RESEARCH and OUTREACH PLAN

A. Project Title

Long Title: Feasibility study for automated image processing techniques to identify and capture serial catch events and obtain length measurements of catch in the commercial small vessel (< 60 LOA) hook and line fishery using stereo cameras

Short Title: Automated image processing

B. Proposal Summary

Electronic monitoring (EM) technologies offer a way to obtain independent fishery data onboard vessels where space is limited and/or safety is a concern for human observers. Since vessels pay for human observers on a cost-per-day basis in the current North Pacific Groundfish Observer Program (NPGOP), it has been proposed that EM technologies such as cameras offer cost-savings to fleet members, although in practice the results of such cost comparisons have been mixed (e.g. Bonney et al. 2009, Cahalan et al. 2010, Dalskov and Kindt-Larson 2009).

This project builds upon lessons learned and recommendations from numerous EM projects. One such example was a multi-year pilot program to test camera based EM technology to collect catch and fishing effort data aboard commercial vessels conducted by the Northeast Fisheries Science center (NEFSC, NOAA, 2010). This study identified a number of deficiencies that would first need to be addressed before EM technology could be considered in lieu of at-sea observers in the Northeast multispecies fishery. Issues included the inability to collect biological information from discard and retained catch (length and weight), poor image quality and difficulty distinguishing like species from the video data. The NEFSC stated that further research would be required to improve the accuracy and reliability of species identification and to reliably monitor weights of discard by species. The NEFSC also identified the need to analyze multiple data sources to improve their ability to validate and identify discrepancies between observer and EM collected data. Given these issues, EM was not incorporated as a monitoring strategy in the 2012 fishing year by the NEFSC.

The development of new EM methods is critical to lower costs, enhance quality and timeliness of fisheries statistics collected by camera-based systems if these tools are to support successful fisheries management. Lower overall costs will provide an opportunity to provide wider coverage rates of the fleet, wider range of vessels and vessel sizes where it is impractical to place an observer. This project incorporates many of the lessons learned from the NEFSC study and from past studies in Alaska and elsewhere. The camera system built in this project greatly improves the camera design used in the NEFSC pilot project and addresses many of the issues they identified with EM systems. The cost of hardware is expected to be comparable to the costs of camera systems deployed in the NEFSC pilot program. The proposed system will improve our ability to not only monitor fisheries with cameras, but collect length composition samples (and weights estimated from length weight relationships). This system will also identify and automatically capture high quality (HD) stereo images of each individual catch events greatly improving our ability to reliably identify catch to species or species group. Because only images of catch events will be stored and therefore reviewed, costs for post processing and storage will be much lower. Substantial reduction in the data product resulting from this system will greatly improve our ability to manage data in-house and allow an increase the number of trips that can be monitored and stored electronically on the vessel before downloading the data. 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, improving future management strategies to lower bycatch. A 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. Another additional benefit to image-based sampling of catch is increased temporal resolution, which can benefit studies of fish behavior and effort. For example, images can allow species composition and catch rates to be evaluated continually during the retrieval of hook and line gear, providing insights into gear efficiency and catch patterns. By capturing image data, a permanent record of the capture event is made, which can be analyzed for different objectives in the future.

This project will compliment the NMFS currently funded 2013 cooperative EM project, which deploys EM camera based systems on hook and line vessels fishing out of the ports of Sitka, Petersburg, Homer, and Kodiak. This work is relevant to NPRB request for collaborative research proposals with industry to promote accurate and cost-effective fishery monitoring strategies to meet management needs in the smaller groundfish and halibut fishing vessels.

Project goals include; 1) develop stereo camera hardware system to capture stereo pairs of catch events, 2) develop software to capture sequential images of catch events from hook-and-line vessel operations and collection of specimen length measurements, 3) evaluate image collection reliability, 4) evaluate precision of length measurements, 5) and evaluate costs associated with this system compared to like observer collected information. This work will provide experience and knowledge to help address potential enforcement challenges and develop regulatory requirements to deploy systems on a large scale. This tool is intended to improve cost effectiveness of electronic data monitoring gained through efficiencies in image processing and allow for collection of length composition data from the catch. The image library be created that will be used in the future projects as reference images to identify key characteristics that can be used to potentially automate species or species group identification.

C. Project Responsiveness to NPRB Research Priorities or Identified Project Need

This project is directly relevant to NPRB request (3.i.2) for collaborative research proposals with industry to promote accurate and cost-effective fishery monitoring strategies to meet management needs in the smaller groundfish and halibut fishery. This system will greatly enhance image processing efficiencies that will lower the costs of post-processing and greatly reduce storage requirements of image data on vessels and servers. It will also allow for collection of length composition of the catch that is not possible using a single camera setup.

D. Project Objectives

1. Develop stereo camera hardware system to capture stereo pairs of catch events
2. Develop software to capture sequential images of catch from hook-and-line vessel operations and enable collection of specimen length measurement
3. Evaluate event collection reliability
4. Evaluate precision of length measurements
5. Evaluate costs associated with this system compared to like observer collected information.

E. Project Design and Conceptual Approach

Our 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. Completion of this project will provide an electronic data collection system that will capture images of single catch events in fisheries where fish are caught serially such as the hook-and-line fishery for halibut, pacific cod and sablefish. This system will enable collection of length compositions for both discarded and retained catch. A robust design will ensure effectiveness and reliability under commercial fishing conditions, enabling it become a standard device for collecting precise length compositions and precise location of catch. 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 unlike images captured using low resolution cameras commonly used in many EM monitored fisheries today. 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.

Since all images will be time stamped and linked to GPS precise location of species-specific catch will enable mapping of high bycatch rate areas potentially improving future management strategies to lower bycatch. Lower overall costs will provide an opportunity to provide wider coverage rates of the fleet, wider range of vessels and vessel sizes where it is impractical to place an observer. An image library will be built to develop a set of key species characteristics including color/shape patterns that could potentially be used to automate species or species group identification in the near future.

Proposed methods to meet the six main project objectives:

1. *Develop stereo camera hardware system to capture stereo pairs of catch events*.

   Stereo cameras have been successfully used to measure fish in controlled aquaculture settings (Ruff et al., 1995; Harvey et al., 2003) and in open water (i.e., van Rooij and Videler, 1996; Shortis et al., 2009). The recent development of high-resolution digital cameras has vastly improved the performance and reduced the complexity of image-based sampling because high quality digital images can be directly analyzed with image-processing software. Williams et al. (2010a) showed that processing of the stereo images allowed fish length, fish orientation in relation to the camera platform, and relative distance of the fish to the trawl netting to be determined. The video system was found useful for surveying fish in Alaska, but it could also be used broadly in other situations where it is difficult to obtain species-composition or size-composition information.

   Hardware used to build a stereo camera system is readily available off-the-shelf technology. The system will consist of several components including a laptop computer that will provide the interface for gathering, storing and processing video data from the two cameras; data from a GPS unit that will provide time stamp for the images and location information. We will use two Prosilica GT industrial grade machine vision cameras (GT1920 and GT2750) that are compact and designed for imaging in extreme temperatures (from -20°C up to 65°C) and fluctuating lighting conditions. The Prosilica GT cameras feature Precise and DC Auto Iris, as well as power over Ethernet (PoE) and the latest CCD sensor technology making them ideal for a wide range of environmental conditions and applications. Machine Vision cameras, widely used in industrial inspection and traffic monitoring, are built for continual use in extreme environments, and are robust to mechanical vibration and shocks. High quality images are acquired by a host computer, removing the need from accessing the cameras. PoE feature simplifies installation, allowing a single Ethernet connection between cameras and the computer. Cameras and Ethernet hub will be housed in waterproof aluminum anodized housings with glass ports to provide protection from the extreme fishing environment. Two camera models will be paired for the analysis; a lower resolution camera (GT1920) will be used for event detection, and the second high-resolution camera (GT2750) triggered when an event (fish retrieval) is detected.

2. Develop software to capture sequential images of catch from hook-and-line vessel operations.

Increased access to custom designed, freely available software tools have made stereo- camera methods easy to implement without direct expertise in the subject. These tools will be used to develop a program to identify catch events, capture images and estimate length composition of catch. OpenCV (Open Source Computer Vision Library) has a vast library of programming functions aimed at real-time computer vision. Much of the original code was initially developed by Intel and has since been greatly expanded upon by numerous individuals and institutions and is now supported by Willow Garage (http://opencv.willowgarage.com/wiki/Welcome) that largely focuses on real-time image processing. The camera calibration parameters will be estimated with the camera calibration toolbox in Matlab, a freely available software analysis toolbox built with Matlab computing language (Mathworks, Inc.; Bouget, 2008).

Software using these tools will serve two purposes; 1) camera control, event detection, and image acquisition, and 2) image analysis for length and species composition. Both efforts will leverage existing software developed for similar machine vision systems operated in survey trawls (Williams et al., 2010b). Image acquisition software will be modified from the trawl version to include robust target detection of catch events with variable backgrounds. Analysis software will be based on an existing suite of graphical user input (GUI) applications for viewing, images, measuring fish lengths automatically and manually, and quickly identifying species. Analysis programs are built using Python computer language, and store all data, including fish measurements, identifications, stereo calibration, etc. in a SQL database. These programs may be modified to better fit the analysis needs of image data collected dockside and onboard commercial hook-and-line fishing vessels. Likewise, calibration procedures used by Williams et al. (2010a) will be used to estimate calibration parameters for the stereo cameras in this project.

3. Evaluate system and event collection reliability

Hardware and software reliability to capture catch events will be tested in three different environmental situations with increasing complexity and difficulty. The first stage of tests will be completed in the lab using fake fish attached to set line gear drawn before the stereo camera system. To understand the underlying mechanisms of identifying catch events we will investigate a number factors potentially affecting catch event detection in the lab. The fake fish will be sized in 10 cm increments from 10 cm to 100 cm in order to evaluate event collection reliability and sensitivity to fish size. We will test for potential bias in event count data by altering lighting conditions, fish color and background color. A minimum sample size of 100 fake fish will be tested using four levels of lighting that will simulate environmental light conditions found in the field, two back ground colors (black and white) and four common fish colors (rockfish red, dark, sandy and mottled). This will result in collecting event count data for 32 combinations of conditions for 10 size classes of fake fish. Generalized linear models with binomial family and logit link will be used to model the relationship among event count data and size of fish, light conditions, fish color and back ground color. This will allow for defining limitations of the stereo camera system and provide development of a general guideline and minimum lighting requirements for installation. We will test the null hypothesis that there is no difference in the number of events detected between conditions of light, color or size.

Second stage testing will be conducted at processing plants in Kodiak where sampled fish of known length and species will be passed down a simple sloping chute one meter from camera system. In the third stage of the study, stereo camera systems will be installed on hook and line on during the fall of 2014. During the final testing stage, systems will again be deployed in the same fleet during the summer 2015. Data will be analyzed during each stage of the study and incremental changes will be made to the image analyses software to improve detection rates prior to deployment in the next stage.

Vessels will also be selected from Petersburg Vessel Owners Association member vessels and owners/operators that have notified NMFS that they want to participate in the 2013 NMFS EM pilot project testing non-stereo camera based systems. To date, 15 hook and line vessels that fish in one or more fisheries that include halibut, sablefish and Pacific cod have volunteered for this program. Given that vessel owners have until March 1st, 2013 to return notice and that NMFS is holding a series of public outreach events in major Alaskan ports prior to the 2013 Observer Restructure program we expect additional vessels will volunteer.

System reliability and detection rates of catch events will have to remain very high for this system to be functional in providing information for fisheries management. Given this, we set a minimum standard of identifying 98% of catch events in the lab, dockside and on vessel trips. Similarly, hardware system must be functional for 100% of all hauls on 95% of trips. Code development and hardware adjustments will continue during each stage of this study to systematically improve both software and hardware robustness to meet these minimum standards. In both the lab experiment and dockside experiments we will test catch event detection against know sized sample of at least 200 fish.

Stereo cameras will be installed on four fishing vessels that already have an existing EM monitoring camera system, allowing for the number of events detected by the stereo camera system to be compared to the number of events collected by the existing continuously monitoring camera. In 2014 and in 2015 these systems will be installed on vessels in May-July. Systems will remain on the vessel for approximately 2-3 months and then switched to other vessels and then removed late fall following the end of the season. This should allow for testing systems on at least 18 unique vessels in the two year time period. Each testing period will be followed by further code development to improve automation and system reliability to detect catch events and measure fish.

4. Evaluate length precision and bias

Length precision of fish derived from stereo images will be tested in both the lab and dockside. In the lab, a minimum of 200 samples of fake fish in each 10 cm size category will be compared against lengths estimated by the stereo camera system. Fish sizes will be estimated from 3-4 successive frames and at camera to target distances of 1, 3 and 5 meters. This will enable us to evaluate potential range and length related bias in the measurements. We will test for a relationship between frames and target distance from camera for length measure bias using linear regression of percent difference in multiple measurements. We will test the null hypothesis that there is no difference in estimated length between conditions of light, color or size and know size.

5. *Evaluate costs associated with this system compared to like observer collected systems.*

Detailed costs will be tracked for all aspects of this project. Information will be used to determine if this type of data collection system will be cost effective compared to like information collected by Observers and compared to EM camera based systems deployed in the 2013 restructured observer program. All costs including hardware, system integration, data recovery, post processing and data storage will be evaluated. Post processing of stereo imagery will be completed by PI's and time spent on this task will be recorded to allow cost comparisons.

This work will provide data to enhance and complement the ongoing research on management of non-target species caught in the halibut fishery. In addition, the data will be shared with NMFS Sustainable

Fisheries, NOAA Office for Enforcement, and the staff of the North Pacific Fishery Management Council to assist in the development of EM monitoring programs for the halibut and other longline fisheries.

F. Education and Outreach

Community and stakeholder involvement is an integral part to the success of this project. In 2012, workshops were held by the NMFS at numerous Alaska communities and at NPFMC meetings informing and seeking involvement of Industry and Communities in the restructured observer program that includes funding for an electronic monitoring pilot project. Funding of this project will continue to support these meetings to inform and promote involvement in collection of fisheries information to support fisheries management including electronic monitoring. This project will provide for active involvement for EM development by communities and stake holders by funding a workshop in both Petersburg and at the June NPFMC in 2014. Project results will also be presented in public forms such as the Alaska Marine Science Symposium meeting and at the NPFMC Council to promote involvement of both stakeholders and communities to aid in development of this tool. Project development phases and results will also be available on the web as well as video footage for broader public coverage.

This project is supported by the fishing industry. The Petersburg Fisheries Association (PVOA) submitted a letter of support for this research and are willing participates in this project. Further, a number of vessel owners have already volunteered for the 2013 restructure EM project may also be participating in this project as needed. If this technology proves effective and reliable under commercial fishing conditions it could become a standard device for collecting precise fishery independent information.

Timeline and Milestones

The first few months of the project will focus on purchasing equipment, building the stereo camera system and the simulated fish and setline gear. Once this is accomplished code development will begin to automate catch events and evaluate event detection reliability in the lab. A workshop will be held in February of the first year of this project in Petersburg and during the June Council meeting. To save on travel funds, immediately following the Anchorage workshop Mr. Wallace will travel to Kodiak and sample fish, captured during the rockfish program dockside, using the camera system in Kodiak. Results from this study test will provide valuable information to improve algorithms for data collection prior to be installed on vessels. During July through October, 2014 the four stereo camera systems will be deployed into the hook-and-line fisheries operating out of Petersburg. Results from this study will provide information to gain improved software development to enhance image analyses for data collection prior to conducting the final field deployment into the fishery in 2015 (April-September). Analyses will conclude December, 2015. Preliminary results will be presented at the 2015 June Council meeting and final study results at the 2016 Alaska Science Symposium during January. Timing of milestones and study deliverables can be found in Table 1 and Figure 1.

G. Project Management

The lead PI Mr. Wallace will be responsible for overall project management and budget tracking. Before taking a position at the AFSC Mr. Wallace worked as a lead research scientist for 20 years at the Washington Department of Fish and Wildlife and has been on the NPFMC SSC for the last 10 years. At WDFW he supervised staff, was lead scientist in the field and responsible for overall management of many research and data collection projects including rockfish tagging, rockfish hook-and-line survey, fishery data collection projects and development of a HD camera system for a small ROV to survey untrawlable habitat in Washington waters. Mr. Wallace is lead scientist for the 2013 Observer program's electronic monitoring program that will place approximately 60 camera based EM units on volunteer small vessel hook and line commercial fleet fishing in the GOA and BSAI targeting halibut, Pacific cod and sablefish.

This project will leverage support from the ongoing NMFS 2013 restructured observer program's electronic monitoring program. Stereo camera systems developed in this project will be installed in tandem with the non-stereo camera EM units that will collect continuous video records of entire hauls. These data will allow for direct comparison of the number of fishing events collected by the stereo camera system to the continuous video record under variable light and environment conditions.

Co-PI Mr. Williams has extensive experience in underwater imaging, including design, assembly and operation of stereo-camera systems for quantitative image-based sampling at the AFSC. In addition, he has developed numerous software applications for analysis of image data. He will be responsible for oversight of code development and building the stereo camera system.

Mr. Williams and Mr. Wallace will be responsible for data analyses and project report write-up.

H. Figures and Tables

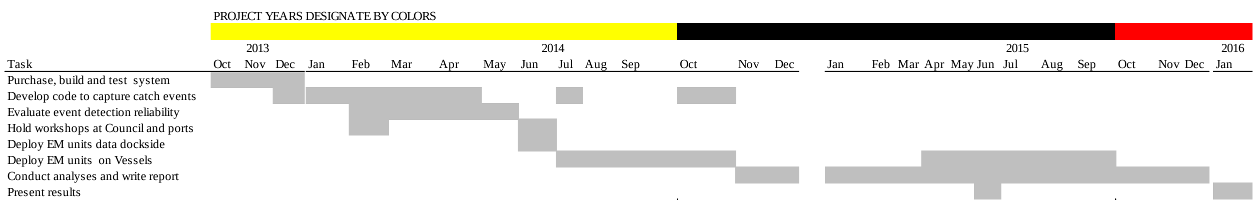

Figure 1. Summary of study activities, proposed milestones and accomplishments.

Table 1. Timing of study activities, milestones, accomplishments and deliverable products.

Project Milestones

	Projected Dates	
Task	**Start**	**End**
Purchase, build and test stereo camera system	Oct-13	Dec-13
Develop code to capture catch events	Dec-13	Apr-14
Evaluate event detection reliability in lab	Feb-14	May-14
Hold workshops at Council and Petersburg	Feb-14	Jun-14
Deploy EM units to collect data dockside	Jun-14	Jun-14
Deploy EM units to collect data on Vessels	Jul-14	Oct-14
Deploy EM units to collect data on Vessels	Apr-15	Sep-15
Conduct analyses and write report	Nov-14	Dec-15
Present results at Council	Jun-15	Jun-15
Present results Alaska Marine Science Symposium	Jan-16	Jan-16
Provide meta data and data submission	Jan-16	Jan-16

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