Developing NPFMC Alternatives to Operationalize EM in North Pacific Fixed Gear Fisheries: A Cooperative Research Project to Field Test Electronic Monitoring Technology

Cooperative Research Tracks 2 and 3

Background

The North Pacific Groundfish and Halibut Observer Program (Observer Program) has had a vital role in the management of North Pacific groundfish fisheries since the program started over 20 years ago. The information collected by observers provides scientific information for managing the groundfish fisheries. However, prior to 2013, the quality and utility of the information was deficient because some boats were not being observed and the structure for deploying observers was flawed. Therefore, beginning in January 2013, important changes were made to how observers are deployed, how observer coverage is funded, and which vessels and processors must have some or all of their operations observed. All sectors of the groundfish fishery, including vessels less than 60 feet length overall (LOA) and the commercial halibut sector, are included in the new Observer Program. As a result, the National Marine Fisheries Service (NMFS) is now deploying observers across more fisheries and onto smaller vessels not previously observed, where logistically it may be difficult to place an observer. Other alternatives to observers are being sought that have the potential to collect fisheries dependent information by means of electronic monitoring (EM) and electronic reporting (ER).

To guide integration of EM and ER into North Pacific fisheries NMFS presented a strategic plan (Loefflad et al., 2014) to the North Pacific Fisheries Management Council (Council) in June, 2013, and the Council adopted the plan as a guidance document for incorporating EM/ER into the Observer Program. The Council recommended use of a catch estimation approach to develop EM tools for the halibut and sablefish fisheries (Appendix A). Monies have been acquired through NMFS and its partners including the North Pacific Research Board and Pacific States Marine Fisheries Commission (PSMFC) to advance on a number of action items to meet goals and objectives listed in the Strategic plan (Appendix B). NMFS is using the Strategic Plan to guide development of advanced camera systems and field testing of these systems.

At the February, 2014 Council meeting the Council expressed approval for cooperative research in 2014 and for convening an EM workshop between NMFS and the fixed gear industry. The workshop has held in February 2014, and NMFS and Industry participants reached agreement on a cooperative research plan and identified roles and responsibilities of the various parties involved in the effort. Workshop participants identified four complementary approaches or tracks including: 1) standard camera systems on 5-10 vessels without observers, 2) AMR/Saltwater camera systems on 2-3 vessels with both EM and at-sea biologists, 3) stereo rail camera and chute systems on 5-10 vessels with at-sea biologists, and 4) e-logbooks. This document describes the study design for tracks 2 and 3 and is intended to provide scientific information to test the efficacy of various EM systems to provide scientific data to estimate discard.

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. The goal of this study is to field test and evaluate the efficacy of four electronic monitoring (EM) systems to estimate discard in

the small vessel North Pacific IFQ fleet. Track 2 part of this study will evaluate the efficacy of the two currently available EM systems one designed by Archipelago Marine Research (AMR) and one designed by Saltwater Inc. Tract 3 part of this study will also evaluate a new EM designs that incorporates a stereo rail and a camera chute system. 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 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 (e.g. the amount of video data to be reviewed) and procedures necessary to achieve a specified level of precision while minimizing costs. Further, 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

This project is a cooperative effort between NMFS, the fishing industry[1], 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 subcommittee, 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, 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 will contract EM providers for installation of their EM systems. PSMFC will issue a Request for Proposals (RFP) to contract a total of approximately 2-3 vessels with standard EM systems and an at-sea biologists (track 2 of the cooperative research project) and approximately 10 vessels to allow installations of the stereo EM systems and an at-sea biologist (track 3). Each EM provider will be responsible for working with the vessels operator to install, troubleshoot and maintain

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

the EM system. At-sea biologists will receive training to troubleshoot and maintain the standard and stereo cameras EM systems. Vessels contracted for the work will be obligated to follow catch handling instructions, maintain the camera systems and fill out e-logbook information on effort, catch, and discard.

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 fixed gear IFQ 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. This project will inform decisions on future investments in technology and which technology or combination of tools will best meet NMFS and Council management objectives.

There are three primary objectives of this study:

1) Collect hook-specific catch data of fish species on the fishing gear using EM and at-sea biologist.
    a. Compare efficacy (accuracy?) of species identification using camera-based monitoring with that of at-sea biologist.
2) Estimate catch and bycatch using data from each of the three data collection methods with that of at-sea biologist
    a. Estimate bycatch and bycatch rates from video data collected using standard, commercially available, EM system.
    b. Estimate bycatch and bycatch rates from video data collected using stereo camera mounted at the rail.
    c. Estimate bycatch and bycatch rates from video data collected using the camera chute.
3) Evaluate precision of estimates and estimated sample sizes required to achieve a specified precision for each species of interest.

Methods

Description of EM system:

There are three major components required to enable collection of scientific data that can be used for catch estimation using EM systems. 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) system. The e-logbook data will be required to capture self-reported information on set locations, total effort (e.g gear set).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 specific catch event captured by the cameras.

The specific cameras will differ between EM systems (AMR, Saltwater, and stereo) however each system will include a validation camera system and the scientific data collection camera system. These two

components will be linked and serve two different purposes. The validation camera(s) will determine if specific vessel operators' responsibilities are being followed and to confirm disposition of the catch. The validation camera system consists of at least one hemispherical wide angle camera that will be mounted in a location to allow monitoring deck activities and confirm that catch handling protocols are being followed (Figure 1).

Figure 1 Typical installation position for validation camera.

The scientific data collection camera system will provide images to collect data on species identification and estimates of catch and bycatch. Scientific data collection cameras will either be a railed mounted system or contained in a chute system. Rail cameras (Figure 2) will be installed next to the hauling station to ensure a clear view of all captured fish and fish that drop-off the line prior to coming on deck. Two types of rail-mounted scientific cameras will be tested: a single (standard EM) camera; and a stereo railed mounted camera.

Figure 2. Typical rail mounting position for a scientific data collection camera.

The chute-camera system will be located within a water-proof camera housing located above a chute (Figure 3) and include stereo cameras. Because camera strobes will be used in this system, the chute will be enclosed with a plastic curtain 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 integrating into vessel operations will be discussed 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.

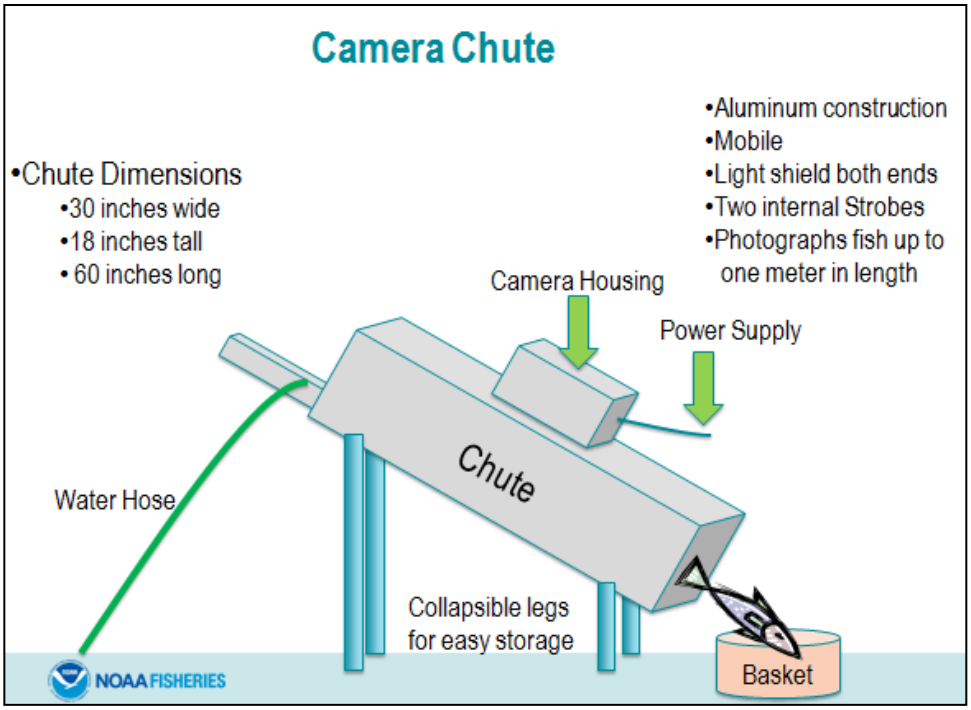

Figure 3 Illustration of camera and chute design that enables imaging as fished are passed through.

Both the rail-mounted and chute stereo 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 will 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; and, 4) 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 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 hook-specific catch data for each species for all hauls and entire sets if possible or a number of randomly chosen sets throughout a portion of the charter trip. This will allow for comparison of observer and EM catch data collection for each hook on each longline set (complete enumeration of catch) and disposition of that catch. Vessels equipped with stereo EM systems will also require some modification to catch handling practices such that all catch that can be practically brought on board from each set will be passed through the chute to allow imaging. In an effort to standardize data collected from the two sampling methods (camera and at-sea biologist) we will employ a single set of species and species-group codes and will distribute species identification materials used by the observer program to 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 (rail and chute cameras).

Since every fish on the longline is assumed to be documented by an at-sea biologist, 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 rail 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.

It will be crucial to identify catch that is being imaged by the chute camera as being either discarded or retained. The validation camera(s) will be used to determine catch disposition (retained, discarded). The GPS position and time code will be used to link the haul camera image and chute camera images to the hook-status 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 hook-status and species composition (including identifying and recording all invertebrates and vertebrates), 3) ensuring all catch that can be practically be brought on board and passed through the camera chute for imaging, 4) identifying fish that drop-off the hook prior to being brought on-board 5) assisting vessel operator in entering haul-specific catch information into an e-logbook between hauls or at the end of each fishing day, 6) transmitting e-logbook information in each port (may be automated) and 7) ensuring EM cameras are triggered to record the hauling events. It will be the intent to sample the entire catch which to be passed through the chute system. The exception to this will be accidental drop offs or catch too large to be safely brought on board.

At-sea biologists 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 can be made for each hook in the sample. In cases where hooks are misaligned due to missed hooks (by either the biologist or the video reviewers) realignment will be based on matching individuals of obvious species.

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, the set number, and the skate number for all sets. The EM 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.

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 four camera systems being tested: standard camera mounted at the rail; stereo camera at the rail; and stereo camera in the chute; validation camera. There will not be side by side comparison of the stereo rail cameras since they will be independently deployed. Analytical methods employed in that study provided an effective evaluation of the information and similar methods will be used in this study. Catch estimation methods will follow methods described in that paper. Validation camera video will be simply reviewed and data summarized to define 1) percent of sets where the entire haul back was recorded and 2) effective video coverage of the deck space and fishing operations during fishing (i.e. are there any blind spots where deck behavior could not be monitored).

A series of four 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 observations of hook-specific species identification made remotely by a video reviewer (based on data either a rail-mounted Stereo camera system or a non-stereo rail mounted camera system) and the camera chute system with those made by a biologist stationed on the vessel. This is a comparison of data collected using each EM to that collected by an at-sea biologist aimed at assessing the variability in species identification between data collection methods.

> *Hypothesis 1: The probability of hook-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 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).

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

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

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 2: Comparison of the number of fish per longline set (for a given species) derived from data (based on data either a rail-mounted Stereo camera system or a non-stereo rail mounted camera system) and the camera chute system with those made by a biologist stationed on the vessel. . 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 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 each of the three camera systems (standard rail, stereo rail and camera chute) and the at-sea biologist) 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 camera system, EM reviewer, vessel, environmental conditions, and image quality.

Comparison 3: Compare the number of fish and species ID obtained from 1) the stereo rail (plus drop offs) and chute 2) the standard rail (plus drop offs) and chute.

> *Hypothesis 3: The difference between the number of fish by species between the stereo camera on the rail and the camera in the chute is zero.*

This analysis will be similar to Comparison 2, except the comparison will be between the two independent camera systems instead of comparing to the at-sea biologist.

Comparison 4: Comparison of the hook-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 4: 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.

Data processing

Data collected by the at-sea biologist will be entered and stored in the AFSC NORPAC database in a separate schema 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 NORPAC by PSMFC video analyses staff. eLogbook data will be transmitted to the eLandings database and accessible to NMFS as part of the Interagency Electronic Reporting System. Application development has already been started and will continue for imagine processing of chute and stereo rail camera video data. Data analysis will be conducted in R (R Core Team (2013). URL http://www.R-project.org/).

Citations

Cahalan, J.A., B.M. Leaman, G.H.Williams, B.H. Mason, and W.A. Karp. 2010. Bycatch characterization in the Pacific halibut fishery: A field test of electronic monitoring technology. U.S. Dep. Commer., NOAA Technical Memorandum NMFS-AFSC-213, 66 p.

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Williams. K., C.N. Rooper., and R. Towler. 2010. Use of stereo camera systems for assessment of rockfish abundance in untrawlable areas and for recording pollock behavior during midwater trawls. Fish. Bull. 108:352–362 (2010).

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Appendix A

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 identified vary, although primary importance is put on fish species, seabirds, and marine mammals that are federally managed. 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. Most discarded organisms, including sea birds incidentally caught, are estimated from at sea data (observers) using a step-wise expansion in the NMFS Catch Accounting System (CAS). 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 fish discarded from any location on the vessel or from the gear, including drop-offs from the gear.
    - weight of discards 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.
- at-sea discards of all non-target species in number and weight.
- 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.
- 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.
    - Estimation may be improved with effort data from all (observed and unobserved) trips.

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 require:

- 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).
- Information on catch, effort, location and time
  - E-logbooks will provide information on catch and effort that is a necessary element in catch expansion.
- All data must be verifiable with great reliability.
  - NMFS is currently contracted with Saltwater, Inc. and they have been able to provide hardware that meets this specification. This camera system is being developed to provide reliable monitoring that ensures catch handling and maintenance procedures are followed.
  - Sensor data from hydraulic or drum sensors will verify location and timing of set and haul events.
  - E-logbooks will provide information to ground truth effort and species composition information collected by the EM system

Appendix B

Research and Development

In an effort to enable scientific data collection using EM systems to estimate catch, NMFS is conducting research and development in multiple disciplines that include 1) evaluating field-tested methods to provide quantifiable image-based data from fisheries, 2) advancing hardware and camera systems to provide consistent, verifiable, high quality data and 3) developing applications to increase efficiencies, capture fish length and reduce costs. NMFS is advancing on a number of individual projects that together will advance EM to meet Council objectives and demands from the fishing industry for EM while building upon lessons learned and recommendations from several EM projects.

A contract was awarded to Saltwater inc. to deploy cameras beginning in April 2013. This camera system is being developed as a validation system to provide information on catch disposition, and catch handling that is highly reliable. In 2014, an e-logbook will become part of this system to evaluate the overall reliability of the system to accurately determine set and haul positions and for activating cameras during haul back. This system is intended to be integrated with stereo camera's which will provide high quality catch images and automated length composition to infer weight.

Recent funding from NPRB will fund development and field testing of a high-resolution stereo digital camera system that vastly improves the performance and reduced the complexity of image-based sampling because high quality digital images can be directly analyzed with image-processing software. PSMFC provided funding that built a first generation system that is built upon a similar system designed by Williams et al. (2010) who showed that processing of the stereo images allowed fish length measurement, regardless of fish orientation in relation to the camera platform. Our main goal of this research is to provide field-tested methods that provide quantifiable image-based data from fisheries with stereo camera-based sampling systems. All images will be stored and used in future projects to develop a set of key characteristics and color/shape patterns that could potentially be used to automate species or species group identification.

Funding from the NMFS Fisheries Information System (FIS) combined with other NMFS funds will support development and deployment of electronic logbook (e-logbook) software on laptops to capture operator estimates of catch and effort. Funding will also support development of an EM hardware system to capture set and haul positions and transmit data from the vessel to NMFS automatically or through user interface.

Supporting software developments will greatly economize video post-processing, since only 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. Information collected by this system will also improve our ability to accurately identify catch since images will be of HD quality providing precise detail of fish characteristics. After the initial testing aboard the larger factory vessel, the system will then be tested on hook and line catcher vessels fishing out of Petersburg.