			CK
Carcass removal	CK, CO, P		
Vessel impacts	CK, CO, P	CK, CO, P	CK, CO, P
Harvest of prey species		CK, CO, P	CK, CO, P
Marine debris	CK, CO, P	CK, CO, P	CK
Derelict gear	CK, CO, P	CK, CO, P	CK
Shellfish harvest		CK, CO, P	
Recreational fishing	CK, CO, P	CK, CO, P	CK, CO, P

Effects To EFH By Gear Type

Roundhaul Gear (includes purse seines, lampara nets, dip nets, and drum seines): Fisheries for coastal pelagic and highly migratory species use purse seines, lampara nets, and other roundhaul gear to target Pacific sardine, northern anchovy, Pacific mackerel, jack mackerel, market squid, and tuna. Most tuna fishing occurs in the western and central Pacific, and tropical eastern Pacific. However, tuna are highly migratory and are present off the U.S. West Coast. They are therefore included in this consideration of habitat impacts from fishing activities.

Roundhaul gear can potentially affect EFH by direct removal of species that are prey for Pacific salmon, as well as for other managed species. It could potentially also affect squid, which are prey for salmon,if nets are allowed to contact the benthos of squid spawning areas.

Pot and Trap Gear: This gear type is dominated by commercial and recreational crab fisheries prevalent in estuaries and the marine environment along the entire West Coast. Lobster traps are used in California, but not typically north of the central California coast. To a lesser extent, pot gear is used in the sablefish fishery but typically at depths in the marine environment much greater than are associated with salmon (NWFSC 2009).

Pot and trap gear can adversely affect EFH by smothering estuarine eelgrass beds and other marine/estuarine benthic habitats such as cobble and vegetated surfaces utilized by Pacific salmon. Although typically placed in areas of sandy bottom, gear can also be deployed in areas of EFH and are often dragged across the benthos by strong tidal or ocean currents. Lost trap and pot gear could potentially affect EFH and are discussed below under derelict gear.

Bottom Trawling: Bottom trawling activity is conducted primarily by the West Coast groundfish fishery, harvesting over 90 species. These include 64 species of rockfish (e.g., widow, cowcod, yelloweye, and Pacific ocean perch); 12 species of flatfish (e.g., English sole, starry flounder, sanddab); six species of roundfish (e.g., lingcod, sablefish, and whiting); six species of sharks and skates (e.g., leopard shark, big skate and spiny dogfish); and several other species (e.g., ratfish, finescale codling, and Pacific rattail grenadier). Bottom trawling is managed under biennial specifications and includes a complicated matrix of sectors, seasons, and spatial limitations. There are many areas closed to bottom contact gear, including bottom trawling, many based on the designated HAPCs in the groundfish FMP EFH designations (PFMC 2008).

Appendix C to Amendment 19 of the Pacific Coast Groundfish FMP (PFMC 2005) presents a risk assessment framework, including a sensitivity index and recovery rates for a variety of groundfish habitats. Several habitats considered would likely overlap with salmonid habitat in the marine environment. Amendment 14 to the Pacific Salmon FMP states that Chinook salmon may be associated with "bottom topography" at depths of 30-70 meters, and juveniles are associated with pinnacles, reefs and vertical walls.

Impacts of bottom trawling to physical and biogenic habitats may include removal of vegetation, corals, and sponges that provide structure for prey species; disturbance of sediments; and possible alteration of physical formations such as boulders and rocky reef formations (NMFS 2005b).

Midwater trawling: Midwater trawls are used to harvest Pacific whiting, shrimp, and other species (PFMC 2008). Like bottom trawling, it is managed under the Pacific groundfish FMP. Effects are generally limited to the effects of (1) removal of prey species, (2) direct removal of adult and juvenile salmon (Bellinger 2009), and (3) effects resulting from loss of trawl gear, potentially resulting in impacts to bottom habitats and ghost fishing (see Derelict Gear section).

Long Line: Pelagic and bottom long-line fishing in the marine environment is prevalent on the Pacific Coast. Pelagic long-lining targets chiefly tuna and swordfish, while bottom long lining targets halibut, sablefish, and other species. Both types of long lining can incidentally harvest managed species as well as prey species. If long-line gear breaks loose and is lost, it can continue ghost fishing and potentially harm bottom habitat (see Derelict gear section).

Removal of Salmon Carcasses

Salmon carcasses provide vital nutrients to stream and lake ecosystems (Scheuerell et al. 2005). Carcasses enhance salmonid growth and survival, but fishing activities remove a portion of returning adults that would otherwise supply nutrients to stream systems. This is especially relevant to nutrient-poor streams that depend on the phosphorous, nitrogen, and other nutrients provided by salmon carcasses. In the Willapa Bay basin an estimated several thousand metric tons of salmon tissue have been lost each year as a nutrient source to streams because of reductions in salmon returns (Naiman et al. 2002), while net transport of marine-derived phosphorous into the Snake River basin over the past 40 years was estimated at less than 2% of historical levels (Scheuerell et al. 2005). Gresh et al (2000) estimated that just 6-7% of the marine-derived nitrogen and phosphorous once delivered to the rivers of the Pacific Northwest by salmon carcasses is currently reaching those streams.

Carcasses have been shown to be an important habitat component, enhancing smolt growth and survival by contributing significant amounts of nitrogen and phosphorus compounds to streams (Spence et al. 1996). These are the nutrients that most often limit production in oligotrophic systems.

Vessel impacts

The variety of fishing and other vessels on the Pacific Coast range can be found in freshwater streams, estuaries, and the marine environment. Vessel size ranges from small single-person vessels used in streams and estuaries, to mid-size commercial or recreational vessels, to large-scale vessels limited to deep-draft harbors and marine waters.

Vessels can adversely affect EFH by affecting physical or chemical mechanisms. Physical effects can include physical contact with spawning gravel and redds (freshwater streams) and propeller wash in eelgrass beds (estuaries). Derelict, sunk, or abandoned vessels can cause physical damage to essentially any bottom habitat the vessel comes into contact with. This could potentially cause harm to corals, sponges, rocky reefs, sandy ocean floor, eelgrass beds, and other habitats.

Chemical effects could come in the form of anti-fouling paint, oil/gas spills, bilge waste, or other potential contaminants associated with commercial or recreational vessels, and could occur in freshwater, estuaries, or the marine environment.

Studies in Alaska and New Zealand (Horton 1994; Sutherland and Ogle 1975) have found that in shallow water where boat use is high and especially where channels are constricted, developing salmon eggs and alevins in the gravel can suffer high mortalities as a result of pressure changes caused by boat operations, which can result in removal of gravel or mechanical shock generated in the area under the midline of the boat. Studies done on the effects of jet sleds, drift boat, or kayak operation on the behavior and survival of free swimming juvenile salmon on the Rogue River have shown minimal effects, although behavioral responses are observed when vessels pass directly overhead (especially nonmotorized kayaks or driftboats) (Satterwaithe 1995). Studies along the Columbia River indicated that the wake of large ships caused significant numbers of Chinook salmon juveniles to be killed from being washed up and stranded on sand bars and mud flats. Stranding was not observed on the Skagit River from jet sled use (K. Bauersfel 1998) or on the Rogue River from private motorboat and commercial tour boat use (Satterwaithe 1995).

Harvest of prey species

Prey species can be considered a component of EFH (NMFS 2006). For Pacific salmon, commercial and recreational fisheries for many types of prey species potentially decrease the amount of prey available to Pacific salmon. Herring, sardine, anchovy, squid, smelt, groundfish, shrimp, crab, burrowing shrimp, and other species of finfish and shellfish are potential salmon prey species that are directly fished, either commercially or recreationally.

Amendment 14 notes that some prey species (e.g., herring and crab) are state-managed while others are federally managed and it concluded that both state and federal management already set aside a portion of the biomass as forage reserves for predator species. For example, the harvest guideline formula for Pacific sardine incorporates a 150,000 metric ton (mt) cutoff, meaning that the annual harvest guideline is based on the estimated biomass minus 150,000 mt. Other prey species such as krill, copepods, and amphipods, are salmon prey species that are not directly fished, but that can be adversely affected by fishing activities.

Derelict gear

When gear associated with commercial or recreational fishing breaks free, is abandoned, or becomes otherwise lost in the aquatic environment, it becomes derelict gear. This phenomenon occurs in fishing activities managed under all four Pacific Coast FMPs, as well as recreational fishing and fishing activities not managed by the Council. In commercial fisheries, trawl nets, gillnets, long lines, purse seines, crab and lobster pots, and other material, are occasionally lost to the aquatic environment. Recreational fisheries also contribute to the problem, mostly via lost crab pots.

Derelict fishing gear, as with other types of marine debris, can directly affect salmon habitat and can directly affect managed species via “ghost fishing.” Ghost fishing is included here as an impact to EFH because the presence of marine debris affects the physical, chemical, or biological properties of EFH. For example, once plastics enter the water column, they contribute to the properties of the water. If debris is ingested by fish, it would likely cause harm to the individual. Another example is in the case of a lost net in a river. Once lost, the net becomes not only a potential barrier to fish passage, but also a more immediate entanglement threat to the individual.

Along the Pacific Coast, Dungeness crab pots are especially prevalent as derelict gear (NWSI 2010). Commercial pots are required to use degradable cord that allows the trap lid to open after some time. This is thought to significantly reduce the effects of ghost fishing. However, only the State of Washington has such a requirement for recreational crab pots. There is little reliable information regarding the numbers or impacts of lost recreational crab pots.

Derelict gear can adversely affect salmon EFH directly by such means as physical harm to eelgrass beds or other estuarine benthic habitats; harm to coral and sponge habitats or rocky reefs in the marine environment; and by simply occupying space that would otherwise be available to salmon. Derelict gear also causes direct harm to salmon (and potentially prey species) by entanglement. Once derelict gear becomes a part of the aquatic environment, it affects the utility of the habitat in terms of passive use and passage to adjacent habitats. More specifically, if a derelict net is in the path of a migrating fish, that net can entangle and kill the individual fish.

The Northwest Straits Initiative estimates that 2493 lost nets were removed in Puget Sound by a project funded under the American Recovery and Reinvestment Act (NWSI 2011b). Since 2002, over 3,800 partial gillnets (average size 7,000 square feet) have been removed from Puget Sound, with an estimated 1000 additional gillnets remaining in the shallow subtidal areas. An analysis of 870 derelict gillnets recovered from Puget Sound found 154 salmon were entangled at the time of recovery (Good et al. 2010). Some of these gillnets that had been derelict as long as 24 years were still catching marine fish, although the report did not note if salmon were among those caught. Most derelict gear removal efforts in Puget Sound are conducted during the winter, when fewer adult salmon are present (NWSF 2007). Nets recovered when adult salmon are more abundant have greater numbers of salmon. For instance, two nets recovered off of Lummi Island after the 2003 chum salmon season had 157 salmon, at least 12 of which were Chinook salmon (NWSF 2007). In 2008, a derelict gillnet was recovered with 14 salmon, and caught an estimated 450 salmon in the 23 weeks since it was lost (NWSI 2011a).

The Columbia River Inter-Tribal Fish Commission recovered a total of 33 derelict gillnets in 2002 and 2004 from the Bonneville and Dalles Reservoirs on the Columbia River (Kappenman and Parker 2007). While Kappenman and Parker (2007) provided no estimate of the number of nets remaining in these reservoirs or in the rest of the Columbia River, they estimated that approximately 10 gillnets are lost each year. In contrast to the derelict gillnets recovered in Puget Sound, white sturgeon, *Acipenser transmontanus*, was the only species found in these nets, some of which had been derelict for as long as seven years. However, the authors acknowledged that the recovery operations were conducted during the winter, when few adult salmon are present. Kappenman and Parker (2004) suggested that in the Columbia River, surface-fishing gillnets targeting salmon are likely to be quickly retrieved by other commercial fishers, river users, or state agencies and do not continue fishing for extended periods, thereby reducing the risk to salmon. In addition, currents in the Columbia River may also cause derelict gillnets to collapse and spin into balls relatively quickly (Kappenman and Parker 2007). Although it is clear that there are derelict gillnets in these reservoirs, the impact that such gear has on salmon in the Columbia River, or other West Coast river systems where the issue has not been examined, is presently unknown.

Recreational fishing

Most recreational fishing impacts are combined in the sections above. One activity not yet captured is the potential for impacts to juvenile salmon and eggs in redds resulting from trampling by recreational fishers. In freshwater streams, recreational fishers often use waders and boots to walk in streams to access good fishing spots. This can crush eggs and alevins in a salmon redd. Trampling of redds has potential to cause high mortality of salmonids. Most information on redd disturbance is anecdotal. However, one study showed that trampling by anglers can kill eggs and pre-emergent fry in trout redds (Roberts and White 1992).

Minimizing Effects

Fishery Management Plans are required to minimize adverse affects to EFH to the extent practicable. Minimization measures can include, but are not limited to, time/area closures, fishing equipment restrictions, and harvest limits. Adverse impacts include incidental harvest of managed species through legal fishing activity, but incidental harvest is addressed in other sections of FMPs, rather than under EFH provisions.

<u>Gear Effects</u>

Amendment 14 does not identify any studies that indicate direct gear effects on Pacific Coast salmon EFH from Council-managed fisheries, although some studies indicate that there may be impacts to benthic organisms and their habitats due to bottom trawling and dredging activities. Outmigrating Pacific salmon juveniles feed on various epibenthic invertebrates and zooplankton, including benthic copepods, implying that there could be impacts to prey species. However, Amendment 14 notes that salmon are not known to be dependent on soft ocean bottom habitats. Therefore, it does not conclude that fishing gear effects in the ocean directly affect benthic prey species. Table 6 lists gear types used in

Council-area fisheries that could impact Pacific Coast salmon EFH. Amendment 14 notes that "detailed management measures have not been developed because of the lack of information demonstrating an adverse effect on EFH from salmon 'gear.'" Amendment 14 recommends research to study gear effects on salmon EFH and their prey, especially disturbance to eelgrass beds and rocky habitat. Amendment 14 also offers minimization measures for prey harvest, carcass removal, redd disturbance, and vessel impacts. However, several fishing impacts are presented here that were not considered in Amendment 14.

Conservation measures for gear effects were not presented in Amendment 14, which instead noted the need for research to study the effects of gear on salmon EFH and prey, especially related to disturbance of eelgrass beds and rocky habitat. The 2008 Final Rule did not address fishing effects to Pacific salmon EFH.

Recommendation

The Panel recommends consideration of newly identified fishing activities that may adversely affect EFH and the consideration of measures to minimize impacts to Pacific salmon EFH, in accordance with the 2002 EFH regulatory guidance.

Non-Fishing Activities That May Affect EFH

The MSA requires FMCs and NMFS to identify non-fishing activities that may adversely affect EFH, as well as actions to encourage the conservation and enhancement of EFH, including recommended options to avoid, minimize, or mitigate for the adverse effects identified in the FMP. Amendment 14 includes 21 such activities and conservation measures, and the Panel identified 10 additional non-fishing threats (Table 7). This section provides a description of 10 non-fishing threats to EFH that have gained attention since Amendment 14 was published. Some threats are more developed than others, and some include preliminary conservation measures while others do not. However, each threat description contains the information necessary to, at a minimum, inform the Council on the potential severity of the adverse effects from these activities. See Amendment 14 for a description of the 21 threats to EFH of Pacific Coast salmon identified in 1999. It is important to note that many projects consist of more than one of these 31 threats, and the cumulative effects of those threats should be considered when making EFH conservation recommendations.

The Panel anticipates that, should the Council amend the Pacific Coast Salmon FMP, the descriptions of all 31 threats will be expanded upon and refined, and that conservation measures will be developed for each threat. In addition, the Council may determine that threats in addition to those discussed here and in Amendment 14 merit inclusion in the amendment.

Table 8. Non-fishing threats to Pacific Coast salmon EFH. Newly identified threats appear in the right column. Detailed information on the threats identified in the first column can be found in Amendment 14.

Threats Identified in Amendment 14 (1999)	New Threats Identified During EFH Review
Agriculture	Pile driving
Artificial Propagation of Fish and Shellfish	Over-water structures
Bank Stabilization	Alternative energy development
Beaver removal and Habitat Alteration	Liquefied natural gas projects
Construction/Urbanization	Desalination
Dam Construction/Operation	Power plant intakes
Dredging and Dredged Spoil Disposal	Pesticide use

Estuarine Alteration	Flood control maintenance
Forestry	Culvert construction
Grazing	Climate change
Habitat Restoration Projects	
Irrigation/Water Management	
Mineral Mining	
Introduction/Spread of Nonnative Species	
Offshore Oil and Gas Drilling	
Road Building and Maintenance	
Sand and Gravel Mining	
Vessel Operation	
Wastewater/Pollutant Discharge	
Wetland and Floodplain Alteration	
Woody Debris/Structure Removal	

Pile driving

Pile driving can generate intense underwater sound pressure waves that can adversely affect the ecological functioning of EFH. These pressure waves have been shown to injure and kill fishes, including salmon (e.g., Caltrans 2001; Longmuir and Lively 2001; Stotz and Colby 2001; Abbott and Bing-Sawyer 2002; Stadler, pers. com. 2002). This issue came to light in 2001 and has gained considerable attention from Federal and state resource and transportation agencies because of the large number of piles that are driven into aquatic habitats for transportation infrastructure and other purposes.

Potential Adverse Impacts

Injuries associated directly with pile driving are poorly studied but include rupture of the swimbladder and internal hemorrhaging. The sounds can over-stimulate the auditory system of fishes and may result in temporary threshold shifts (a non-injurious temporary reduction in hearing sensitivity) or physical injury, such as a loss of hair cells of the sensory maculae (Hastings and Popper 2005).

The type and intensity of the sounds produced during pile driving depend on a variety of factors including, but not limited to, the type and size of the pile, the firmness of the substrate into which the pile is being driven, the depth of water, and the type and size of the pile-driving hammer. Injury or death associated with pile driving appears to be positively correlated with the size of the pile because the greater energy required to drive larger piles produces higher sound levels. Fish-kills have been associated with driving of hollow steel piles ranging from 24 to 96 inches in diameter. Wood and concrete piles appear to produce lower sound pressures than hollow steel piles of a similar size, although it is not yet clear if the sounds produced by wood or concrete piles are harmful to fishes. Firmer substrates require more energy to drive piles, and produce more intense sound pressures. Sound attenuates more rapidly with distance from the source in shallow than in deep water (Rogers and Cox 1988).

Two main types of hammers are used to drive piles – impact and vibratory. Impact hammers use a large weight or piston to strike the top of the pile and drive it into the substrate and appear to pose the greater risk to fishes. All reported instances of fishes killed or injured during pile driving have occurred when impact hammers were used. Vibratory hammers, on the other hand, vibrate the pile vertically to emulsify the surrounding sediment and cause the pile to sink. While injury and death have not been observed from vibratory hammers, there are no data to show they are harmless. One reason for these observed differences is the different types of sounds that each hammer produces. Impact hammers produce intermittent but intense spikes of sound while vibratory hammers produce continuous sounds of lower intensity. The magnitude of the effect on salmon that are exposed to the sounds from pile driving will depend on the size and physical condition of the fish, the depth of the fish in the water column, and the characteristics of the received sound including the shape and energy content of the sound pressure wave.

To aid in the assessment of the risks posed by impact pile driving, the Fisheries Hydroacoustic Working Group (FHWG), a group of Federal and state agencies with a stake in this issue, developed and adopted a set of interim criteria to estimate the response of fishes exposed to these sounds (FHWG 2008). These are dual criteria based on protective thresholds for two sound metrics: peak pressure and sound exposure level (SEL). SEL is an energy index that is indicative of mechanical work done on the tissues and can be summed over all pile strikes to which the fishes are exposed. Using these criteria, injury is expected to any fish that is exposed to either a peak pressure that exceeds 206 decibel (dB) (re: 1 μPa) or a size-dependent cumulative SEL that exceeds 187 dB (re: 1 μPa^2-sec) for fishes larger than 2 grams, and 183 dB (re: 1 μPa^2-sec) for fishes smaller than 2 grams.

Sounds have been shown to alter the behavior of fishes; including salmon (see review by Hastings and Popper 2005). The observed behavioral changes include startle responses and increases in stress hormones. Other potential changes include reduced predator awareness and reduced feeding. Feist et al (1991) observed that juvenile pink salmon and chum salmon appeared to be less prone to spooking by an observer on the shore when piles were being driven. This reduced awareness could lead to increased predation. Directed studies on the effects of pile driving sound on the behavior of salmonids are limited, although Ruggerone et al (2008) found no observable changes in the behavior of caged coho salmon in the vicinity of pile driving. Faced with the paucity of data, NMFS is currently using a conservative criteria of 150 dB (re: 1 μPa) root-mean-square as a trigger for closer analysis of potential adverse behavioral effects from all types of sounds, including those from impact and vibratory hammers. The potential for adverse behavioral effects will depend on a number of factors, including the life stages that are present. For example, the level of concern would be higher for juvenile salmon that are migrating through an estuary and are more prone to predation than for a subadult or adult in marine waters.

Potential Conservation Measures

- Avoid driving piles when salmon are present, if possible, especially the younger life stages.
- Avoid driving hollow steel piles with an impact hammer. Drive the piles with a vibratory hammer or select piles that are made of alternate materials produce less-harmful sounds.
- Drive piles during low tide periods when located in intertidal and shallow subtidal areas.
- Under those conditions where impact hammers are required, the piles should be driven as deep as possible with a vibratory hammer prior to the use of the impact hammer.
- Implement measures to attenuate the sound. Such measures include the use of a bubble curtain or a dewatered pile sleeve or coffer dam. Monitor the sound levels during pile driving to ensure that the attenuation measures are functioning as expected.
- Drive piles when the current is reduced (i.e., centered on slack current) in areas of strong current to minimize the number of fish exposed to adverse levels of underwater sound.

Overwater Structures

Overwater structures include commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys. These structures are typically located in intertidal areas out to about 15 meters below the area exposed by the mean lower low tide (i.e., the shallow subtidal zone). Light, wave energy, substrate type, depth, and water quality are the primary factors controlling the plant and animal assemblages found at a particular site. Overwater structures and associated activities can alter these factors and interfere with key ecological functions such as spawning, rearing, and refugia. Site-specific factors (e.g., water clarity, current, depth) and the type and use of a given overwater structure determine the occurrence and magnitude of these impacts.

Potential Adverse Effects

The following description of the potential impacts of overwater structures and associated activities on EFH, unless otherwise cited, is taken from a recent, comprehensive literature review by Nightingale and Simenstad (2001). For a more detailed discussion, the reader is directed to this review.

Overwater structures and associated developments may adversely affect EFH in a variety of ways, including construction related impacts, changes in ambient light conditions, alteration of the wave and current energy regime, and through activities associated with the use and operation of the facilities, such as increased vessel traffic and pollutants.

Overwater structures create shade which reduces the light levels below the structure. The size, shape and intensity of the shadow cast by a particular structure depend upon its height, width, construction materials, and orientation. High and narrow piers and docks produce narrower and more diffuse shadows than do low and wide structures. Increasing the numbers of pilings used to support a given pier increases the shade cast by pilings on the under-pier environment. In addition, less light is reflected underneath structures built with light-absorbing materials (e.g., wood) than from structures built with materials that allow light transmission (e.g., glass, steel grates). Structures that are oriented north-south produce a shadow that moves across bottom substrate throughout the day, resulting in a smaller area of permanent shade than those with an east-west orientation.

The shadow cast by an overwater structure affects both the plant and animal communities below the structure. Distributions of plants, invertebrates, and fishes have been found to be severely limited in under-dock environments when compared to adjacent, unshaded vegetated habitats. Light is the single most important factor affecting aquatic plants. Under-pier light levels have been found to fall below threshold amounts for the photosynthesis of diatoms, benthic algae, eelgrass, and associated epiphytes and other autotrophs. These photosynthesizers are an essential part of nearshore habitat and the estuarine and nearshore foodwebs that support many species of marine and estuarine fishes. Eelgrass and other macrophytes can be reduced or eliminated, even through partial shading of the substrate, and have little chance to recover.

Fishes rely on visual cues for spatial orientation, prey capture, schooling, predator avoidance, and migration. The reduced-light conditions found under an overwater structure limit the ability of fishes, especially juveniles and larvae, to perform these essential activities. Shading from overwater structures may also reduce prey organism abundance and the complexity of the habitat by reducing aquatic vegetation and phytoplankton abundance (Kahler et al. 2000; Haas et al. 2002). Biotic assemblages on pilings have been demonstrated to differ from natural hard substrate (Glasby 1999a) with these differences attributed to shading effects (Glasby 1999b). Other studies have shown shaded epibenthos to be reduced relative to that in open areas. These factors are thought to be responsible for the observed reductions in juvenile fish populations found under piers and the reduced growth and survival of fishes held in cages under piers when compared to open habitats (Able et al. 1998; Duffy-Anderson and Able 1999).

The shadow cast by an overwater structure may increase predation on EFH managed species by creating a light/dark interface that allows ambush predators to remain in a darkened area (barely visible to prey) and watch for prey to swim by against a bright background (high visibility) (Helfman 1981). Prey species moving around the structure are unable to see predators in the dark area under the structure and are more susceptible to predation. Furthermore, the reduced vegetation (i.e., eelgrass) densities associated with overwater structures decrease the available refugia from predators.

In-water structures (e.g., pilings) also provide perching platforms for avian predators such as double-crested cormorants (*Phalacrocorax auritis*), from which they can launch feeding forays or dry their plumage. These piscivorous birds congregate near hydroelectric dams throughout the Columbia River Estuary and forage on salmonids (Roby et al. 2007; Collis et al. 2002).

Wave energy and water transport alterations from overwater structures can impact the nearshore detrital foodweb by altering the size, distribution, and abundance of substrate and detrital materials. Disruption of longshore transport can alter substrate composition and can present potential barriers to the natural processes that build spits and beaches and that provide substrates required for plant propagation, fish and shellfish settlement and rearing, and forage fish spawning.

Pilings can alter adjacent substrates by increasing shell deposition from piling communities and changing substrate bathymetry. Changes in substrate type can alter the nature of the flora and fauna native to a given site. In the case of pilings, native dominant communities typically associated with sand, gravel, mud, and eelgrass substrates are replaced by communities associated with shell hash substrates.

Treated wood used for pilings and docks releases contaminants into saltwater environs. Polyaromatic hydrocarbons (PAHs) are commonly released from creosote-treated wood. PAHs can cause a variety of deleterious effects (cancer, reproductive anomalies, immune dysfunction, and growth and development impairment) to exposed fish (Johnson et al. 1999; Johnson 2000; Stehr et al. 2000). Wood also is commonly treated with other copper-based chemicals such as ammoniacal copper zinc arsenate (ACZA) and chromated copper arsenate (CCA) (Poston 2001). Copper is a common contaminant in salmon habitat and can increase susceptibility to disease, cause hyperactivity, impair respiration, or disrupt osmoregulation. Moreover, salmon use olfactory cues to convey important information about habitat quality, predators, mates, and the animal's natal stream, and copper can impair olfactory performance. Research has shown that fish behaviors can be disrupted at concentrations of dissolved copper that are at, or slightly above, background concentrations. Therefore, substantial copper-induced loss of olfactory capacity will likely impair behaviors essential for the survival or reproductive success of salmon. These preservatives are known to leach into marine waters for a relatively short period of time after installation, but the rate of leaching is highly variable and dependent on many factors. Concrete or steel, on the other hand, are relatively inert and do not leach contaminants into the water.

Although not the cause of direct introductions, artificial overwater structures and associated substrate may provide increased opportunity for nonnative species colonization and exacerbate the increase in their abundance and distribution (Bulleri and Chapman 2010). In the San Francisco Estuary, the Smithsonian Institute conducts Rapid Assessment Surveys to determine nonnative species distribution on overwater structures. Of the294 distinct nonnative taxa observed, 60% were found on floating docks, 20% on intertidal benthos, and 13% from benthic grabs (Cohen et al. 2005). Overwater structures can serve as focal points for nonnative species known to prey on salmon (Kahler et al. 2000) or otherwise alter salmon habitat processes and functions (Nightingale and Simenstad 2001).

Construction and maintenance of overwater structures often involves driving of pilings (see Pile Driving) and dredging of navigation channels (see Dredging and Dredged Spoil Disposal in Amendment 14). Both activities may also adversely affect EFH.

Construction of docks may result in increased vessel traffic. Docks may be built for small marinas (small boats), ferry terminals (ferries), or commercial use. Depending on the size of the boat using the dock, increased vessel traffic may have negligible to significant effects on EFH. Boat traffic creates energy that suspends fine sediments and increases turbidity. Ferry docking and departing may result in multiple propeller wash events per hour (Olson et al. 1997). Ferry propeller wash may cause elevated turbidity, coarsening of sediments underneath ferry terminals (Francisco 1995), and scour pits (Shreffler and Gardiner 1999; Haas et al. 2002). Propeller wash may increase current by up to six times the background current (Olson et al. 1997), which may result in epibenthic meiofauna flushing (Haas et al. 2002). Ferry terminals have been shown to significantly alter epibenthic juvenile salmonid prey during periods of salmon outmigration in Washington (Haas et al. 2002).

Boat traffic may adversely affect submerged aquatic vegetation present in the area. Eelgrass has been shown to be shorter in areas directly affected by boat traffic (Burdick and Short 1999). Propeller wash may erode away the rhizome of seagrasses or cause extensive scarring (Sargent et al. 1995). Boat traffic creates energy that suspends fine sediments and increases turbidity. Ferry docking and departing may result in multiple propeller wash events per hour (Olson et al. 1997). Ferry propeller wash may cause elevated turbidity, coarsening of sediments underneath ferry terminals (Francisco 1995), and scour pits (Shreffler and Gardiner 1999; Haas et al. 2002). Propeller wash may increase current by up to six times the background current (Olson et al. 1997), which may result in epibenthic meiofauna flushing (Haas et al. 2002). Ferry terminals have been shown to significantly alter epibenthic juvenile salmonid prey during periods of salmon outmigration in Washington (Haas et al. 2002).

While the effect of some individual overwater structures on EFH may be minimal, the overall impact may be substantial when considered cumulatively. The additive effects of these structures increase the overall magnitude of impact and reduce the ability of the EFH to support native plant and animal communities.

Potential Conservation Measures

- Use upland boat storage whenever possible to minimize need for overwater structures.
- Locate overwater structures in sufficiently deep waters to avoid intertidal and shade impacts, to minimize or preclude dredging, to minimize groundings, and to avoid displacement of submerged aquatic vegetation, as determined by a pre-construction survey.
- Design piers, docks, and floats to be multi-use facilities in order to reduce the overall number of such structures and the nearshore habitat that is impacted.
- Incorporate measures that increase the ambient light transmission under piers and docks. These measures include, but are not limited to, maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint; grated decking material; using solar tubes to direct light under the structure and glass blocks to direct sunlight under the structure; illuminating the under-structure area with metal halide lamps and use of reflective paint or materials (e.g., concrete or steel instead of materials that absorb light such as wood) on the underside of the dock to reflect ambient light; using the fewest number of pilings necessary to support the structures to allow light into under-pier areas and minimize impacts to the substrate; and aligning piers, docks and floats in north-south orientation to allow arc of sun to cross perpendicular to structure and reduce duration of light limitation.
- Use floating breakwaters whenever possible and remove them during periods of low dock use. Encourage seasonal use of docks and off-season haul-out.
- Use waveboards to minimize effects on littoral drift and benthic habitats.
- Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal zone, and maintain at least one foot of water between the substrate and the bottom of the float.
- Use mid-water floats or other technology to keep anchor chains from contacting the substrate.
- Conduct in-water work during the time of year when EFH-managed species and prey species are least likely to be impacted.

- Avoid use of treated wood timbers or pilings to the extent practicable. Use of alternative materials such as untreated wood, concrete, or steel is recommended.
- Fit all pilings and navigational aids, such as moorings and channel markers, with devices to prevent perching by piscivorous bird species.
- Orient night lighting such that illumination of the surrounding waters is avoided.
- Mitigate for unavoidable impacts to benthic habitats that is adequately provided, properly monitored, and adaptively managed.
- Elevated turbidity during construction may be avoided with the use of a silt curtain if site conditions allow.

Alternative Energy Development

Marine, estuarine, and freshwater hydrokinetic energy refers to electrical energy that comes from "waves, tides, and currents in oceans, estuaries, and tidal areas; free flowing water in rivers, lakes, and streams; free flowing water in man-made channels; and differentials in ocean temperatures (ocean thermal energy conversion)" (US DOE 2009). For the purpose of considering threats to designated salmon EFH on the West Coast of the United States, this report focuses on nearshore wave energy and tidal turbine energy development because it is the most likely form of hydrokinetic technology to move forward within the next 5-years. Ocean thermal energy and offshore wind development is not considered in this discussion because they are not likely to be proposed off the West Coast of the United States in the near future.

Wave energy conversion devices can be grouped by the design features to capture wave energy, into six main types: point absorbers, attenuators, oscillating wave surge converters, oscillating water column, overtopping devices, and submerged pressure differential devices (U.S.DOE 2009). Tidal turbines are placed on the bottom and can have an exposed or closed blade. Although each design is unique, these devices are typically attached to the seafloor, channel bottom, or some type of structure and deployed at or near the water's surface or at depth.

In order to develop and operate wave or tidal hydrokinetic projects, there are four phases of activities that can potentially affect salmon EFH. The potential effects of each phase of a hydrokinetic project (preconstruction, construction, operation and maintenance, and decommissioning) need to be considered (Boehlert and Gill 2010; Gill 2005; Kramer et al. 2010; Previsic 2010; U.S.DOE 2009). In addition to the design features and footprint of an individual device, the spatial and temporal scales of a project (single device /short-term; single device /long term; multiple devices /short term; multiple devices /long term) are important considerations when evaluating effects to salmon EFH (Boehlert and Gill 2010). The potential cumulative effects of the spatial arrangement (vertical and horizontal) of multiple devices in the water column also need to be evaluated.

Construction activities typically include: horizontal directional drilling to land cables from the device to the shoreline; laying of subsea transmission cable; foundation/mooring installation; deployment and commissioning of device(s). Operation and maintenance include the mechanical functioning of the devices and appurtenances, as well as inspection and repair of equipment. Decommissioning at the end of the project (typically 5-30 years) involves removal of all equipment in the water column and transmission cables and restoration of the site, if needed.

Related activities that pertain to both the construction and operations phases include installation and maintenance of navigation buoys to mark the deployment area; and reliable port infrastructure to accommodate work vessels as well as delivery and retrieval of large hydrokinetic devices to pier-side for repair and maintenance, if necessary.

Potential Adverse Impacts

Because the majority of hydrokinetic renewable energy technologies remain at the conceptual stage and have not yet been developed as full-scale prototypes or tested in the field, there have been few studies of their environmental effects. Currently, identification of the potential environmental effects have been developed from: (1) predictive studies; (2) workshop reports from expert panels; and (3) report syntheses prepared from published literature related to other technologies, e.g., noise generated by similar marine construction activities, measurements of electromagnetic fields (EMFs) from existing submarine cables, environmental monitoring of active offshore wind farms in Europe, and turbine passage injury reduction mechanisms employed in conventional hydropower turbines.(Boehlert and Gill 2010; Kramer et al. 2010; Nelson et al. 2008; U.S. DOE 2009).

The majority of potential effects to salmon EFH are from the presence and operation of a wave energy convertor device or turbine. Although all phases of an individual project will alter the physical marine environment, the types and duration of those changes are varied. Numerous reviews (Kramer et al. 2010; U.S.DOE 2009) have identified the following potential effects of the wave energy converter devices, all of which may affect the quality and quantity of salmon EFH: (1) alteration of current and wave strengths and directions; (2) alteration of substrates and sediment transport and deposition; (3) interference with animal movements and migrations, including fish (prey and predators) and invertebrate attraction to subsurface components of device, concentration of displaced fishing gear; (4) presence of rotor blades or other moving parts; and attraction and concentration of predators on surface components of device; (5) alteration of habitats for benthic organisms; (6) sound and vibration in water column during construction and operation; (7) generation of EMFs by electrical equipment and transmission lines; (8) release into water column of toxic chemicals from paints, lubricants, antifouling coatings, as well as spills of petroleum products from service vessels. These potential effects to salmon EFH apply to tidal turbines as well.

Presence of subsurface structures may affect water movements, as well as sediment transport, erosion, and deposition at a local scale. During construction and decommissioning, the installation and removal of the foundations, anchors, and transmission cables will disturb and suspend sediments, and may mobilize contaminants, if present. Disturbances to the benthic habitat will occur during temporary anchoring of construction vessels; clearing, digging and refilling trenches for power cables; and installation of permanent anchors, pilings, and other mooring devices. Prior to installation of a buried cable, any debris is typically cleared from the cable route using a ship-towed grapnel (Carter et al. 2009). Cables are buried using a ship mounted plow, whereas buried cables are usually exposed and reburied using a water-jetting technique when needing repair (Carter et al. 2009). Water quality will be temporarily affected by: (1) increased suspended sediments and resultant increased turbidity and decreased water clarity; (2) localized reduction of dissolved oxygen where anoxic sediments are suspended; and (3) mobilization of anoxic or buried contaminated sediments during cable route clearing and installation of cables.

The physical structures associated with ocean and tidal energy operations could potentially interfere with the migration and rearing habitat functions for juvenile and adult salmonids (U.S.DOE 2009). The floating and submerged structures, mooring lines, and transmission cables may create complex structural habitat that could act as a fish aggregation/attraction device (FAD), as well as provide substrate for attachment of invertebrates (considered biofouling where unwanted). Salmonids may be attracted to the physical structure itself, and/or to forage fish attracted to the structure. Floating offshore wave energy facilities could potentially (1) create artificial haul-out sites for marine mammals (pinnipeds) and roosting of seabirds; and (2) trap floating vegetation (e.g., kelp, eelgrass, large wood), and lost fishing gear (e.g., nets, traps, and crab pots). Aggregation of predators (e.g., fish, marine mammals, sea birds) near FADs may reduce the safe passage attribute of a migration corridor by subjecting juvenile or adult salmonids to increased predation. Drifting nets and other fishing gear that may become entangled on mooring lines or the devices may decrease the quality of salmon migration routes due to capture from passive fishing of gear. Deposition of organic matter from biofouling on the structure can change the chemical properties and biological communities near the structures. There will be new lighted, fixed surface structures (devices and navigation buoys marking the project area) in the marine environment which may attract prey and predators of juvenile and adult salmonids.

Depending on the frequency and amplitude of the sound of the moving parts of the device, as well as how far the sound waves propagate, the operational sounds of the devices may affect rearing and migration corridor habitat. There is limited information on sound levels produced during construction (e.g., offshore pile driving) and operation of ocean energy conversion devices, as well as the spatial extent of any altered acoustic environment. Turbines with exposed rotor blades may imped or entrained salmon.

Migrating adult and juvenile salmonids may be exposed to EMFs generated at a project site, which may affect the movement of salmon. The electric current in the cables will induce a magnetic field in the immediate vicinity (U.S.DOE 2009). During transmission of produced electricity, the matrix of vertical and horizontal cables will emit low-frequency EMFs. The source and effects of EMFs in the marine environment are limited and uncertain (Gill 2005).

Accidental, but acute, release of chemicals from leaks or spills (e.g., hydraulic fluids from a wave energy conversion device, drilling fluids during horizontal drilling) could have adverse effects to water quality. Anti-fouling coatings inhibit the settling and growth of marine organisms, and chronic releases of dissolved metals or organic compounds could occur from these compounds (U.S.DOE 2009). The cumulative effects to salmon and their prey from decreased water quality associated with the release of toxic chemicals could vary substantially depending upon the number of units deployed, type of antifouling coating used, and the maintenance frequency of the coating.

Recommended Conservation Measures

Structural and operational mitigation options are often unique to the technology or issue of concern.

- Locate and operate devices at sites and times of the year, to avoid salmon migration routes and seasons, respectively.
- Schedule the noisiest activities, i.e., pile driving, at times of the year to minimize exposure of juvenile and adult salmon.
- Schedule transmission cable installation to minimize overlap with salmon migration seasons.
- Conduct pre-construction contaminant surveys of the sediment in excavation and scour areas.
- To avoid concentration of predators, above water structures could have design features to prevent or minimize pinniped haul-out and bird roosting.
- Sheath or armor the vertical transmission cable to reduce transmission of EMF into the water column.
- Bury transmission cables on the sea floor to minimize benthic and water column EMF exposure.
- Align transmission cables along the least environmentally damaging route. Avoid sensitive habitats (e.g., rocky reef, kelp beds) and critical migratory pathways.
- Use horizontal drilling where cables cross nearshore and intertidal zones to avoid disturbance of benthic and water column habitat.

- Design the mooring systems to minimize the footprint by reducing anchor size, and cable/chain sweep.
- Develop and implement a device/array maintenance program to remove entangled derelect fishing gear and other materials that may affect passage.
- Use non-toxic paints and lubricating fluids where feasible.
- Limit the number of devices and size of projects until effects are better understood and minimization measures tested.

Liquefied Natural Gas Projects

Liquefied natural gas (LNG) is expected to provide a large proportion of the future energy needs in the United States. In recent years there has been an increase in proposals for new LNG facilities along the west coast including a number of onshore and offshore facilities in Oregon and California. The LNG process cools natural gas to its liquid form at approximately -162^{o} C. This reduces the volume of natural gas to approximately 1/600th of its gaseous state volume, making it possible for economical transportation with tankers. Upon arrival at the destination the LNG is either vaporized onshore or offshore and sent out into an existing pipeline infrastructure or transported onshore for storage and future vaporization. The process of vaporization occurs when LNG is heated and converted back to its gaseous state. LNG facilities can utilize open loop, closed loop, combined loop, or ambient air systems for vaporization. Open loop systems utilize warm water for vaporization, and closed loop systems generally utilize a recirculating mixture of ethylene glycol for vaporization. Another type of closed-loop system is submerged combustion vaporization (SCV) which provides a water bath with submerged pipe coils. Combined loop systems utilize a combination of these systems.

Onshore LNG facilities generally include a deepwater access channel, land-based facilities for vaporization and distribution, storage facilities, and a pipeline to move the natural gas. Offshore facilities generally include some type of a deepwater port with a vaporization facility and pipelines to transport natural gas into existing gas distribution pipelines or onshore storage facilities. Deepwater ports and onshore terminals require specific water depths and include an exclusion zone for LNG vessel and/or port facility security.

<u>Potential adverse effects to EFH</u>

Construction and operation of LNG facilities can affect the habitat of salmonids in a variety of ways. Direct conversion and loss of habitat can occur through dredging and filling, construction of overwater structures, placement of pipelines, and shoreline armoring. Construction-related effects to habitat include generation of underwater noise from pile driving and vessel operations, turbidity, and discharge of contaminants. Long-term degradation of habitat can result from impingement and entrainment at water intakes for vaporization water and ballast and engine cooling water for LNG vessels, discharge of contaminants, discharge of cooled water from open-loop systems, and stranding of fishes by vessel wakes. Short- and long-term habitat degradation can result from accidental spills of LNG and other contaminants. With the exception of the discharge of contaminated water, discharge of vaporization water, and accidental spills of LNG, these effects are covered under other threats described in either this document or Amendment 14.

Contaminants can enter aquatic habitats through accidental releases associated with onshore and offshore operations, discharge of water containing biocides used to control fouling of piping systems, and discharges of the condensates from heat exchangers. A rapid phase transition can occur when a portion of LNG spilled onto water changes from a liquid to a gas virtually instantaneously. The rapid change from a liquid to vapor state can cause locally large overpressures ranging from a small pop to a blast large enough to potentially damage structures (Luketa et al. 2008). Because rapid phase transition would occur at the surface of the water it would be unlikely to affect fishes that are several feet under the surface. However, any fish present at or near the surface of the water would likely be killed. Effects on the aquatic environment from an LNG spill include thermal shock from the initial release (cold shock from the cryogenic liquid) and thermal shock from ignition of the vapor (Hightower et al. 2004). Condensates from heat exchanger such as SCV systems are generally acidic and require buffering with alkaline chemicals (FERC 2010). The condensate can include a wide range of metals and other contaminants. These contaminants may include copper, a known disruptor of salmonid olfactory function (e.g., Baldwin et al. 2003). The concentration of these chemicals will vary depending on the water source and facility design.

The operation of LNG facilities can result in the alteration of temperature regimes. Water utilized for the purposes of vaporization could be discharged at temperatures that differ significantly from the receiving waters and can be 5-10^{o} C below ambient temperature. Changes in water temperatures can alter physiological functions of marine organisms including respiration, metabolism, reproduction, and growth; alter migration pathways; and increase susceptibility to disease and predation. Thermal effluent in inshore habitat can cause severe problems by directly altering the benthic community or adversely affecting marine organisms, especially egg and larval life stages (Pilati 1976, cited in NMFS 2008; Rogers 1976, cited in NMFS 2008).

Potential Conservation Measures

- Site LNG facilities in areas that minimize the loss of habitat such as naturally deep waters adjacent to uplands that are not in the floodplain.
- Recommend the vaporization systems that do not rely on surface waters as a heat source, such as an ambient air system. This will avoid impingement and entrainment of living resources. If a water-sourced system must be used, recommend closed loop systems over open loop systems. This will minimize water withdrawals and the associated impingement and entrainment of living marine resources.
- Locate facilities that use surface waters for vaporization and engine cooling purposes away from areas of high biological productivity, such as estuaries.
- Design intake structures to minimize entrainment or impingement.
- Regulate discharge temperatures (both heated and cooled effluent) such that they do not appreciably alter the temperature regimes of the receiving waters. Strategies should be implemented to diffuse this effluent.
- Avoid the use of biocides (e.g., aluminum, copper, chlorine compounds) to prevent fouling where possible. The least damaging antifouling alternatives should be implemented.

Desalination

Global population growth continues to place high demand on available supplies of potable water, and areas with limited supplies of this essential resource are turning to desalination (Roberts et al. 2010). Recent estimates suggest that up to 24 million cubic meters of desalinated water are produced daily (Latterman and Hoepner 2008). Expansion of desalination capacity can be found in the U.S., Europe, China, and Australia. California is leading the way in the U.S., with projections indicating that up to 20 new desalination plants, with a capacity of 2 million cubic meters per day, will be constructed by 2030. Desalination plants have a strong potential to detrimentally impact the ecology of marine habitats through water extraction and discharge of effluent. The following discussion is taken, unless otherwise cited, from a recent critical review by Roberts et al. (2010) of the available, peer-reviewed literature on the effects of effluent discharge.

Desalination of seawater to produce potable water uses one of two basic processes: thermal distillation such as multi-stage flash (MSF) distillation, and reverse osmosis (RO). Both of these methods have a saltwater intake and an effluent discharge. The effluent is water remaining after desalination and the concentrated salts from the seawater, commonly referred to as "brine." The brine also may contain various chemicals used in the desalination process, heavy metals from the machinery, and concentrated contaminants that were in the seawater. Reverse osmosis plants are increasingly common compared to the MSF plants.

Potential Adverse Effects

The potential effects are largely concerned with intake of seawater, which can entrain and impinge marine organisms, and discharge of the brine, which can affect the physiochemistry and, therefore, the ecology at the discharge site and beyond. The effects from intake of seawater at desalination plants are expected to be similar to those described under Power Plant Intakes, and will not be discussed here.

The discharge of brine can affect the salinity, temperature, and contaminant loading of the receiving body. Changes to salinity have been the most studied of these potential effects. Depending on the desalination method used, the design of the plant, and the salinity of the intake water, the salinity of the brine can range from as low as 37.3 parts per thousand (ppt) to as high as 75 ppt. In general, for an RO plant, the salinity of the brine will be roughly double that of the intake water. Published research shows that the extent of the brine plume (the area where the salinity is elevated) varies greatly, from 10s of meters, to 100s of meters, or in extreme cases, to several kilometers from the discharge point. The extent of the plume depends on a variety of factors, including the capacity of the plant, the salinity of the brine, the location of the discharge, the design of the diffuser, and local hydrologic conditions. However, in most cases studied, the intensity of the plume diminishes rapidly with distance from the outfall and is usually no greater than 2 ppt above background salinity within 20 m of the outlet.

Brine is usually denser than seawater and will, therefore, sink to the bottom and extend farther along the seafloor than at the surface. Where prevailing currents carry the plume further alongshore than offshore, the coastal fringe may be especially susceptible to impacts. During times of high tide, the brine may be concentrated around outfalls. Thus, the area impacted by the plume is likely to be both spatially and temporally variable.

A number of studies have shown that discharge of brine can lead to detectable ecological impacts to seagrass habitats, as well as phytoplankton, invertebrate and fish communities. The effects to seagrasses are the most widely studied. However, the results of these studies are highly variable. Several studies on the Mediterranean seagrass, *Posidonia oceana,* showed clear adverse effects, with significant increases in mortality and leaf necrosis at increases of only 1-2 ppt. Others found no significant effects, even six years after plant operations began. A study on eelgrass (*Zoster marina*) from marine and estuarine waters of the Netherlands found increased mortality at salinities 30 ppt and 25 ppt respectively, which are at the upper end of the salinity range in these habitats (van Katwijk et al. 1999). This suggests that eelgrass, a species of particular importance to Pacific Coast salmon (Fresh 2007), is sensitive to salinity changes and could be at risk if exposed to a brine plume.

Infaunal and epifaunal invertebrate communities were found to be impacted by the brine plume in several studies. Close to the outfall, nematodes dominated the community and reduced diversity of other taxa up to 400 meters from the outfall. The diversity and abundance of benthic diatoms may also be reduced near the outfall. These communities are an important part of the food web upon which juvenile and adult salmon depend, and could be at risk from exposure to brine plumes. In contrast, other studies found no change in the macrobenthic organisms where the brine dissipated within 10 m from the outfall. Some of the studies that showed changes to the benthic community were associated with older plants that discharged excessive levels of copper, an issue that is largely avoidable.

Salinities of 55 ppt or higher were found to be acutely toxic to juvenile sea bream and larval flounder. The implications of this for Pacific Coast salmon are not clear, but brine discharge could affect their survival, depending on the location of the outfall. Salmon entering the estuarine and marine environment are undergoing smoltification, the adaptation to saltwater. During this time, they gradually adapt to full-strength seawater, and are under considerable physiological stress. Exposure to a concentrated brine plume at this sensitive life stage could increase this already high level of physiological stress and reduce their chances of survival.

Depending on the design of the plant, the brine may be warmer than the receiving waters. This is primarily limited to MSF plants, while RO plants tend to result in plumes that are near ambient temperature. Because RO plants are becoming more common, relative to the MSF plants, this is a lesser problem than in the past. MSF plants can produce brines that are 10-15° C warmer than the receiving waters. However, most studies have found that the thermal impacts dissipate quickly, typically diminishing to background levels within tens of meters of the outfalls. The extent and severity of the thermal plume is dependent upon a variety of factors, such as the temperature of the discharge and receiving waters, the plant capacity, and local hydrologic conditions. Given the potentially high water temperatures in the immediate vicinity of the plume, there is a potential for salmon, particularly juveniles, to be affected. Mesa et al. (2002) found that exposure to increased temperature did not increase mortality or predation in juvenile Chinook salmon, but there was clear evidence of increased physiological stress.

Desalination can clearly impact the ecology of the receiving waters, but the extent of those effects depend on a variety of factors, such as plant capacity, discharge location and design, temperature and salinity differences between effluent and receiving water, and hydrologic conditions at the discharge site. Such variables should be considered when assessing the effects of these plants.

Power Plant Intakes

The withdrawal of water for power plant cooling purposes is termed once-through cooling (OTC). Withdrawal of cooling water removes billions of aquatic organisms every year (CEC 2005). Discharges of heated and/or chemically-treated discharge water may also occur. Adverse impacts to EFH from OTC and subsequent discharges may adversely affect EFH in the source or receiving waters via 1) entrainment, 2) impingement, 3) discharge, 4) operation and maintenance, and 5) construction-related impacts.

Potential Adverse Effects

Entrainment is the withdrawal of aquatic organisms along with the cooling water into the cooling system. OTC indiscriminately entrains phytoplankton, zooplankton, and the eggs and larval stages of fish and shellfish. These entrained organisms are subjected to mechanical stress, heated water, and occasionally biocides. Of primary concern is the entrainment of early life history stages of fish and shellfish. Entrainment of larval stages can have a greater on fish and shellfish species than to phytoplankton or zooplankton due to a shorter spawning season, a more restricted habitat range, and greater likelihood of mortality. Long-term water withdrawal may adversely affect fish and shellfish populations by adding another source of mortality to the early life stage, which often determines recruitment and year-class strength (Travnichek et al. 1993). OTC units utilizing estuarine or marine waters are unlikely to entrain larval Chinook salmon or coho salmon given that spawning and larval development for these species occur in freshwater environments. Pink salmon are likely to be more susceptible to impingement and entrainment than the other two species because they typically enter the estuarine and marine habitats immediately after emergence and are, therefore, much smaller. Entrainment studies at power plants located in coastal lagoons and embayments have demonstrated that a large percentage of entrained larvae are composed of resident fishes that serve as a forage base for other species (EPRI 2007). Thus, entrainment may reduce the forage base for salmon species that may utilize the various coastal lagoons and embayments in which OTC units operate. Power plants utilizing OTC in open coastal environments have far less potential for population-level effects on fish populations than power plants located in coastal lagoons and embayments (EPRI 2007). However, localized reductions in forage opportunities may still occur near open coast OTC units.

Impingement occurs to organisms that are too large to pass through in-plant screening devices and instead become stuck or impinged against the screening device or remain in the forebay sections of the system until they are removed by other means (Grimes 1975; Hanson et al. 1977; Langord et al. 1978; Moazzam and Rizvi 1980; Helvey 1985; Helvey and Dorn 1987). The organisms cannot escape due to the water flow that either pushes them against the screen or prevents them from exiting the intake tunnel. Similar to entrainment, the withdrawal of water can entrapped particular species especially when visibility is reduced (Helvey 1985). This condition reduces the suitability of the source waters to provide normal EFH functions necessary for subadult and adult life stages of salmon and/or their prey. Population level impacts have not been observed for individual species

The ecological implications of entrainment and impingement are complex and difficult to assess. Although population level impacts are not consistently observed, the use of OTC may significantly decrease biological productivity in estuarine and marine systems. With modern entrainment sampling and analyses, a more scientifically robust method of determining appropriate compensation may be done through the use of habitat production foregone analyses. A combined habitat foregone estimate for 13 power plants using OTC in California bays and estuaries was approximately 10,800 acres of wetlands (CEC 2005).

Thermal effluents in inshore habitat may alter the benthic community or kill marine organisms, especially larval fish. Temperature influences biochemical processes of the environment and the behavior (e.g., migration) and physiology (e.g., metabolism) of marine organisms (Blaxter 1969). Thermal impacts are generally site-specific and depend upon the type of habitat and circulation at the discharge site. The thermal impacts of some West Coast plants have been large when discharge occurs either into bays and estuaries with reduced mixing or into the open coast where heated water quickly contacts rocky habitats (Duke 2004a; Schiel et al. 2004; Foster 2005). Significant impacts to sensitive habitats, such as eelgrass and kelp, have been observed with some California power plants. However, heated water discharged offshore on the open coast experiences rapid mixing before touching benthic habitat, which likely results in little impact (CEC 2005). The water clarity of the receiving waters may also be diminished if the intake water is more turbid than that around the discharge structure. Water clarity and quality may also be altered by the increased dead organic matter in the discharge, as well as by scour if discharge occurs on shore (CEC 2005).

Other impacts to aquatic habitats may result from construction related activities, such as dewatering or dredging, as well as routine operation and maintenance activities. The effects of some of these activities are discussed elsewhere. There is a broad range of impacts associated with these activities depending on the specific design and needs of the system. For example, dredging activities may cause turbidity, degraded water quality, noise, and substrate alterations. Power plants using once-through cooling may also periodically use biocides such as sodium hypochlorite and sodium bisulfate to clean the intake and discharge structures. Chlorine is extremely toxic to aquatic life. In addition, heat treatments are frequently used to control fouling organisms in the forebay area of OTC units. This kills the fish that remain in the forebay and the fouling invertebrate organisms along the tunnels and racks.

Potential Conservation Measures

- To the extent feasible, power plants should utilize cooling alternatives that avoid or minimize the use of river, estuary, or ocean water for cooling purposes. Alternatives such as dry cooling, closed-cycle wet cooling, utilizing recycled water for cooling water are more benign to EFH.
- Locate facilities that rely on surface waters for cooling in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where EFH species or their prey concentrate. Discharge points should be located in areas that have low concentrations of living marine resources.
- Design intake structures to minimize entrainment or impingement. Velocity caps that produce horizontal intake/discharge currents should be employed, and intake velocities across the intake screen should not exceed 0.5 foot per second.
- Design power plant cooling structures to meet the “best technology available” requirements (BTAs) as developed pursuant to Section 316(b) of the Clean Water Act. Use of alternative cooling strategies, such as closed cooling systems (e.g., dry cooling) should be used to completely avoid entrainment/impingement impacts in all industries that require cooling water. When alternative cooling strategies prove infeasible, other BTAs may include but are not limited to fish diversion or avoidance systems, fish return systems that convey organisms away from the intake, and mechanical screen systems that prevent organisms from entering the intake system, and habitat restoration measures.
- Regulate discharge temperatures (both heated and cooled effluent) such that they do not appreciably alter the temperature in a way that could cause a change in species assemblages and ecosystem function in the receiving waters. Strategies should be implemented to diffuse the heated effluent.
- Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible. The least damaging antifouling alternatives should be implemented.
- Mitigate for impacts related to power plants and other industries requiring cooling water. Mitigation should compensate for the net loss of EFH habitat functions from placement and operation of the intake and discharge structures. Mitigation should be provided for the loss of habitat from placement of the intake structure and delivery pipeline, the loss of fish larvae and eggs that may be entrained by large intake systems, and the degradation or loss of habitat from placement of the outfall structure and pipeline as well as the treated water plume. A habitat production foregone approach or equivalent habitat equivalency analysis should be used for determining mitigation.
- Treat all discharge water from outfall structures to meet state water quality water standards at the terminus of the pipe. Pipes should extend a substantial distance offshore and be buried deep enough to not affect shoreline processes. Buildings and associated structures should be set well back from the shoreline to preclude the need for bank armoring.

Pesticide use

Pesticides are a diverse group of chemicals that are broadly used to control unwanted organisms in agriculture and a range of non-agricultural uses (e.g., forestry, rights-of-way, horticulture, outdoor solid waste containers, irrigation ditches, stagnant water, households and domestic dwellings). They include fungicides, herbicides, insecticides, nematicides, molluscicides, rodenticides, fumigants, disinfectants, repellents, wood preservatives, and antifoulants among others. In Willapa Bay and Grays Harbor, two estuaries in Washington State, the insecticide carbaryl is often sprayed into the aquatic habitat to control burrowing shrimps that interfere with shellfish culture. Given this wide-spread use, pesticides are ubiquitous contaminants in the aquatic environment, and are known to adversely affect many types of organisms, including salmonids by either injuring or killing them, or by degrading the habitats upon which they depend.

Pesticides contain “active” ingredients that kill or otherwise affect targeted organisms (listed on the label). There are more than 900 active ingredients, and they must be registered under the Federal Insecticide, Fungicide, and Rodenticide Act. Registered pesticide products, known as formulations, typically contain active ingredients and a variety of “inert” or other ingredients which are generally not assessed for toxicity, although they are released into the environment. Examples may include chemical adjuvants to make pesticide products more efficacious, surfactants to reduce the interfacial, surface tension and increase uptake by the target, solvents, or other chemicals. Many of these ingredients have their own toxic properties that may result in adverse effects to salmon or their prey. Beginning in 2008, NMFS has issued three Opinions (NMFS 2008b; 2009b; 2010a) to the Environmental Protection Agency (EPA) on the registration of 18 pesticides, and is scheduled to complete consultation on 19 others by 2012. These Opinions determined that when applied according to the label instructions, many of these pesticides can have severe effects to individual and populations of threatened and endangered Pacific salmonids under NMFS’ jurisdiction. The Opinions concluded that many of the pesticides analyzed present a limiting factor to the recovery of at least some of the 27 ESUs of Pacific Coast salmonids, and that application according to the labels would jeopardize the continued existence as well as adversely modify designated critical habitats of many of them. The following summary is drawn from the first two Opinions (NMFS 2008b; 2009b), which covered a total of six of the pesticides: chlorpyrifos, diazinon, malathion, carbaryl, carbofuran, and methomyl.

The risk analyses in the Opinions used existing literature to evaluate the effects of these pesticides on a number of important endpoints (survival, growth, reproduction, swimming, olfactory-mediated behaviors, and prey survival) and found strong evidence of adverse responses at concentrations that would be expected to occur in the habitats used by salmon. In off-channel habitats that are very important to juvenile salmonids, estimates of pesticide concentrations appeared to be especially high. The Opinions concluded the following:

- Direct, acute exposure to pesticides can kill salmonids. Monitoring data and modeling estimates show that some pesticides can reach lethal concentrations in some of the habitats used by salmon, especially in off-channel habitats.

- Acute or chronic exposure to sublethal concentrations of some active ingredients can lead to lower feeding success and likely results in reduced growth. Survival of juvenile salmonids has been correlated with growth rates, where lower growth rates result in lower survival.

- Salmonid prey are highly sensitive and affected by real-world exposures to many of the pesticides and mixtures of pesticides, particularly, neurotoxic insecticides. Aquatic habitats that are routinely exposed to certain pesticides showed reductions in the abundance and species diversity of the prey community, and reduced growth rates in juvenile salmon have been associated with low prey abundance.

- Exposure to real-world sublethal concentrations of some pesticides has been shown to impair swimming behavior in salmonids. Swimming speed, distance swam, and acceleration can be reduced after such exposure. The ecological consequences of aberrant swimming behavior are impaired feeding that translates into reduced growth, interrupted migratory patterns, survival, and reproduction.

- Definitive evidence supports that olfaction can be impaired by some pesticides at concentrations that are expected to occur in salmon habitats. Juveniles with impaired olfactory functions have been shown to more susceptible to predation, while adult spawning migration and mate detection can be affected by impaired olfaction.

- Mixtures of pesticides, including the "inert/other" ingredients, can act in combination to increase the potential adverse effects to salmon and salmon habitat compared to exposure to a single ingredient

It is important to note that the potential for pesticides to adversely affect EFH depends on a variety of factors, and not every application will result in an adverse effect. The specific pesticide being applied, the application method and concentration, the distance from salmon habitat that the pesticide is applied, and the general pattern of pesticide use in the area will all affect the pesticide concentrations in the aquatic habitat. In addition the time of year and the species and life stages present are important considerations.

Potential conservation measures will vary depending on the specific pesticide being applied, the species and life stage in the area, and the time of year. In general, they include:

- Avoid the use of pesticides near aquatic habitats, if possible.
- Implement measures that reduce the need to apply pesticides, such as planting pest-resistant crops.
- Use less toxic alternatives to pesticides.
- Establish a minimum no-application buffer width.
- Install or establish a minimum non-crop vegetative buffer where no pesticides are applied.
- Maintain healthy riparian zones alongside salmon-bearing waters.
- Restrict applications under certain environmental conditions, such as during periods of high wind, rain, or wet soils.

Flood Control Maintenance

The protection of riverine and estuarine communities from flooding events can result in varying degrees of change in the physical, chemical, and biological characteristics of existing shoreline and riparian habitat. Land surrounding rivers is in high demand for agricultural and developmental purposes, prompting creation of artificial structures that improve flood control (SRSRB 2006). These structures include levees, weirs, channels, and dikes.

Potential Adverse Effects

Managing flood flows with these structures can disconnect a river from its floodplain eliminating off-channel habitat important for salmon (WSCC 2001b) Floodplains serve as a natural buffer to changes in water flow: they retain water during periods of higher flow and release it from the water table during reduced flows (Ziemer and Lisle 2001). These areas are typically well vegetated, lowering water temperatures, regulating nutrient flow and removing toxins. Juvenile salmon use these off channel areas because their reduced flows, greater habitat complexity and shelter from predators may increase growth rates and their chance of survival.

Artificial flood control structures have similar effects on aquatic habitat, as do bank stabilization efforts and woody debris removal. Riverbanks are artificially steepened, eliminating much of the inshore, shallow-water habitat used by larval and juvenile salmonids. Channel complexity is also lost, reducing naturally formed pool-riffle sequences (NMFS 2008c). Pools provide deepwater habitat for larger fish, as well as thermal and spatial refugia during low flow periods. Riffles support benthic invertebrates and juvenile fishes (Thompson 2002). The woody debris that provides shelter and helps structure heterogeneous flows is also lost (USFWS 2000). As a result, water moves at a uniform, increased rate, thereby decreasing spawning habitat and altering sediment dynamics. Sediment size distribution is important for providing habitat to salmonid prey items such as stoneflies and mayflies (NMFS 2009z). In addition, the routing of water through specific flood channels may isolate or strand migrating salmon. Earthen levees can be prone to failure due to cracks caused by rooting plants, and may thus be periodically cleared or stripped of vegetation, leaving denuded banks and barren riparian zones. This leads to decreased shading, higher water temperatures, less large woody debris recruitment, reduced filtering of overland nutrients, sediment, and toxics, and a loss of bank stability.

The use of dikes and berms can also have long-term adverse effects in tidal marsh and estuarine habitats. Dikes, levees, ditches, or other water controls at the upper end of a tidal marsh can cut off all tributaries feeding the marsh, preventing freshwater flushing and annual flushing, annual renewal of sediments and nutrients, and the formation of new marshes. Water controls within the marsh proper intercept and carry away freshwater drainage, block freshwater from flowing across seaward portions of the marsh, increase the speed of runoff of freshwater to the bay or estuary, lower the water table, permit saltwater intrusion into the marsh, and create migration barriers for aquatic species. In deeper channels where reducing conditions prevail, large quantities of hydrogen sulfide are produced that are toxic to marsh grasses and other aquatic life. Acid conditions of these channels can also result in release of heavy metals from the sediments.

Long-term effects on the tidal marsh include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, greatly reduced invertebrate populations, and general loss of productive wetland characteristics. Loss of these low-salinity environments reduces estuarine fertility, restricts suitable habitat for aquatic species, and creates abnormally high salinity during drought years. Low-salinity environments form a barrier that prevents the entrance of many marine species, including competitors, predators, parasites and pathogens.

Potential Conservation Measures

- Minimize the loss of riparian habitats as much as possible.
- The diking and draining of tidal marshlands and estuaries should not be undertaken unless a satisfactory compensatory mitigation plan is in effect and monitored.
- Wherever possible, “soft” approaches (such as beach nourishment, vegetative plantings, and placement of large woody debris) to shoreline modifications should be utilized.
- Include efforts to preserve and enhance EFH by providing new gravel for spawning areas; removing barriers to natural fish passage; and using weirs, grade control structures, and low flow channels to provide the proper depth and velocity for fish.
- Construct a low-flow channel to facilitate fish passage and help maintain water temperature in reaches where water velocities require armoring of the riverbed.
- Replace in-stream fish habitat by providing rootwads, deflector logs, boulders, and rock weirs and by planting shaded riverine aquatic cover vegetation.
- Use an adaptive management plan with ecological indicators to oversee monitoring and ensure mitigation objectives are met. Take corrective action as needed.
- Retain trees and other shaded vegetation along earthen levees.
- Screen inappropriate flood control channels.
- Ensure adequate inundation time for floodplain habitat that activates and enhances near-shore habitat for juvenile salmon.
- Ramp and convey flood flows appropriately to reduce stranding events.
- Reconnect wetlands and floodplains to channel/tides.

Culvert construction

Culvert construction, maintenance, and replacement are common activities occurring in Pacific Coast salmon habitat, typically—but not always—associated with roads. Culverts convey water from upslope portions of terrain to downslope areas, thereby minimizing the risk of flooding, erosion, and undesired impacts to infrastructure and habitat. In the past, however, many culverts were constructed too small to convey large flow events, too steep to allow adequate fish passage, or without other physical characteristics to avoid the impacts to habitat and species that are now recognized to be significant problems.

Regulatory requirements under the ESA and MSA, as well as best practices developed by states, counties, tribes, and federal agencies, have established a suite of construction, maintenance, and replacement actions to minimize adverse impacts to habitats and species. Habitat restoration programs have provided support for installation of "fish friendly" culverts, and the state of the art culvert is typically an open-bottom arched culvert that is designed to better mimic a natural stream bed.

Amendment 14 includes culvert construction and maintenance under the Road Building and Maintenance section. However, the effects and conservation recommendations are cursory. Any revisions to Pacific Coast salmon EFH would benefit from an updated stand-alone section on culvert effects and conservation recommendations.

Potential Adverse Effects

The physical and chemical components to culvert construction that lead to potential adverse habitat impacts include slope, jump height, lack of instream structure, contaminants, and water velocity. These can lead to compromised fish passage, lethal and sublethal effects to individuals, and loss of ecological connectivity (Castro 2003; NMFS 2008b). Culverts may pose significant barriers to migration in salmon habitat. Road crossings are a common bottleneck to migrating adult salmon, as many employ faulty or poorly designed culverts (Chestnut 2002). For example, if a culvert is too small compared to the surrounding river, water velocities will increase rapidly via a Venturi effect. Debris will not readily flow through the culvert, eventually clogging it and making fish passage even more difficult. This blockage also prevents woody debris from reaching lower stretches of the stream, removing valuable fish habitat.

The slope of a culvert can affect fish passage directly by providing conditions that lead to excessive water velocity. This can create a passage barrier to upstream migrating fish. Velocities greater than one foot per second (fps) can create a barrier for juvenile salmon, regardless of the culvert length. For adult passage, velocities can range between two and six fps, depending on culvert length (NMFS 2001).

Excessive water velocity also can cause scouring at the downstream end of a culvert leading to a "perched" culvert requiring migrating fish to jump just to access the culvert. A perched situation can also occur when a culvert is simply placed too high and dries out during periods of low flow, or is placed too far above the stream at the outflow, thereby preventing fish from accessing it or safely exiting (Sylte 2002; Flanders 2000). NMFS (2008a) states that there should ideally be no difference in water height between water inside a culvert and water in the adjacent stream; and offers criteria for maximum jump heights.

Culverts can also impact a stream's geomorphology by trapping sediment above the culvert and increasing erosion below through a process called downcutting (Castro 2003; Wheeler et al. 2005). Downstream scour of stream bed and banks often occurs when large flow events through inadequately-sized culverts create a fire hose effect, mobilizing sediment and potentially eroding stream banks. This situation not only introduces excess sediment into the stream (potentially smothering redds), but also can remove riparian vegetation, a vital component of salmonid habitat. These physical changes can impact the entire lotic system, particularly harming macroinvertebrates that are prey for salmon (Vaughan 2002).

Numerous other effects resulting from the presence of culverts have been identified. These include loss of ecological connectivity, loss of (or excessive) transport of sediment and woody debris downstream, loss of spawning or rearing habitat, and effects to benthic invertebrates and aquatic vegetation (. et al 2003). It is important to remember that various culvert characteristics can act synergistically, even when one factor alone isn't enough to adversely affect habitat. For example, a too-steep slope can be mitigated by the presence of instream structure that allows for resting pockets and serves to slow water velocity. However, a too-steep slope plus lack of instream structure can make a culvert less passable for fish than if only one of those conditions existed.

The cumulative effects of multiple culverts in a stream system and multiple adverse elements associated with each culvert can increase the physiological stress of migrating salmon and may lower the probability of successful passage and subsequent adult spawning.

Potential Conservation Recommendations

NMFS (2001), Bates et al. (2003), and NMFS (2008a) offer design criteria that address the effects listed above. These criteria are often incorporated into conservation recommendations for individual projects, in ESA and EFH consultations, and could be used to develop a general suite of conservation recommendations germane to culvert construction.

- In instances where culverts are used to bridge stream crossings, specific engineering care should be given to maintain the stream's ecological function including use of alternative designs such as Active Channel Design, Stream Simulation Design and Hydraulic Design.
- Where applicable, baffles, weirs, and resting pools should be established to create hydraulic refuges for upstream migrating fish.
- Water velocities and jump heights should not exceed the swimming performance of critical life stages for Pacific salmon (adult or juvenile) or be increased beyond NMFS's culvert specific passage criteria.
- Regular maintenance should be conducted to ensure culverts remain clear of debris, operable, and have suitable hydraulic conditions.
- Where applicable, alternatives to culverts (such as bridges) should be explored.

Climate change

Human activities that emit greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases contribute to a changing climate. Global climate change is correlated to the residence time of these compounds in the atmosphere and their ability to warm the planet. Examples of human activities that contribute to GHG emissions include burning fossil fuels, deforestation, and land development. While climate change remains controversial and future conditions rely on mathematical models, strong evidence suggests the direction climate change will take and the effects it can have on Pacific salmon species (Zabel et al. 2006; ISAB 2007).

Pacific Northwest temperatures have increased by about 0.8° C, and models project warming of 2.0° C by the 2040s and 3.3° C by the 2080s (Mote and Salathé 2009). Precipitation is also projected to increase with a more intense seasonal cycle - autumns and winters may become wetter and summers may become drier. Regional climate models indicate that overall extreme precipitation in western Washington will increase and the snowpack in the Cascades will decrease (Mote and Salathé 2009).

These climate changes will likely have widespread impacts on Pacific salmon throughout their native range (Battin et al. 2007; ISAB 2007). Decreased summer precipitation could reduce spawning habitat for salmon populations that have already experienced habitat loss from impassable barriers. Winter precipitation increases causing a higher frequency of flooding that would scour eggs and larvae from the riverbed. Adult salmon that prefer slow moving pools would also see a decrease in this type of habitat. High winter flows may also degrade valuable estuarine zones through pollution, variable freshwater influx and physical disturbance. As the climate warms and regional snowpacks would reduced, snow fed streams would become more reliant on rainfall, and cold water flows that support salmonid growth and survival, freshwater ecosystems and human water supplies would be affected (Mote et al. 2003; Climate Impacts Group 2004). Warmer temperatures will likely also melt snow packs earlier and would change the timing of juvenile emigration from freshwater habitats (ISAB 2007). Changes in snowpack would further alter flow patterns leading to intensified summer droughts and reduced habitat for rearing and migrating juvenile salmon (Battin et al. 2007; Luce and Holden 2009).

Regional models also predict increase water temperatures throughout salmon habitats (ISAB 2007). Warmer water may cause salmon to experience direct mortality, become more susceptible to disease and contaminants or encounter decreased populations of freshwater prey items. Existing impassable barriers prevent salmon from reaching cool water spawning areas found at higher elevations. This problem would be exacerbated if the limited number of currently accessible cold-water spawning habitat areas were eliminated due to increased temperatures. Additionally, water temperature increases would also affect water chemistry by reducing dissolved oxygen levels. In the marine environment, increased water temperatures would promote stratification between warmer surface waters and cooler, nutrient rich deep waters. The resulting thermocline could prevent nutrient cycling between regions diminishing growth of phytoplankton that form the base of marine food webs (Climate Impacts Group 2004; Scheuerell and Williams 2005). Without this food source, fewer juvenile salmon would be able to reach maturity.

The ocean is a major sink for atmospheric CO_2, and changes in atmospheric concentrations will affect oceanic conditions. Specifically, as the level of CO_2 in the atmosphere increases, it will dissolve more readily in the ocean, increasing the concentration of carbonic acid and lowering the pH of seawater. This change may not directly harm salmon, as they are able to survive lower pH in freshwater habitat, but their ecosystem may be far less productive. Planktonic organisms that form the base of many marine food webs secrete $CaCO_3$ shells necessary for survival. Lower pH will dissolve or prevent the formation of these shells causing mortality (Orr et al. 2005). Juvenile salmon rely on plankton as a food source and decreased plankton abundance could affect salmon growth and survival. Changing ocean temperatures may later salmon behavior, distribution and migrations (ISAB 2007).

Future climate scenarios predict increased fire frequency and intensity in western North America (ISAB 2007). Drought, and hot, dry weather will result in an increase in outbreaks of insects, which will affect forest and watershed health. Finally, climate change is expected to increase the demand placed on already-limited sources of water, increasing the conflict between meeting the needs of humans and those of salmon (Miles et al. 2000). Streams may be diverted more frequently for drinking, irrigation, frost protection or other purposes as human populations continue to increase along the Pacific Coast (Vicuna et al. 2007).

Recommendation

The Panel recommends that the Council give further consideration to updating the non-fishing threats to EFH contained in Amendment 14, adding the newly identified threats described above, and developing conservation recommendations for each threat.

5. INFORMATION AND RESEARCH NEEDS

This report and Amendment 14 identified the following information and research needs:

1. Improve fine scale mapping of salmon distribution to inform future reviews of EFH for Pacific Coast salmon and aid in more precise and accurate designation of EFH and the consultation process. Potential approaches include, but are not limited to:
    a. Develop distribution data at the 5^{th} or 6^{th} HUs, across the geographic range of these species.
    b. Develop habitat models that can be used to predict suitable habitat, both current and historical, across the geographic range of these species.
    c. Develop seasonal distribution data at a 1:24,000 or finer scale.
2. Improve data on habitat conditions across the geographic range of Pacific Coast salmon to help refine EFH in future reviews.
3. Improve data on marine distribution of Pacific Coast salmon, and develop models to predict marine distribution to inform revisions to EFH in future reviews.
4. Improve data on the potential adverse effects of fishing gear on the EFH of Pacific Coast salmon.
5. Advance the understanding of how a changing climate, can affect Pacific Coast salmon.

Recommendation

The Panel recommends further consideration of the information and research needs for refining EFH during the next review, based on the data gaps identified in this review and Amendment 14.

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APPENDIX A: ANNOTATED BIBLIOGRAPHY FOR 2010 ESSENTIAL FISH HABITAT REVIEW

MEMORANDUM

Date: May 25, 2011

From: Pacific Coast Salmon Essential Fish Habitat (EFH) Review Oversight Panel

To: All interested parties

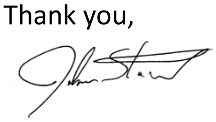
Re: Revisions to Final Report on the 5-year review of EFH for Pacific Coast salmon

In response to comments by Council Members, Advisory Committees, Management Bodies, and the public at the April Council Meeting, the Oversight Panel made several revisions to the March 23, 2011 Final Report on the 5-year review of EFH for Pacific Coast salmon. The revised report is available as an "electronic attachment" in the June 2011 Briefing Book (see Supplemental Informational Report 3, ELECTRONIC Attachment 1) . These revisions include:

1. Addition of a cover page that was inadvertently omitted from the March 23 Final Report.
2. Correction of several typographical errors.
3. Page 36: Added the following sentence to the caption for Table 6: "Note that an impassible barrier limits EFH extent only above that particular barrier. The remainder of the HU would still be considered EFH." This sentence clarifies that designation of a dam as "the upstream extent of EFH" means that only the waters that are blocked by that dam are not designated as EFH. The remaining waters in the 4th field HU are designated as EFH, unless access to them is blocked by another dam on the list. In response to comments made by CRITFC, McKay Dam was specifically identified as the upstream extent of EFH in McKay Creek.
4. Page 36: Correctly identified the Umatilla River as being in the State of Oregon.
5. Page 55: Included additional literature on the loss of marine-derived nutrient from salmon carcasses.
6. Page 56: Referenced the State of Washington's requirement for biodegradable cord on recreational crab traps.
7. Pages 56-57: Refined the section on derelict gillnets. In particular, the revisions include additional information on the threat to salmon from derelict gillnets in Puget Sound, and that in the Columbia River, white sturgeon are the only species that have been documented to have been caught in derelict nets. An inaccurate citation was also removed.
8. Page 57: Revised text on effects to survival of eggs and alevins from trampling of redds.

It is important to note that this report is purely advisory in nature, and does not, by itself, constitute any actual changes to EFH. Any changes would have to be made by the Council and NMFS, via normal processes. The Oversight Panel considers this Revised Final Report as the final step in the 5-year review process.

Thank you,



John Stadler, PhD
Oversight Panel Chair

Regional Fishery Management Council Coordination Committee

March 31, 2011

Eric C. Schwaab
Assistant Administrator for Fisheries, NOAA
1315 East West Highway
Silver Spring, MD 20910

Dear Eric,

The purpose of this letter is to provide you with the Council Coordination Committee's (CCC) position on the National Marine Fisheries Service's (NMFS) allocation project. At the recent CCC meeting George Lapointe presented an update on the project and indicated the purpose is to examine both commercial and recreational allocation issues across the Nation. The implication was that NMFS viewed this as an opportunity to look at, and potentially revise, the various existing Council allocations as stocks continue to rebuild. As you are aware, the subject elicited significant debate during the meeting.

After much discussion the CCC unanimously approved a motion "requesting that the Service's allocation initiative not include any new directives to the Councils requiring or directing the Councils to revisit allocations, but that any initiatives to revisit allocations be left to the Councils". On behalf of the CCC I am making this request.

We are concerned the Councils may be directed or required to revise existing allocations, based on some nationally derived criteria. This could create the potential for opening old wounds that were suffered when the existing allocations were developed. Currently, as fisheries evolve and allocation issues arise, the Councils address them on a case by case basis, and we believe that is as it should be.

Thank you for your consideration of our request.

Sincerely,

David Cupka

David Cupka
Chairman

cc: CCC Members
Sam Rauch
George Lapoint