North Pacific Fishery Management Council
Electronic Monitoring Cooperative Research and Implementation Program

Introduction

The North Pacific Fishery Management Council has established an intention to integrate electronic monitoring (EM) tools into the Observer Program for the fixed gear small-boat groundfish and halibut fisheries. The Council's intent is to develop EM to collect data to be used in catch estimation for this fleet. The Council has set an interim goal of pre-implementation in the small boat longline fleet in 2016, focusing on vessels that have trouble carrying an observer. This research plan describes multiple research projects targeted for 2015, which will collect information that will help inform pre-implementation decisions and future Council alternatives for integrating electronic monitoring (EM) into the Observer Program.

These research projects were developed and refined through a Council committee, the fixed gear EM Workgroup (EMWG). The EMWG provides a forum for all stakeholders including the commercial fishing industry, agencies, and EM service providers to cooperatively and collaboratively design, test, and develop EM systems that are consistent with Council goals to integrate EM into the Observer Program.

The Cooperative Research Plan includes analytical and field work projects to address the following four elements:

- Deployment of EM Systems
  - Operational testing with standard camera
  - Self-reported data elements
- Research and Development of EM Technologies
  - Assess the feasibility of EM data to estimate catch by weight
    - Pot Gear, IFQ setline, IPHC survey
  - Integration of Sensor Data with e-logbook
- Infrastructure to support EM implementation
  - Application development to support EM data integration into the observer database
- Analyses to support EM implementation decision points

Project Goal

The overall goal of this cooperative research project is to assess the efficacy of EM (in combination with other tools) for catch accounting of retained and discarded catch, and to identify key decision points related to operationalizing and integrating EM systems into the Observer Program for fixed gear vessels in a strategic manner. As an interim step, the Council has endorsed a target date of 2016 for taking the first steps towards operationalizing EM on small fixed gear vessels, especially for the vessels for which accommodating a human observer onboard is problematic. Information from the 2015 research projects will be used to identify procedures to test EM in an operational mode, to estimate catch from a group of vessels in 2016.

Conceptual Approach, and Integration of Research Elements

This goal will be achieved through: 1) field trials testing methods to provide quantifiable image-based data from fisheries, which can be used to support discard estimation in Alaska's fixed gear fleet; and 2) analysis of information from these field trials and past EM research where appropriate. This cooperative research will inform evaluation of multiple EM program design options and consider various EM

integration approaches to achieve management needs. The research will: assess the functionality of EM for catch accounting, evaluate the operational costs for implementation of EM technology, identify implementation needs (e.g., people, training, infrastructure), and identify what self-reported data is required from vessel operators for data validation, accountability and catch accounting.

Data and analysis produced on costs, data quality, risks, operational procedures, and vessel compatibility will inform decisions on implementation phases, future investments in technology, and identify the combination of tools that will best meet NMFS, Council, and stakeholder management objectives for catch accounting. These decision points will be analyzed in a regulatory amendment, and the Council's recommendation, and subsequent NMFS rulemaking that will result in integration of EM options into the Observer Program.

Linkage to Council's EM Strategic Plan

This cooperative research program (CRP) has been developed to be responsive both to the implementation of the North Pacific Fishery Management Council (Council) EM Strategic Plan, adopted in June 2013, and to Senate language included in the 2014 NMFS appropriations bill, which directed NMFS to work with the small boat fixed gear fleet to implement a program designed to test the functionality of available electronic monitoring systems. The cooperative study addresses the following components of the Council's EM Strategic Plan:

- **Goal II, Objective 1**: Conduct scientific research to advance the science of monitoring and data integration.
    - Strategy C: Evaluate EM technologies in the 2013-14 EM project on volunteer vessels in the <57.5 ft longline and pot vessels.
        - Action: Evaluate species identification issues.
        - Action: Identify data gaps and potential solutions for species weight estimates, biological samples and rare species interactions.
        - Action**:** Assess the efficacy of using technology for capturing information that would quantify discard and provide spatial and temporal distribution of effort.

Analyses of the results from the cooperative study will be used to develop a suite of alternatives for the Council to choose from, to address:

- **Goal III, Objective 1**: Implement EM/ER technology where appropriate and cost effective to improve catch estimation and better inform stock assessments.
    - Strategy A: Implement EM as appropriate based on scientific research from goal II.
        - Action: Select EM approach.
        - Action: Analyze EM approach, impacts, cost, and benefits. Following Council action, the next step will be to initiate Strategic Plan
        - Action: Write implementing regulations,
        - Action: Implementation, roll out, outreach.

- **Goal I, Objective 3**: Continue to develop the regulatory framework to implement EM/ER requirements.
    - Strategy A: Develop requirements to use EM for catch estimation.
        - Action: Identify agency/industry responsibilities
        - Action: Identify performance-based standards for regulations.
        - Action: Assign and prioritize staff for regulation development.
        - Action: Develop vessel monitoring

Integration of EM fieldwork with the Council process and the Observer Program

The focus of this cooperative research effort is to identify and resolve implementation issues associated with integrating EM into the North Pacific Groundfish and Halibut Observer Program. These implementation issues will then be evaluated in a Council analysis, leading to a regulatory amendment to allow the use of EM to be integrated with the Observer Program. The regulations will specify technical requirements for EM, after which the Council and NMFS may use the Annual Deployment Plan process to deploy EM and/ or human observers to the groundfish and halibut fleets. The Council and NMFS are not able to use the observer fee, currently collected from vessels participating in the partial coverage category of the observer program, to support EM until the regulatory process is complete.

EM development is expected to be an ongoing process, with a sustained Council commitment to building EM capacity. EM integration may be implemented in phases upon recommendation by the Council, as results warrant, with ongoing refinement of EM technology, field services, and data review elements, as circumstances warrant. The timeline described below is subject to change.

Year	Fieldwork / Pre-implementation (Pre-Imp)	Council process, Regulations	Observer Program/ Annual Deployment Plan (ADP)
2014	*Fieldwork*	EMWG developing purpose & need, alternatives, 2015 Cooperative Research Plan (CRP)	October – 2015 ADP places 10 vessels that are participating in EM research into the no selection pool
2015	Jan-Feb – stereo camera field research on pot vessel (RFP)		
	Feb – SSC reviews CRP	Feb – SSC reviews CRP	
	Mar-Apr – stereo camera field research on longline (RFP and NPRB) Mar-Sep – operational research	EMWG evaluates field data	
	(other fieldwork too)	October – present a refined 2016 Pre-Imp concept to Council	October – 2016 ADP proposes all EM Pre-Imp vessels in no selection pool
2016 (Pre-imp 1)	Pre-implementation will likely focus on longline vessels <57.5'. Size of fleet will be dependent on available funding *(independently sourced)* and Council requirements.		
	Fieldwork as necessary/ possible for other elements (e.g., pot vessels, >57.5') *(requires independent funding)*	October – initial review for EM analysis. Focus on what type of EM program should go forward, and what regulatory changes are needed to allow it	October – 2017 ADP proposes all EM Pre-Imp vessels in no selection pool
		December – final action on EM analysis	
2017 (Pre-Imp 2)	Pre-Imp 2, potentially expanded to include other fixed gear vessels *(requires independent funding)*	Develop regs for integrating EM	June – 2016 Observer Annual Report provides preliminary analysis to support how to allocate observer fee between observer and EM deployment
			October – 2018 ADP allocates funding between observers and EM deployment
2018	**Integrated observer/EM monitoring program**		

Council decision junctures:

- **February 2015** – SSC review and Council approval of the utility of each of the 2015 Cooperative Research Plan to inform decisions points related to 2016 pre-implementation.
- **October 2015** – Council approves proposal for 2016 pre-implementation year. Involves approving design of 2016 program, and allowing an exemption from human observer coverage for those vessels that are participating.
    - Scale of pre-implementation will largely be determined by funding and number of boats that are life raft or bunk space limited. Both factors remain to be determined, but the scale is anticipated to be considerably larger than the 14 vessels participating in 2015 research.
    - In considering the scope of pre-imp, the Council will also need to weigh the higher risk that monitoring data from pre-imp may not be usable in catch accounting system in 2016, as kinks of integration are worked out.
    - While the constraints of the 2016 pre-imp program will be reconsidered in the final analysis, significant changes in the pre-implementation design could potentially delay implementation.
- **October/December 2016** – Council decides on regulations to integrate EM into the monitoring plan, including decision points about how the EM option will look
- **October 2017**, and subsequent years – Council decides how to allocate the available observer fee funding between human observer days and EM deployment

Overview of cooperative research projects

The various research projects that have been initiated by the EM Workgroup to inform Council decision points for moving forward to pre-implementation and eventual implementation are summarized in the tables that follow. Detailed study designs for the 2015 field research projects are provided in the appendices.

Project	Deployment	R&D	Infrastructure	Analysis	Description	Key Outcomes
Deployment projects						
Operational testing fieldwork *(study design in Appendix A)*	x				Results from the spring 2014 field season and written products (described above) will be used to determine research priorities for the 2015 season. It is expected that the field program will continue to evaluate program operational infrastructure in key ports, continue to socialize EM technology with the fleet, and test some aspects of the strawman monitoring options. This work will be a collaborative effort involving service providers, the fishing industry, NMFS and PSMFC.	Field testing: The key elements of this program include decision points, operational plans, field work, EM data sets, dockside monitoring data, and a technical report, jointly prepared by PSMFC and service providers.
Vessel Obligations	x			x	Each strawman monitoring option will carry specific vessel obligations in order to ensure the data collection objectives are met. This work task provides a comprehensive description of vessel requirements for each option, including duty of care responsibilities, on board catch handling requirements, ancillary data collection and other reporting obligations.	Discussion document summarizing the vessel requirements for each monitoring option; feasibility evaluation for each fishery/fleet; analysis of strengths and weaknesses of each approach.

Project	Deployment	R&D	Infrastructure	Analysis	Description	Key Outcomes
Monitoring Program Deployment Design	x			x	The use of EM technology for fisheries monitoring requires support services to ensure technology is deployed correctly, operator responsibilities are met, and on-board data sets collected and evaluated against dockside information in a timely manner. This task outlines key elements of an operational EM program, tailored to the Alaska fixed gear fishery.	Discussion document outlining the key elements of the monitoring program and relative cost contribution. The report will present different strategies for equipment deployment and examine the impact of the number of service ports.
Strawman Monitoring Options	x			x	There are a series of 'strawman' monitoring options that can be used to address the different alternatives. A 'strawman' is a methods summary of the key elements of each monitoring option and describes how EM technology integrates with other tools to meet management needs. Key elements include vessel size criteria, data requirements for catch estimation, vessel operator responsibilities, EM system operating specifications, EM data collection specifications, analysis requirements, and integration with other tools. The strawman links the data requirements with the specific way EM technology and other tools are being used.	Discussion document to provide a summary of monitoring approach and decision points for an EM configuration that meets the Council's goal for estimating catch; analysis of each approach in terms of overall suitability, the level of difficulty, decision points, strengths and weaknesses and operational feasibility by fishery/fleet.
Dockside Monitoring Program Design	x			x	Some of the monitoring options require dockside monitoring to obtain an independent estimate of landed catch by species. This task summarizes the information requirements, monitoring procedures, and other program elements for a dockside monitoring program.	Discussion document of key elements and decision points of a dockside monitoring program, information needs, monitoring procedures and cost elements.
Self-Reported data elements	x				Discussion of what self-reported (fishery dependent) data elements need to be collected to support EM catch, the timelines and accuracy of these data.	Outline of self-reported data fields & how those compare to current IPHC and NMFS logbook data elements; the timelines and accuracy needs of these data for EM.
Data review protocol	x	x			Identify which data elements should be extracted from the imagery obtained under the various field studies, and the review processes that should be followed.	Continue to refine the video data review protocol procedure document
Seabird Handling	x			x	1) the handling procedures that will be required for seabird interactions when operating EM, and 2) if any permits will be required of EM vessels	Recommendations for handling procedures for 2015 fieldwork
Research and Development projects						
Standard configuration fieldwork *(study design in Appx C, D)*		x			The research is intended to provide field-tested methods that allow collection of quantifiable image-based data from fisheries that can be used to estimate species-specific catch and at-sea discard amounts. Specifically, we will evaluate the applicability of EM technologies in a standard configuration at the rail to collect catch, effort, and species composition data.	A research document that will describe results of testing: differences in count and species composition data between EM (single and stereo cameras) in a standard configuration at the rail and an at-sea biologist; ability to derive length from stereo camera.

Project	Deployment	R&D	Infrastructure	Analysis	Description	Key Outcomes
Chute camera fieldwork		x	x		Image quality from EM systems are often influenced by environmental conditions and system maintenance reducing our ability to distinguish species, an essential part of estimation. A camera chute system provides a way to collected high definition images constantly thus has the potential to derive lengths and improve reliability of species identification.	Appendix C provides a research document that describes hypothesis testing to be completed: differences in count, length, and species composition data between a stereo camera in a chute and an at-sea biologist; ability to derive length; potential for automation of species identification.
Stereo camera fieldwork		x			A stereo camera system provides a way to accurately derive lengths from which weight could be inferred. This is a requirement since catch estimation is designed to produce discard estimates of weight by species.	Appendix D provides a research document that describes hypothesis testing to be completed: differences in count, length, and species composition data between a stereo camera in a chute and an at-sea biologist; ability to derive length; potential for automation of species identification.
Halibut discard mortality rate (DMR) fieldwork		x			Fieldwork to investigate the relationship between release methods and discard mortality rates. IPHC interested in pursuing this for fixed gear as well as trawl vessels.	Research study that will allow IPHC to assign discard mortality rates based on a release method, rather than based on injury codes.
Incorporate e-logbook into EM system		x	x		Application development and testing of e logbook that could be used to collect self-reported data elements for EM and capture sensor data. Sensor data has great potential for automated identification of set and haul positions in setline fisheries.	Identify QC procedures and automation methods for improving data accuracy and fishermen friendly attributes that could into e-logbooks (e.g. could sensor data automate entry of set and haul positions in elogbook).
Infrastructure projects						
Programmer			x		NMFS will hire an application developer to support EM data integration that includes development of GUI interface to enable post-processing video and image data into the observer database that feeds into catch accounting. The infrastructure support and work is a necessary component regardless of the type of EM system it will support.	The meta-data derived from sensor information and e-logbook/self-reported data will provide the link to sample data information both temporally and spatially.
Evaluations that will be used in the analysis						
Alternatives				x	Refine the 'purpose and need' and alternatives document to be analyzed for a Council amendment package, and how the elements of the strawmen mesh with the amendment analysis.	Discussion draft of 'purpose and need' and alternatives
Fishery Demographics				x	Summarize the fishery demographics - number of vessels, gear used, landing ports, target fishery. Also, summary of effort (trips, length, hauls per day, length of sets), vessel configurations (side/stern haul, shelter deck or open).	Summary paper that describes demographics of the fixed gear fleet in terms of effort, retained and discarded catch by catch area and/or port.
Catch Composition				x	Summarize the catch composition and disposition in each fixed gear target fishery (halibut, sablefish, Pacific cod), and which species are discarded; also which species need inseason data.	Tables describing the catch composition in appendix B

Project	Deployment	R&D	Infrastructure	Analysis	Description	Key Outcomes
Catch Estimation *(Initial discussion in Appx B)*				x	List potential catch estimation procedures for EM data for a presumed strata (alternative).	Discussion paper that describes the tradeoffs and assumptions of various catch estimation procedures for expanding catch to the fishery level.
Weight *(Initial discussion in Appx B)*				x	There are a number of potential methods to derive weight for piece counts. Each of these methods will have an accompanying list of assumptions and data collections that will be evaluated.	Summary paper that describes potential ways to derive weight estimates for piece counts.
Video Review Tradeoffs				x	Analysis of how much video review is needed	Summary paper describing the tradeoffs of reviewing video for all fish, or only discards; subsampling; etc.
Cost Framework				x	How will costs be analyzed with respect to EM decision points, what is the framework that will be used in the analysis? What are major cost centers in the program, and how does that affect design or decisionmaking?	Discussion paper framing the range of costs that might be associated with different decisions in the suite of alternatives, and how fieldwork or other methods will be employed to inform those costs.

Overview of parallel EM projects

There are several other EM research projects underway in Alaska, which are not strictly part of this cooperative research plan, but whose results may influence the Council's eventual EM implementation discussion. A summary of these projects is provided below.

NFWF project – Transitioning EM from Pilot to Integrated Component of Management

Organization:	Alaska Longline Fishermen's Association
Award Amount:	$ 135,000.00
Matching Contribution:	$ 38,000.00
Grant Period:	6/30/2014 - 6/30/2016

The goal of this project is to construct a structured, transparent process with extensive stakeholder collaboration to transition electronic monitoring (EM) from pilot program to an operational and integrated component of the North Pacific Research Plan/Groundfish Observer Program (NPRP) for Alaska's fixed gear fisheries. As originally proposed, the project had four objectives. The first was to support and coordinate stakeholder participation in the Council's EM workgroup meetings. The need for "all hands at the table" has been documented as critical to the success of developing EM programs in numerous forums including, the National EM workgroup meeting in January 2014, and most recently in a paper published on development of the Canadian EM program[1]. The second objective was to develop local capacities needed to support EM integration. This objective was intended to build EM support capacity through the training of local port coordinators to install and service EM systems. Requested budget reductions by NFWF forced a significant reduction in this objective. The third objective was to develop a process for timely data review and feedback to the fleet. Quality control methods and timely feedback to the vessels have been identified as critical lessons learned from past pilot programs. The ability to achieve this objective is directly tied to developing local EM field support capacities. Both of objectives 2 and 3 are now largely dependent on outside cooperative research funds to support. The final objective was to

[1] Stanley, R.D., Karim, T., Koolman, J., and McElderry, H. Design and implementation of electronic monitoring in the British Columbia groundfish hook and line fishery: a retrospective view of the ingredients of success—ICES Journal of Marine Science, doi: 10.1093/icesjms/fsu212.

actively communicate EM pre-implementation results to stakeholders and fishery managers. This is ongoing and part of the stakeholder coordination and outreach activities.

NFWF project – GPS data loggers as a low cost alternative to Vessel Monitoring Systems

Organization:	Alaska Longline Fishermen's Association
Award amount:	$ 110,000.00
Matching Contribution:	$ 181,500.00
Grant Period:	5/01/2013 - 4/30/2015

This two stage field-trial is intended to evaluate and document the use of GPS data loggers and sensors as a low cost alternative to VMS in Alaska's catch share halibut and sablefish fisheries. The first stage of the project tested GPS data loggers on three halibut and sablefish vessels in Southeast Alaska for an average of 18 sea days/vessel. The data loggers deployed represented various technologies including archival GPS data loggers, multiple sensor input data loggers, and cellular transmitting GPS data loggers. Cost and reliability were documented as well as the ability to detect fishing events based on various polling rates, speed filters, and hydraulic sensors. Stage 2 testing focused on reliability over longer deployments. Five vessels were equipped with GPS data loggers for deployments ranging between one and five months. Data from Stage 2 is being evaluated and a final report will be prepared documenting lessons learned in early 2015. In addition to evaluating data loggers as a potential VMS replacement, the work done on detecting fishing events based on polling rates, speed filters, and hydraulic sensors may be informative to related work on e-logs and "EM lite".

NFWF project – Testing EM on Small Fixed-Gear Cod Boats

Organization:	North Pacific Fisheries Association, working with Saltwater Inc.
Award amount:	$ 127,400.00
Matching Contributions:	$ 120,000.00
Grant Period:	10/01/2013 – 12/31/14, extended through 3/31/2015 with NMFS funding

The project goal is to assess whether EM could capture data on pot cod boats that would allow for an accurate record of effort, and counts and identification of catch and bycatch in a cost effective way. Saltwater is working closely with active pot cod fishers to adapt an EM system to their vessels and fishing operations. Industry volunteers have helped to define camera placement, appropriate sensor options, power supply considerations, use of RFID reader, and are commenting throughout the project on the EM system and the experience of having it onboard. Through December 31, 2014 Saltwater installed EM systems on 6 pot cod boats of different sizes (49' to 82') in three ports – Kodiak, Homer, and Adak. Work is continuing with three vessels in the first quarter of 2015.

Saltwater developed data review protocols and conducted data review to evaluate system performance (completeness and quality of image) as well as catch information (fishing effort data, species composition). To date Saltwater Inc. has reviewed EM data from 4 vessels representing 18 trips, 85 sea days, and 4,155 hauls. Initial findings support industry's view that the Pacific cod pot fishery is an ideal fishery to monitor using EM. Over 97% of the fish catch items were able to be enumerated and identified to the species level.

Saltwater Inc. and NPFA are looking for money to continue the pot cod research with the industry volunteers from July 2015 – July 2016, focusing on a) capturing weights and b) making the data collection and review process more efficient through the use of RFID. They have submitted a NFWF pre-proposal to collect weights by: a) creating a visual reference on the sorting table that would facilitate

estimates of lengths from video imagery, and b) using piece counts and average weights to estimate total bycatch weight.

NMFS project – Pre-Implementation of EM/ER in the North Pacific

Organization:	NMFS
Award amount:	$ 375,505.00
Funding Period:	11/01/2015 – 12/31/16

This project proposes to develop automatic detection, sizing, and classification of fish targets from stereo-video imagery of fish passing on a conveyor belt or sliding on a chute. The project involves controlling image acquisition, developing and applying computer algorithms for image processing, and providing user interfaces and suitable data outputs for operation of software by fisheries biologists. Tasks can be accomplished by applying and modifying classification algorithms developed in computer vision industry, with improvements and adjustments for the specific challenges of fish imagery. This project also proposes to integrate EM data collection into the Observer database (NORPAC) that could eventually be used in catch estimation.

NMFS project – Image Data Collection

Organization:	NMFS
Award amount:	$ 78,113.00
Funding Period:	3/01/2015 – 2/28/16

This project will provide HD images and size data to support applications development needs for the currently funded FIS project "Automated Image Processing for Fisheries Applications". The image data set will be compared to at-sea sampler information to test the accuracy of EM sizing and automated species identification. We plan to collect a wider range of images during the 2015 Gulf of Alaska Bottom Trawl Survey conducted by the AFSC's RACE Division. The trawl survey vessel allows for interception of many species that would be difficult to collect from the fishery due to the wide coverage area of the survey and difficulty of collecting multiple images of less frequently occurring species in the fishery. GUI application development for human processing images and video will proceed late in 2014 based on standard images collected from volunteer vessels and a single chartered vessel. High definition images from this project will support automation of species identification beginning July, 2015 as images are recovered from the first leg of the trawl survey.

Appendix A: PLACEHOLDER

Appendix B: Estimation Requirements

Catch Estimation

Catch estimation refers to the process NMFS uses to estimate the catch of all organisms caught in the process of fishing. This includes halibut and sablefish managed under the IFQ Program, all other species managed under the fishery management plans, and all other organisms caught in the process of fishing. The taxonomic levels to which species are managed and identified vary, although primary importance is put on fish species, seabirds, and marine mammals that are federally managed (Table B-1). Retained catch of halibut, sablefish, and all other federally managed fish and invertebrates will continue to be accounted for under regulations governing the reporting of those species on landing reports (Table B-2). Currently, discarded organisms, including sea birds incidentally caught, are estimated from at-sea observer data using a step-wise expansion in the NMFS Catch Accounting System (CAS) (Table B-2) (see Cahalan et al, 2014 for more details). Mammal interactions are reported to NMML staff and are estimated independent of the CAS.

In order to accomplish catch estimation, NMFS needs information about:

- species identification, count, and length of all FMP-managed species discarded from any location on the vessel or from the gear, including drop-offs from the gear.
    - weight of discarded fish will need to be derived from video images and might be able to be done with length-weight keys if fish lengths can be derived and validated from video images. This methodology is currently being examined.
    - Catch estimates will need to be derived from video within the season to enable inseason management
- at-sea discards of all non-FMP species in number and weight.
    - Catch estimates could be generated at the end of the year, since these species are not managed inseason;
    - Catch estimates could be derived from EM or from observer data that is expanded to the EM strata.
- fishing effort: set and retrieval dates, times, and location for all sets that occur on the fishing trip, and the number of hooks on each set
- number, species identifications, and tag recoveries of sea-birds caught or killed by fishing gear.
- number, species identifications, and types of interactions with marine mammals.
- number, species identification, length, photographs, tissue samples, and disposition (dead, released alive, etc) of marine mammals caught in the gear.

Supporting documentation on catch reporting needs for stock assessment for the GOA hook-and-line fishery are also addressed in a February 2014 Alaska Fisheries Science Center memo, available at http://www.npfmc.org/wp-content/PDFdocuments/conservation_issues/Observer/EM/AFSCmemo214.pdf.

EM Technical Requirements

NMFS intends to ultimately store and use EM data in catch estimation as an input into the catch accounting system to the extent this is feasible. In order to make sure the processes can be developed to accomplish this goal, NMFS would expect to play the primary role in data extraction and interpretation. To meet that requirement, NMFS will develop regulations that specify the EM technical requirements. Three regulatory approaches have been used to implement the electronic reporting and EM programs so far in Alaska: 1) prescriptive requirements; 2) type approval requirements; and 3) performance standards. In some cases, for example where EM is used for compliance monitoring on catcher/processors, a combination of these regulatory approaches has been implemented to support the program. The details of

the regulatory approach and the specific EM technical requirements to support catch estimation will be developed and refined throughout the CR project. Some initial considerations are:

- Video data/images in high resolution;
  - Digital formats enable storage and retrieval solutions enabling future efficiencies in EM processing and interpretation.
  - Species identifications have been hampered by poor resolution video while improved resolution cameras and data storage are available at competitive costs.
  - Video data collection must be highly reliable and of quality under all environmental conditions and lighting.
- Applications written in a standard, open source, format;
  Open source formats allows NMFS to utilize the video images using a range of commercially available viewers, without having to purchase licenses from vendors who collected the data. NMFS policy encourages the use of open source code (see: http://www.nmfs.noaa.gov/op/pds/documents/30/30-133.pdf).
- All data must be verifiable with great reliability.
  - hardware will need to meet specifications or performance standards
  - maintenance procedures and vessel responsibilities will need to be developed and incorporated into regulations.
  - Sensor data from hydraulic or drum sensors will verify location and timing of set and haul events.
  - Self-reported e-logbook information may provide information to cross-check EM data for completeness and verification

Table B-1 List of species, both targeted and incidental catch, in the GOA halibut, sablefish, and Pacific cod fisheries (source: 2013 observer data). Species are listed by management category where: FMP = federally-managed groundfish species under a Fishery Management Plan; IFQ = species managed under an Individual Fishing Quota; PSC = Prohibited Species as identified in the FMP, which are required to be discarded in the groundfish fisheries; non-FMP = species that are caught incidentally and not federally managed; state managed = species that are managed by the state of Alaska.

Species	Management category	Management Resolution (in GOA)	GOA group name	Management timing needs for discard data	Notes on species ID
Arrowtooth Flounder	FMP	Species		Inseason	
Atka Mackerel	FMP	Species		Inseason	
Big Skate	FMP	Species		Inseason - timing critical	Need species ID to distinguish from "skates" group
Dusky Rockfish	FMP	Species		Inseason	
Flathead Sole	FMP	Species		Inseason	
Longnose Skate	FMP	Species		Inseason - timing critical	Need species ID to distinguish from "skates" group
Northern Rockfish	FMP	Species		Inseason	
Pacific Cod	FMP	Species		Inseason - timing critical	
Pacific Ocean Perch	FMP	Species		Inseason	
Pollock	FMP	Species		Inseason	
Rex Sole	FMP	Species		Inseason	
Rougheye/ Blackspotted Rockfish	FMP	Species		Inseason - timing critical	Species ID critical
Shortraker Rockfish	FMP	Species		Inseason	Species ID critical
Arrowtooth/ Kamchatka Flounder	FMP	n/a		Inseason	Currently, in instances where the species is not identified by observer, we use other observer data to determine species ratios. Method for EM?
Shortraker/Rougheye Rockfish	FMP	n/a		Inseason	Currently, in instances where the species is not identified by observer, we use other observer data to determine species ratios.
Deepsea Sole	FMP	Group	Deepwater Flatfish	Inseason	
Dover Sole	FMP	Group	Deepwater Flatfish	Inseason	
Greenland Turbot	FMP	Group	Deepwater Flatfish	Inseason	
Kamchatka Flounder	FMP	Group	Deepwater Flatfish	Inseason	
Canary Rockfish	FMP	Group	Demersal Shelf Rockfish	Inseason - timing critical	Species ID critical
China Rockfish	FMP	Group	Demersal Shelf Rockfish	Inseason - timing critical	Species ID critical
Copper Rockfish	FMP	Group	Demersal Shelf Rockfish	Inseason - timing critical	Species ID critical
Rosethorn Rockfish	FMP	Group	Demersal Shelf Rockfish	Inseason - timing critical	Species ID critical
Tiger Rockfish	FMP	Group	Demersal Shelf Rockfish	Inseason - timing critical	Species ID critical
Yelloweye Rockfish	FMP	Group	Demersal Shelf Rockfish	Inseason - timing critical	Species ID critical
Octopus	FMP	Group	Octopus	Inseason	
Harlequin Rockfish	FMP	Group	Other Rockfish	Inseason	Species ID needed to distinguish from DSR
Quillback Rockfish	FMP	Group	Other Rockfish	Inseason	Species ID needed to distinguish from DSR
Red Banded Rockfish	FMP	Group	Other Rockfish	Inseason	Species ID needed to distinguish from DSR
Redstripe Rockfish	FMP	Group	Other Rockfish	Inseason	Species ID needed to distinguish from DSR
Rockfish Unidentified	FMP	Group	Other Rockfish	Inseason	Species ID needed to distinguish from DSR
Silvergray Rockfish	FMP	Group	Other Rockfish	Inseason	Species ID needed to distinguish from DSR
Bigmouth Sculpin	FMP	Group	Sculpins	Inseason	

Species	Management category	Management Resolution (in GOA)	GOA group name	Management timing needs for discard data	Notes on species ID
Darkfin Sculpin	FMP	Group	Sculpins	Inseason	
Great Sculpin	FMP	Group	Sculpins	Inseason	
Irish Lord Unidentified	FMP	Group	Sculpins	Inseason	
Myoxocephalus Sculpin Unidentified	FMP	Group	Sculpins	Inseason	
Plain Sculpin	FMP	Group	Sculpins	Inseason	
Red Irish Lord	FMP	Group	Sculpins	Inseason	
Sculpin Unidentified	FMP	Group	Sculpins	Inseason	
Spinyhead Sculpin	FMP	Group	Sculpins	Inseason	
Warty Sculpin	FMP	Group	Sculpins	Inseason	
Yellow Irish Lord	FMP	Group	Sculpins	Inseason	
Rock Sole	FMP	Group	Shallow water Flatfish	Inseason	
Southern Rock Sole	FMP	Group	Shallow water Flatfish	Inseason	
Starry Flounder	FMP	Group	Shallow water Flatfish	Inseason	
Alaska Plaice	FMP	Group	Shallow water Flatfish	Inseason	
Butter Sole	FMP	Group	Shallow water Flatfish	Inseason	
Flatfish Unidentified	FMP	Group	Shallow water Flatfish	Inseason	
Northern Rock Sole	FMP	Group	Shallow water Flatfish	Inseason	
Yellowfin Sole	FMP	Group	Shallow water Flatfish	Inseason	
Pacific Sleeper Shark	FMP	Group	Sharks	Inseason	Species ID important for stock assessment
Spiny Dogfish Shark	FMP	Group	Sharks	Inseason	Species ID important for stock assessment
Alaska Skate	FMP	Group	Skates	Inseason	
Aleutian Skate	FMP	Group	Skates	Inseason	
Bering Skate	FMP	Group	Skates	Inseason	
Commander Skate	FMP	Group	Skates	Inseason	
Mud Skate	FMP	Group	Skates	Inseason	
Roughtail Skate	FMP	Group	Skates	Inseason	
Skate Unidentified	FMP	Group	Skates	Inseason	
Soft Snout Skate	FMP	Group	Skates	Inseason	
Stiff Snout Skate	FMP	Group	Skates	Inseason	
Whiteblotched Skate	FMP	Group	Skates	Inseason	
Whitebrow Skate	FMP	Group	Skates	Inseason	
Squid Unidentified	FMP	Group	Squids	Inseason	
Longspine Thornyhead Rockfish	FMP	Group	Thornyhead rockfish	Inseason - timing critical	Species ID critical
Shortspine Thornyhead	FMP	Group	Thornyhead rockfish	Inseason - timing critical	Species ID critical
Thornyhead Rockfish Unidentified	FMP	Group	Thornyhead rockfish	Inseason - timing critical	Species ID critical
Sablefish (Blackcod)	FMP, IFQ	Species		Inseason	
Pacific Halibut	IFQ	Species		Inseason - and PSC of halibut critical in pcod fishery before IFQ season opens	
Bairdi Tanner Crab	PSC	Group	Bairdi Tanner Crab	Inseason	
Blue King Crab	PSC	Species		Inseason	
Brown King Crab	PSC	Species		Inseason	
Chum Salmon	PSC	Species		Inseason	
Coho Salmon	PSC	Species		Inseason	
King Crab Unidentified	PSC	Species		Inseason	Currently, if the species is not identified by observer, we use other observer data to determine species ratios.
Opilio Tanner Crab	PSC	Species		Inseason	
Red King Crab	PSC	Species		Inseason	

Species	Management category	Management Resolution (in GOA)	GOA group name	Management timing needs for discard data	Notes on species ID
Tanner Crab Unidentified	PSC	Group	Bairdi Tanner Crab	Inseason	
Tanneri Tanner	PSC	Group	Bairdi Tanner Crab	Inseason	
Giant Grenadier	FMP - Ecosystem	Group	Grenadiers	End of year	
Grenadier Unidentified	FMP - Ecosystem	Group	Grenadiers	End of year	
Ascidian - Sea Squirt - Tunicate Unident	non-FMP			End of year	
Barnacles Unidentified	non-FMP			End of year	
Basket Starfish	non-FMP			End of year	
Bering Wolffish	non-FMP			End of year	
Brittle Starfish Unidentified	non-FMP			End of year	
Corals-Bryozoans Unidentified	non-FMP			End of year	
Couesi King Crab	non-FMP			End of year	
Crab Unidentified	non-FMP			End of year	
Crinoids Unidentified	non-FMP			End of year	
Eelpout Unidentified	non-FMP			End of year	
Fish Unidentified	non-FMP			End of year	
Greenling Unidentified	non-FMP			End of year	
Hermit Crab Unidentified	non-FMP			End of year	
Invertebrate Unidentified	non-FMP			End of year	
Jellyfish Unidentified	non-FMP			End of year	
Korean Horsehair Crab	non-FMP			End of year	
Lumpsucker Unidentified	non-FMP			End of year	
Lyre Crab Unidentified	non-FMP			End of year	
Miscellaneous Unidentified	non-FMP			End of year	
Mussels Oysters Scallops Clams	non-FMP			End of year	
Pacific Flatnose	non-FMP			End of year	
Poacher Unidentified	non-FMP			End of year	
Polychaete Unidentified	non-FMP			End of year	
Prowfish	non-FMP			End of year	
Ronquil Unidentified	non-FMP			End of year	
Sea Anemone Unidentified	non-FMP			End of year	
Sea Cucumber Unidentified	non-FMP			End of year	
Sea Onions Unidentified	non-FMP			End of year	
Sea Pen-Sea Whip Unidentified	non-FMP			End of year	
Sea Potato Unidentified	non-FMP			End of year	
Sea Urchins-Sand Dollars Unidentified	non-FMP			End of year	
Skate Egg Case Unidentified	non-FMP			End of year	
Snail Eggs Unidentified	non-FMP			End of year	
Snail Unidentified	non-FMP			End of year	
Snailfish Unidentified	non-FMP			End of year	

Species	Management category	Management Resolution (in GOA)	GOA group name	Management timing needs for discard data	Notes on species ID
Sponge Unidentified	non-FMP			End of year	
Spotted Ratfish	non-FMP			End of year	
Starfish Unidentified	non-FMP			End of year	
Sunstar Starfish	non-FMP			End of year	
Wrymouth Unidentified	non-FMP			End of year	
Bird Unidentified	Protected Species			End of year	
Black-Footed Albatross	Protected Species			End of year	
Glaucus Gull	Protected Species			End of year	
Glaucus-Winged Gull	Protected Species			End of year	
Gull Unidentified	Protected Species			End of year	
Laysan Albatross	Protected Species			Inseason - timing critical	If use EM for bird estimation, need to identify albatross (as group) and collect all albatross
Northern Fulmar	Protected Species			End of year	
Sea Birds Unidentified	Protected Species			End of year	
Shearwater Unidentified	Protected Species			End of year	
Short-Tailed Shearwater	Protected Species			End of year	
Black Rockfish	State-Managed				
Dark Rockfish	State-Managed				
Lingcod	State-Managed				

Table B-2 Data sources currently used to estimate retained and discard catch, and those that could potentially be used when EM data are available.

	Current method		Potential method when EM is available	
	Retained Catch	**Discards**	**Retained Catch**	**Discards**
FMP - groundfish	Landing report	At-sea discard rate from observer data in small vessel strata is applied to landing report	Landing report	At-sea discard in numbers of fish derived from EM, converted to weight
FMP- IFQ				
State Managed				
FMP - Prohibited Species (PSC)	n/a – all discarded		n/a – all discarded	
non-FMP				At-sea discard rate in numbers derived from EM applied to landing report *Or* At-sea discard rate from observer data in small vessel strata is applied to landing report
Protected Species (Birds)				

Appendix C: EM Pot Study

Conceptual Research Approach

The purpose of this research is to support Council EM objectives by exploring alternative monitoring methodologies that have the potential to be more cost effective and/or to increase accuracy of the estimates, ultimately providing a viable alternative data-collection methodology. Information collected from this study will be used to inform the final NEPA analysis and development of potential alternatives for deploying EM/ER into the fishery to estimate catch. The goal of this study is to field test and evaluate the efficacy of three electronic monitoring (EM) systems to collect catch data in pot gear fisheries. This study will evaluate the efficacy of a single camera, stereo camera and a camera chute system. The research is intended to provide field-tested methods that allow collection of quantifiable image-based data from fisheries that can be used to estimate species-specific catch and at-sea discard amounts.

We will evaluate the applicability of EM technology to collect catch, effort, and species composition data aboard vessels through use of video and sensor technologies. Catch weights will be based on length approximations from the video record to estimate individual fish weight. At-sea observers will collect pot specific catch information throughout each trip to allow comparison of species composition and species count generated from each EM system to that collected by an at-sea biologist. The hypothesis to be tested is: "There is no significant difference in estimates generated using EM data from estimates generated using at-sea observer data."

Data gathered during this study will also be used to inform infrastructure improvements, evaluate data integration, and develop video processing applications. The main infrastructure and image processing objective is to develop applications that will provide preprocessing of video data in real time to gain efficiencies in post-processing and reduce costs. This will minimize data storage requirements; shorten the time delay between data collection and when information is available for management. The study will also provide information to evaluate EM sampling rates and procedures necessary to achieve a specified level of precision while minimizing costs (e.g. deployment rates and/or the amount of video data to be reviewed). Further, the study will provide valuable information on the compatibility of EM systems with vessels, logistic and operational constraints or opportunities associated with deploying various camera systems on pot gear vessels. Finally, this study will inform development of regulations, performance standards, and vessel operator responsibilities.

Project Implementation

This project is a cooperative effort between NMFS, the fishing industry[2], Pacific States Marine Fisheries Commission (PSMFC), and the North Pacific Fishery Management Council (Council). Study design, goals, and objectives were developed by NMFS and PSMFC staff and will be vetted through the Council's EM work group (EMWG), Science and Statistical Committee (SSC), and the Council at upcoming meetings during 2014 And 2015.

Project responsibilities are shared by NMFS Observer Program staff, PSMFC Staff, EM providers, and vessel operators. Both NMFS and PSMFC staff will work cooperatively to develop the study design and conduct data analyses. PSMFC contracted an EM provider (Archipelago Marine Research) for installation of EM systems and contracted the single vessel (Northern Endurance) that applied through a competitive bid process. The EM provider is responsible for working with the vessels operator to install, troubleshoot and maintain the EM system(s). At-sea biologists will receive training to troubleshoot and maintain both the chute and stereo camera EM systems. The vessel contracted for the work will be

[2] Comprised predominantly but not exclusively of the small hook and line fleet with vessels <58 feet in length

obligated to follow catch handling instructions, help maintain the camera systems and complete e-logbook information on effort, catch, and discard as specified in the charter contract.

Research Goals and Objectives

The main goal of this research is to provide field-tested methods to provide quantifiable image-based data from fisheries that can be used to support discard estimation in the small vessel pot fleet operating in the North Pacific. Testing of multiple EM designs will provide necessary data to evaluate the effectiveness, reliability, and logistical feasibility of each system under commercial fishing conditions using pot gear. This project will inform decisions on future investments in technology and identify appropriate technology that will best meet NMFS and Council management objectives.
There are three primary objectives of this study:

1) Collect pot-specific catch data of fish species using an EM system and an at-sea biologist.
    a. Compare accuracy of species identification and species counts obtained using the EM system with species identification as determined by an at-sea biologist.
2) Estimate catch and bycatch amounts based on data from each of the three data collection methods:
    a. Estimate bycatch and bycatch amounts from video data collected using non-stereo, commercially available, EM system. Because there is no mechanism to collect length or weight with the standard camera system, weight will be "borrowed" from observer data.
    b. Estimate bycatch and bycatch amounts from video data collected using a stereo camera focused on retained catch and a second camera contained within a discard chute. Here weight will be inferred from species specific length information collected by the chute camera and stereo camera.
    c. Estimate bycatch and bycatch amounts from data collected by an at-sea biologist.
3) Evaluate precision of estimates and estimated sample sizes required to achieve a specified precision for each species of interest for each data collection system.

Study Methods

EM system will be deployed onto vessels along with an at-sea biologist (observer) simultaneously to collect side-by-side data for each sampled set. Throughout the study, individual hauls will be identified to ensure that haul-specific data from each data collection system are available. In addition to catch data (species composition and amounts), effort data (set locations and times, amount of gear set) will be collected and used in the estimation Process and other analyses.

Approximately 8 trips targeting Pacific cod with pot gear will include a standard EM system that consists of a non-stereo data collection camera located above the sorting table, wide angle or hemispheric validation (deck view) camera, , camera chute GPS and hydraulic sensors, and an at-sea biologist. We will then phase in additional sensors (RFID) and the stereo and chute camera systems on later trips.

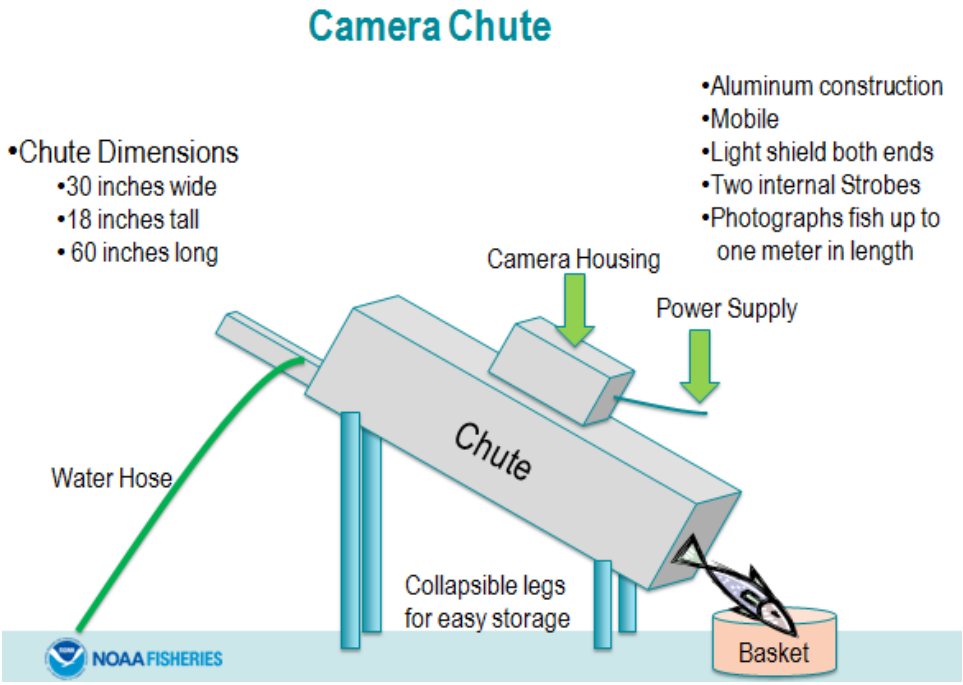
Description of EM systems:

There are three major components of all of the EM system that are required to enable collection of scientific data that can be used for catch estimation using an EM system. They are highly interdependent and are major determinants of the success or failure of this system. The components are 1) e-logbook, 2) validation camera(s) system, and 3) scientific data collection camera(s) 4) sensors. The e-logbook data will be required to capture self-reported information on set locations, total effort (e.g. gear set), catch, and catch disposition. These data will be compared with sensor data (validating logbook reports) and Integrated with the video data (and/or images) to provide location of effort for each specified catch event captured by the cameras. In addition, all three EM systems will time stamp images and events to allow the separate data streams to be matched. The validation camera(s) will determine if specific vessel operators' responsibilities are being followed and to allow monitoring of deck activities to confirm the catch

handling protocols are being followed. Validation camera video data will be reviewed to determine if the camera(s) can fully document vessel catch handling and discard events during an entire trip.

The scientific data collection camera systems (non-stereo, stereo and chute) will provide images that will be processed to collect information on species composition, count and length. Scientific data collection cameras will be mounted above the catch sorting table. The chute-camera system will be located within a water-proof camera housing located above a chute (**Error! Reference source not found.**). Because camera strobes will be used in this system, the chute will be enclosed that allows passage of the fish while minimizing light leakage. This system will test whether clear, high definition images can be taken reliably in any weather condition, allowing consistent species recognition, automated length measurements, and facilitating on-board processing of image data. The unit is mobile and can be moved between hauls or stored; the system weighs approximately 50 lbs and its location and integration into vessel operations will be determined between NMFS personnel and the vessel operator to maintain safety and operability. This system will require a power connection and potentially a water hose connection to improve specimen flow through the chute and is fully automated to collect images as fish are passed through the chute.

Figure 1 Illustration of camera and chute design that enables imaging as fish are passed through



Both the stereo and chute camera systems borrow many of the features developed for CamTrawl (Williams et al., 2010a; Williams et al., 2010b) that was deployed during AFSC acoustic pollock surveys in 2011 and 2012. A stereo camera is actually two cameras in one housing that create two images that are processed using automated software routines that isolate fish targets, estimate fish length using stereo-correspondence, and track individuals across frames to provide accurate fish counts. Automated species classification algorithms are currently being developed to complete the analysis process. An image library will be created to store all images and meta-data that could be used in future projects to develop a set of key characteristics including color/shape patterns that could potentially be used to automate species or species group identification. Because all images will be time stamped and linked to GPS information, precise location of species specific catch could enable other analysis such as mapping of high bycatch rate areas, potentially improving future management strategies to lower bycatch.

Each EM system may also include a number of additional components including: 1) a dedicated GPS receiver to collect positional information; 2) a magnetic rotation sensor to trigger recording when the drum is setting or hauling gear; 3) an electronic hydraulic pressure transducer; 4) RFID tags attached to individual pots to record onboard presence of gear, 5) a laptop for system operations and e-logbook data entry. Sensors will provide information on vessel position, confirm when fishing activity is taking place, and trigger video data recording. A computer will run the system from inside the vessel cabin allowing monitoring of system activity and enabling troubleshooting if problems occur. The catcher vessel e-logbook program developed by the NMFS AKR will be installed on the computer or notebook for logging haul-specific catch information on a daily basis. Computer monitors will be provided as a means to monitor all camera functions and evaluate whether lens cleaning is required.

Sampling Design

An at-sea biologist will collect pot-specific catch data for each species for those sets that are randomly chosen to be sampled. For each selected set, data will be collected for a systematic random sample of retrieved pots; these pots will be identified explicitly either in the imagery or using a time-stamp match so that pot-specific data from each data collection method can be used in the analysis. This will allow for comparison of observer and EM catch data collection for each pot on each set (complete enumeration of catch within each sampled pot) and disposition of that catch. Vessels participating in the study will be required to modify their catch handling practices such that all discarded catch will be passed through the chute to allow imaging.

A single set of species and species-group codes and species identification materials will be used by both the EM reviewer and at-sea biologists. We will compare estimates of numbers of fish based on at-sea biologist documentation with similar estimates from the review of electronic monitoring (EM) video recordings.

Since every fish within a pot is documented by an at-sea biologist, the total number of fish of a given species in the pot will be without sampling error (subject to measurement errors only). The camera system is designed to collect images of every fish, but experience has shown that this is typically not the case since image quality is a function of environmental conditions and camera maintenance.
It will be crucial to identify the disposition for each catch item as either being discarded or retained. The validation camera(s) will be used to help determine catch disposition (retained, discarded). Disposition of the discarded portion of the catch will be easily identified because only at-sea discards will be passed through the chute system. Data for the retained portion of catch will be collected from either the non-stereo or stereo camera located above the sorting table as the catch is being transferred to the hold. The GPS position and time code will be used to link the haul camera image and chute camera images to the retained/discarded data recorded by the observer.

At-sea biologist(s) will make sure project protocols for data collection are followed and equipment is operating as designed. The at-sea biologist responsibilities will include: 1) assisting crew to manage and maintain the EM system, 2) recording complete species composition (including identifying and recording all invertebrates and vertebrates), 3) ensuring all discarded catch be passed through the camera chute for imaging unless the catch item is too large for the chute it will be individually sampled for species and length by the at-sea biologist, 4) assisting vessel operator in entering specific catch information into an e-logbook between hauls or at the end of each fishing day, 5) transmitting e-logbook information in each port (may be automated) and 6) ensuring EM cameras are triggered to record the hauling events.

At-sea biologist catch data will be aligned with the video record (using time code and coordinates) so that direct comparisons can be made for each sample of catch within each pot. Discrepancies in the identification and the enumeration of the catch by the at-sea biologists and the video analyst will be investigated to determine the reason for and type of discrepancy. At-sea biologists will record the date

and haul time for each set/pot, the set/pot number, and the skate number for all sets. The EM will record precise location and time stamp for each frame either in the first row of pixels or key identifier within the name of the image to allow precise identification of a specific catch event.

Data Analysis

Our study design closely follows that of an earlier electronic monitoring study aboard volunteer vessels from the IFQ fixed gear fleet (Cahalan et al., 2010) noting however that there will be three camera systems being tested: non-stereo camera; and stereo camera and the camera chute. Analytical methods employed in that study provided an effective evaluation of the information and similar methods will be used in this study. Modification of catch estimation methods described in that paper will be used here. A series of three analytical comparisons and associated hypothesis tests will be conducted. These comparisons are designed to fully assess the differences in the catch monitoring data collected using EM and at-sea biologist.

Comparison 1: Comparison of the number of fish per pot set of a given species collected using each EM system (standard camera; stereo rail camera; chute-camera) and collected by an at-sea biologist. This is a comparison of data collected using EM with data collected by an at-sea biologist aimed at assessing the variability between the three data collection methods in the number and species of fish caught by the gear.

> *Hypothesis 1: The difference in the number of fish (of a given species) counted in a single pot between the data collection methods is zero.*

In this analysis, there will be one observation for each comparison and each species (difference in numbers between the each of the three camera systems and the at-sea biologist) for each set. A simple t-test will be used to test the hypothesis of no difference; additional analyses may evaluate the potential effects of camera system, EM reviewer, vessel, environmental conditions, and image quality.

Comparison 2: Comparison of observations of pot-specific species identification made remotely by a video reviewer (based on data collected from camera system) with those made by a biologist stationed on the vessel. This comparison of data collected using each EM system (non-stereo, stereo and camera chute) to that collected by an at-sea biologist will assess the variability in species identification between data collection methods.

> *Hypothesis 2: The probability of pot-specific species identification agreement between EM video reviewers and at-sea biologist is equal to or greater than some predefined constant (e.g., 0.95).*

The proportion of matching species identification for a given pot haul will be estimated as follows. Let:

$X_{i,v}$ = an indicator of matching species identification for fish i in pot v, $X_{i,v}=\{0,1\}$, $i=1, \ldots, n_v$
n_v = number of pots set by haul v
v = index on the haul, $v=1, \ldots. V$.

The estimated proportion of pots with matching observations (for a given species) is given in Eqn. (1) with the empirical variance presented in Eqn. (2)

$$\hat{p}_v = \frac{\sum_{i=1}^{n_v} X_{i,v}}{n_v} \quad (1)$$

$$Var(\hat{p}_v) = \frac{\sum_{i=1}^{n_v} (X_{i,v} - \hat{p}_v)^2}{n_v - 1} \quad (2)$$

Given adequate sample size and using $\hat{p}_v$ as replicate observations, these data will be used to model the potential impacts of covariates including camera system used, EM reviewer, vessel, environmental conditions, and image quality.

Comparison 3: Comparison of the pot-specific species identification from a subsample of all video made by two video reviewers. This is a comparison of data collected by two different EM reviewers aimed at assessing the between reviewer variability in species identification.

> *Hypothesis 3: The probability of pot-specific species identification agreement between two EM video reviewers is equal to or greater than some predefined constant (e.g., 0.95).*

This analysis will be similar to that used in Comparison 2.

Data processing

Data collected by the at-sea biologist will be entered and stored in an AFSC database developed for this study. Hard-drives containing the video data will be sent to PSMFC. Video data will be post-processed and also entered into this database by PSMFC video analysis staff. eLogbook data will be transmitted to the eLandings database and will be accessible to NMFS staff as part of the Interagency Electronic Reporting System. Application development has started and will continue for imagine processing of non-stereo and stereo camera video data. Data analysis will be conducted in R (R Core Team, 2013. URL http://www.R-project.org/).

Appendix D: EM Setline Study

Conceptual Approach

The purpose of this research is to support Council EM objectives by exploring alternative monitoring methodologies that have the potential to be more cost effective and/or to increase accuracy of the estimates, ultimately providing a viable alternative data-collection methodology. Information collected from this study will be used to inform the final NEPA analysis and development of potential alternatives for deploying EM/ER into the fishery to estimate catch. The goal of this study is to field test and evaluate the efficacy of electronic monitoring (EM) systems to estimate discard in the small vessel North Pacific IFQ fleet. This study will evaluate a new EM design using a stereo rail and a standard camera system on IPHC survey vessels. It will also test these camera systems and in addition a camera chute system on the single contracted Halibut IFQ vessel. This research is intended to provide field-tested methods that allow collection of quantifiable image-based data from fisheries that can be used to estimate discard.

We will evaluate the applicability of EM technology to collect catch, effort, and species composition data aboard vessels through use of video technologies. Discard estimation will be based on using length approximations from the video record to infer fish weight. At-sea observers will collect hook-by-hook catch information throughout each trip to allow comparison of species composition and discard estimates generated from each EM system to data collected by an observer. The hypothesis to be tested is: "There is no significant difference in discard estimates generated using EM data from estimates generated using at-sea observer data."

Data gathered during this study will also be used to improve infrastructure, evaluate data integration, and develop video processing applications. The main infrastructure and image processing objective is to develop applications that will provide preprocessing of video data in real time to improve efficiencies in post-processing thereby reducing costs. This will minimize data storage requirements; shorten the time delay between data collection and when information is available for management. The study will provide information to evaluate EM sampling rates (e.g. the amount of video data to be reviewed) through simulations and procedures necessary to achieve a specified level of precision while minimizing costs. The study will also provide valuable information on the compatibility of EM systems with vessels and the logistic and operational constraints or opportunities associated with deploying various camera systems on vessels. Finally, this study will inform development of regulations, performance standards, and vessel operator responsibilities.

Project Implementation

The project is a cooperative effort between NMFS, IPHC, the fishing industry, Pacific States Marine Fisheries Commission (PSMFC), and the North Pacific Fishery Management Council (Council). Study design, goals, and objectives were developed by PSMFC and NMFS staff and vetted through the Council's EM workgroup committee, Observer Advisory Committee (OAC), Science and Statistical Committee (SSC), and the Council at the February 2014 meeting.

Project responsibilities will be shared by NMFS Observer Program staff, IPHC staff, PSMFC Staff, EM providers, and vessel operators. Both NMFS, IPHC and PSMFC staff will work cooperatively to develop the study design and conduct data analyses. PSMFC will contract EM providers for installation of the EM systems. This study design applies to both the fishing industry and IPHC survey vessels participating in this project defined below.

Industry vessel

PSMFC issued a Request for Proposals (RFP) in July, 2014 to contract vessels to carry EM/ER systems and at-sea biologists. A single respondent (Northern Endurance) was contracted to conduct this work. PSMFC have also contracted an EM provider (Archipelago Marine Research) who will be responsible for working with the vessel operator to install, troubleshoot and maintain the standard EM system. At-sea biologists will receive training to troubleshoot and maintain the stereo camera EM systems. The contracted vessel will be obligated to follow catch handling instructions, maintain the camera systems and fill out e-logbook information on effort, catch, and discard. This work will be carried out during the IFQ halibut fishery beginning early March, 2015 and will include approximately 8 trips until IFQ quota has been taken.

IPHC Grid Survey vessel(s)

Each year, the International Pacific Halibut Commission (IPHC) receive requests from various staff and external organizations to assist in research projects by collecting additional data on the IPHC grid survey vessels. Although the grid surveys are for halibut stock assessment purposes, there can be opportunities to collect additional data. NMFS submitted a special request project form to IPHC in November, 2014 for review; decision on the scope of the project is dependent upon finalizing survey vessel contracts and whether vessels have the capacity to carry a third at-sea sampler to collect hook specific catch information. It is expected that camera installation(s) will occur on approximately 2-3 survey vessels.

Overall Project Goals:

The main goal of this research is to provide field-tested methods to provide quantifiable image-based data from fisheries with stereo camera based sampling systems. This stereo camera system will enable collection of length compositions for both discarded and retained catch at the rail. Testing of this design will allow evaluation of effectiveness and reliability under commercial fishing conditions. The stereo camera has been shown to be effective for collecting precise length compositions in a trawl survey application (Williams, et al. 2011). The automated camera chute system has also been shown to collect precise length information during a field test on a factory trawler in 2014 (Wallace, personal communication).

The Camera chute system and supporting software developments is intended to improve collection of EM images in three ways. First, it will economize video post-processing, since only single capture events will be imaged, allowing analysts to focus on a collection of high-resolution images of an individual fish for identification instead of reviewing an entire retrieval for catch events. Second, images collected by this system will improve our ability to accurately identify catch since images will be of high consistent quality providing precise detail of fish characteristics. This is in contrast to images captured by exposed camera systems where image quality is dependent on environment conditions and system maintenance by operators. We are attempting to address these issues on the stereo camera systems by incorporating wiper blades and washing spray. The wiper systems are readily available and in use in security camera applications. Thirdly, collection of consistent high quality images support development of automated species identification applications based on a set of key characteristics, color/shape patterns and other salient features that could be used to automate species or species group identification.

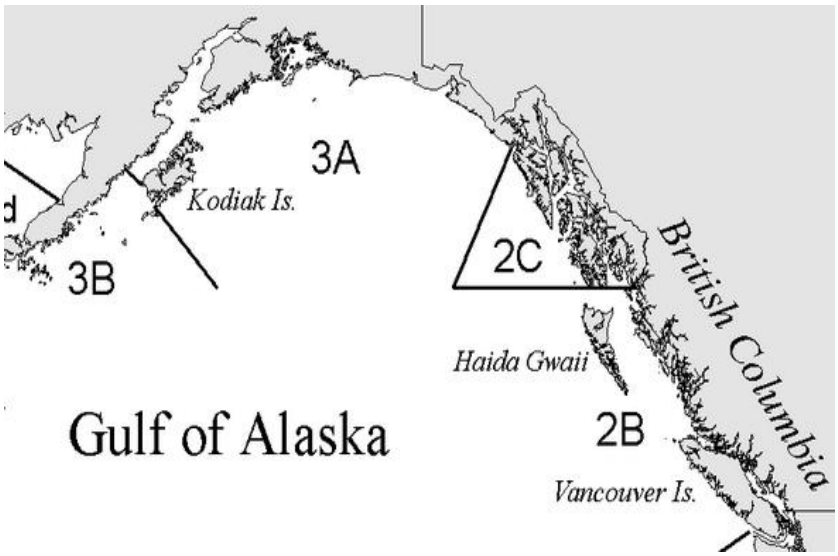
Scope of project

It is anticipated that this study will implemented on 2-3 IPHC survey vessels operating in areas 2A 2B, 2C, 3A or 3B (Figure 1). The number of survey vessels is dependent on space for a third observer or already have a third observer for collecting hook-by-hook tallies. The survey will be conducted between May 1st and August 31st. The fishing vessel Northern Endurance will be fishing during the halibut IFQ

fishery beginning early March 2015, based out of Kodiak and will end when IFQ Quota has been taken (approximately 8 trips). This project will be completed in 2015 and unlikely to continue in future years.

A third sampler will be required in addition to the two standard IPHC samplers to completely enumerate the catch (each fish on the line; retained and discarded). A single at-sea sampler will be responsible for collecting the same information aboard the Northern Endurance.

Figure 1 General study area for EM project



EM system requirements

The EM system must be continuously powered while the vessel is at sea and requires 120v ac power with maximum power consumption 230 watts. An EM provider is responsible to work with the vessel operators to install the standard system and NMFS staff will be present during installation of stereo camera and/or camera chute. All costs associated with installation and removal of system will be covered by NMFS as will be the sampler.

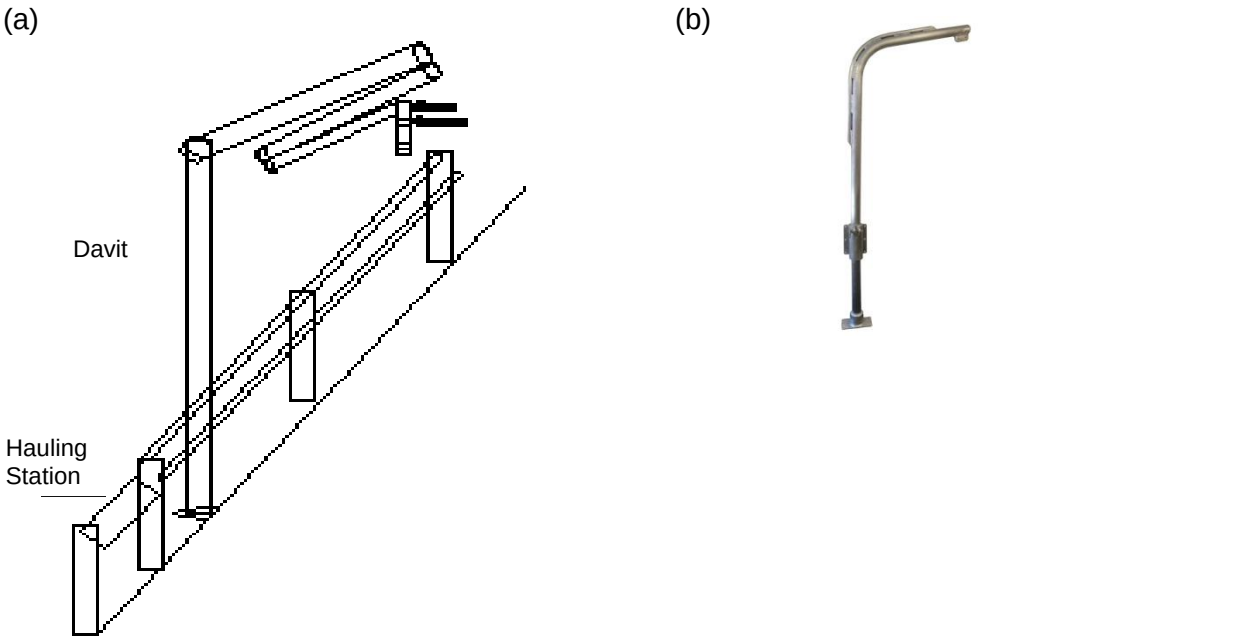
Description of EM system

The EM system will include a number of components including; 1) a dedicated GPS receiver to collect positional information 2) a magnetic rotation sensor will be installed to trigger recording when the drum is setting or hauling gear and 3) an electronic hydraulic pressure transducer 4) a standard and stereo rail camera and 5) a computer system for operations. Sensors will provide information on vessel position, confirm when fishing activity is taking place and trigger recording. A laptop will run the system from inside the vessel cabin, can be used to monitor system activity and enable troubleshooting if problems occur. The catcher vessel e-logbook program developed by the NMFS AKR will be installed on the computer system with which at-sea samplers will log haul-specific catch information on a daily bases and transmit when they reach port. Monitors will also provide the vessel crew and samplers a way to monitor camera function and evaluate whether system maintenance is required.

This stereo rail camera system will require installation of a camera deployment system which is a modified davit that consistently places the camera in a location to allow consistent recording and lighting of the retained and discarded catch (Figure 2). The davit system is designed to be easily deployed once hauling of catch is underway and easily retracted once the haul ends. A technician and NMFS staff will work with the vessel operator to locate an area at the deck rail adjacent to the hauling station for design

and placement of the camera deployment system as to not interfere in fishing handling or deck operations. The stereo camera system will be located in a water-proof camera housing located at the end of the davit. This system is necessary to ensure that clear high definition images can be taken consistently and reliably allowing consistent species recognition and facilitating on-board processing of image data. This system will require a power and Ethernet connection and that will be run through the davit system eliminating external wiring. This camera is dedicated to imaging all catch as it clears the water surface collecting information on drop-offs and discards at the rail.

Figure 2 (a) Line drawing of the modified davit which the stereo camera is mounted; (b) commercial davit



This stereo camera system borrows many of the same features developed for CamTrawl (Williams et al., 2010) that has been deployed during AFSC acoustic pollock surveys in 2011 and 2012. Images are processed using automated software routines that isolate fish targets, estimate fish length using stereo-correspondence, and track individuals across frames to provide accurate fish counts. Automated species classification algorithms are currently being developed to complete the analysis process. Because all images will be time stamped and linked to GPS information, precise location of species specific catch will enable mapping of high bycatch rate areas, potentially improving future management strategies to lower bycatch. An image library is being created to store all images and meta-data that could be used in future projects to develop a set of key characteristics including color/shape patterns that could potentially be used to automate species or species group identification.
This project will compliment several field projects planned in 2015 including the Councils Cooperative Research Project with the Industry, which deploys EM camera based systems on hook and line vessels fishing out of the ports of Sitka, Petersburg, Homer, and Kodiak. This project will also compliment the 2014-2015 NPRB funded projects to further development and testing of stereo camera based systems in cooperation with the Petersburg Vessel Owners Association member vessels. Lessons learn from this proposed project will be crucial in developing the next generation of stereo cameras systems and applications for fixed gear vessels.

An additional deck camera system will be installed to validate protocols are being followed on board the fishing vessel, validate sampling and determine if the system is working properly. This information will

be used to improve next generation camera system to facilitate future deployments. The deck video will be used to demonstrate the system to the Industry and gain acceptance among the commercial fleet.

Sampling Methods and Analyses:

Figure 3 Typical placement of deck camera

A third sampler (or single sampler on board the fishing vessel) will be required to collect hook-specific catch data for each species for the entire set throughout selected charter vessels where there is space. An additional sampler will allow for catch data collection for each hook on each longline set (complete enumeration of catch) and disposition of that catch. In an effort to standardize data collected from the two sampling methods (standard IPHC hook-status method and video method) we will employ a single set of species and species-group codes (presumably IPHC codes) and will distribute species identification materials used by the IPHC to both the EM reviewer and at-sea samplers. We will compare estimates of numbers of fish based on at-sea sampler (combined sea sampler and additional hook-specific sampler) documentation with similar estimates from the review of electronic monitoring (EM) video recordings.

Since every fish on the longline is assumed to be documented by the sampler, the total number of fish of a given species on the gear will be assumed to be enumerated without sampling error (subject to measurement errors only). The stereo haul camera is also designed to collect images of every fish, but experience has shown that this is typically not the case since image quality is a function of environmental conditions and camera maintenance. A sampler and/or vessel crew will be required to clean camera lens as needed a task that is much simpler since the stereo camera can be easily retracted. The collection of high quality images is a necessary requirement that is fundamental to developing to automate post processing of video, consistent identification of species and development of applications to automate species identification.

Discrepancies between the number of fish on the hook tally form and those imaged by the rail camera will be investigated using the deck camera imagery. The GPS position and time code will be used to link the haul camera image and rail camera images to the hook-status from using station number.

At-sea sampler(s) will make sure project protocols for data collection are followed and equipment is operating as designed. Responsibilities will included; 1) managing and maintaining the EM system, 2) recording complete hook-status, catch disposition and species composition, to include identifying and recording all invertebrates and vertebrates caught, 3) enter haul specific catch information into e-logbook between hauls or at the end of each fishing day, 4) transmit e-logbook information in each port of call and 5) ensure EM cameras are triggered to record the hauling events.

At-sea samplers will sequentially record the catch for each hook in the set and the status of that catch. Each hook-status record will be aligned with the video record so that direct comparisons could be made for each hook in the sample. In cases where hooks are misaligned due to missed hooks (by either the sampler or the video reviewers or snarls) realignment will be based on matching individuals of obvious species. Discrepancies in the identification and the enumeration of the catch by the at-sea samplers and the video analyst will be investigated to determine the reason for and type of discrepancy. At-sea samplers will record the date and haul time for each set, the set number, and the skate number for all sets. The EM system will record precise location and time and stamp each frame in the first row of pixels to allow precise identification of a specific catch event.

Our study design closely follows that of an earlier electronic monitoring study aboard volunteer vessels from the IFQ fixed gear fleet (Cahalan et al., 2010). Analytical methods employed in that study provided an effective evaluation of the information and these methods will be used in this study. Catch estimation methods will follow methods described in that paper.

Comparison 1: Comparison of observations of hook-specific species identification made remotely by a video reviewer with those made by a sampler stationed on the vessel. This is a comparison of data collected using EM to that collected by an at-sea sampler aimed at assessing the variability in species identification between the two data collection methods.

> *Hypothesis 1: The probability of hook-specific species identification agreement between EM video reviewers and at-sea samplers is equal to or greater than some predefined constant (e.g., 0.95).*

The proportion of hooks with matching species identification for a given haul will be estimated as follows.

Let:

$X_{i,v}$ = an indicator of matching species identification for hook i on haul v, $X_{i,v}=\{0,1\}$, $i=1, \ldots, n_v$
n_v = number of hooks set by haul v (all trips and longline sets)
v = index on the haul, $v=1, \ldots. V$.

The estimated proportion of hooks with matching observations (for a given species) is given in Eqn. (1) with the empirical variance presented in Eqn. (2)

$$\hat{p}_v = \frac{\sum_{i=1}^{n_v} X_{i,v}}{n_v} \quad (1)$$

$$Var(\hat{p}_v) = \frac{\sum_{i=1}^{n_v} (X_{i,v} - \hat{p}_v)^2}{n_v - 1} \quad (2)$$

We expect data for 200-300 hauls during the survey, hence using $\hat{p}_v$ as replicate observations, these data will be used to model the potential impacts of covariates such as EM reviewer, environmental conditions, and image quality.

Comparison 2: Comparison of the number of fish per longline set (for a given species) derived from data collected using EM and data collected by an at-sea sampler. This is a comparison of data collected using EM with data collected by an at-sea sampler aimed at assessing the variability between the two data collection methods in the number of fish caught by the gear.

> *Hypothesis 2: The difference in the number of fish (of a given species) counted in a segment of gear between the data collection methods is zero.*

In this analysis there will be one estimate (difference in numbers between the two methods) for each species on each set. A simple t-test will be used to test the hypothesis of no difference; additional analyses may evaluate the potential effects of EM reviewer, environmental conditions, and image quality.

Comparison 3: Comparison of the hook-specific species identification made by two video reviewers. This is a comparison of data collected by two different EM reviewers aimed at assessing the between reviewer variability in species identification.

> *Hypothesis 3: The probability of hook-specific species identification agreement between two EM video reviewers is equal to or greater than some predefined constant (e.g., 0.95).*

This analysis will be similar to that used in Comparison 1.

This suite of comparisons and associated hypothesis tests was designed to fully assess the differences in the catch monitoring data collected using EM and at-sea samplers.

Estimated time required to complete field portion of project

- Daily - As part of fishing
  - Other
- Per Trip* (i.e. downloading data)
- Pre/Post Charter (prep, dismantle, etc.)

Activity	Time
Hook Status per skate	2 hrs per haul
Monitor/manage data storage	15 mins daily
Haul data entered into e-logbook	30 mins daily
Install and remove EM system	2 days each

** Trip length for western AK regions are generally 7-14 days, whereas other regions are typically 5-8 day trips.*

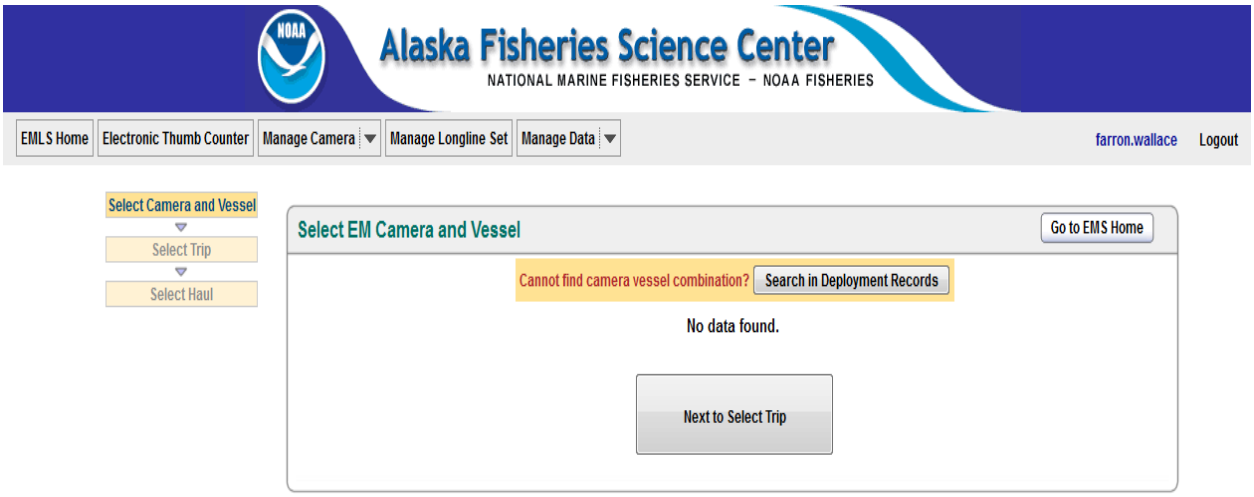
E-logbook

A separate e-logbook will be maintained by the third at-sea sampler. Information will include set specific information on catch, time and location. The standard IPHC hook tally form will be used to summarize specific haul information. NMFS is developing an application where transmittal of this information will be automated as the vessel returns to a port. At-sea samplers will fill in e-logbook on a daily basis. These data will be made available to IPHC and will be used to improve application in future projects and potentially fisheries.

Data storage

Data will be stored in the AFSC NORPAC database in a separate schema developed for this study. Application development has already been started and will continue into the future. GUI interface for post-processing video data are in development. Data analysis will be conducted in R (R Core Team (2013). URL http://www.R-project.org/).

Figure 4 Data entry page to enter image data into the NORPAC (observer) database



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