NOAA Technical Memorandum NMFS-AFSC-147

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**U.S. DEPARTMENT OF COMMERCE**
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

September 2004

NOAA Technical Memorandum NMFS

This document should be cited as follows:

McElderry, H., J. Schrader, D. McCullough, J. Illingworth, S. Fitzgerald, and S. Davis. 2004. Electronic monitoring of seabird interactions with trawl third-wire cables on trawl vessels - a pilot study. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-147, 39 p.

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September 2004

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# ABSTRACT

Archipelago Marine Research Ltd. was selected by the Alaska Fisheries Science Center to test electronic monitoring (EM) equipment for possible use to examine seabird interactions with trawl third-wire cables on trawl vessels. This pilot study involved field testing of EM systems on shoreside delivery and head and gut bottom trawl vessels conducting operations in the Bering Sea, U.S. Exclusive Economic Zone. EM systems, consisting of two closed circuit television cameras, GPS, hydraulic and winch sensors, and on-board data storage, were deployed on five fishing vessels for 14 fishing trips during a one-month period in the fall of 2002. Detailed analysis of about 200 hours of fishing imagery occurred, representing 20 shoreside delivery vessel fishing events and 32 head and gut fleet fishing events. Results from the study demonstrated that EM could effectively monitor seabird interactions with trawl third-wire cables. The EM system provided imagery of sufficient quality to detect the presence, abundance, and general behavior of seabirds during most daylight fishing events. As well, EM-based imagery was also able to detect third-wire entanglements of seabirds although it was not possible to determine the cause of these entanglements. EM imagery was not very useful for seabird enumeration and species identification. In regard to monitoring seabird interactions with trawl third-wires, EM would be suitable for monitoring the use and effectiveness of mitigation measures.

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# INTRODUCTION

Fishing vessels using trawl gear target a variety of groundfish species throughout Alaskan waters. These vessels range in size, time and area of operation, and other aspects such as processing mode, target species, use of pelagic versus bottom gear, trip length, and observer coverage requirements. Observer coverage occurs on vessels 60 feet length overall (LOA) and greater. In this fleet, the incidental take of seabirds during deployment and retrieval of trawl gear has been documented by NMFS-certified groundfish observers and sightings of short-tailed albatross (*Phoebastria albatrus*) around trawl fishing vessels have been reported.

In some trawl fisheries, equipment mounted on the trawl net sends signals to the vessel so net performance can be monitored. This is most important in midwater fisheries but is also employed in some bottom-trawl fishing applications as well. This equipment, typically known as a trawl sonar, is mounted to the trawl's headrope. The trawl sonar provides information regarding how the net is deployed, where the net is in relation to the ocean bottom, and more importantly where the net is in relation to the target catch. This system saves fishermen a great deal of time and effort because they can fish more effectively and either fine-tune the net performance while towing, or realize early on that there is a major problem and bring the gear back to the surface. The trawl sonar is hard-wired to the vessel through a cable typically known as the sonar cable or "third wire". Signals sent over this third wire are superior to those sent acoustically, as the third wire carries more information, sends a constant signal, and is not susceptible to disturbance from ambient noise or noise from the vessel itself.

Seabirds attracted to offal and discards from the ship may either strike the hard-to-see third wire while in flight, or get caught and tangled in the cable while they sit on the water due to the forward motion of the vessel. Some birds that strike the third wire may fly away without injury, while others may be injured or killed. When the third wire encounters a bird sitting on the water, the bird can be forced underwater and drowned.

Seabird mortality resulting from interactions with the third wire has been documented, but groundfish observers do not directly monitor third-wire interactions. Therefore, the magnitude and temporal and spatial distribution of seabird mortalities or injuries by species is unknown. This issue was pertinent because at the time this project began the National Marine Fisheries Service's

(NMFS) Alaska Regional Office was engaged in an Endangered Species Act Section 7 consultation with the U.S. Fish and Wildlife Service due to a joint determination that the trawl third wires are likely to adversely affect the endangered short-tailed albatross. Since then, a Biological Opinion[1] has been published that requires NMFS to evaluate the extent of this problem by carrying out a systematic monitoring program, and potentially develop seabird avoidance measures for third wire cables.

Monitoring the third wire on several types of trawl vessels is the critical component to evaluating the potential threat to short-tailed albatross. While groundfish observers who are deployed to these vessels could do this, other critical duties important to fisheries management and science would have to be reduced or eliminated. More importantly, viewing the third wire may require placing observers in dangerous areas on some vessels. In addition to concerns over observer safety and responsibilities, we have limited observer coverage in the Gulf of Alaska relative to that in the Bering Sea, whereas short-tailed albatross have been sighted in both areas. Given the expected low frequency of interaction between third wires and seabirds, the possible safety concerns for observers, and the straightforward monitoring required, this situation was an excellent candidate for field application of electronic monitoring (EM) systems using video and other vessel sensor devices.

The Alaska Fisheries Science Center (AFSC), NMFS, selected Archipelago Marine Research Ltd. (Archipelago) to examine the use of EM systems for trawl third-wire interactions with seabirds. The project was conceived to generally promote development of EM technology in a fisheries application and more specifically to evaluate the feasibility of using EM to detect and identify interactions of seabirds with the trawl third wire during trawl fishing operations.

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[1] Biological Opinion on the Effects of the Total Allowable Catch (TAC)-Setting Process for the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) Groundfish Fisheries to the Endangered Short-tailed albatross (*Phoebastria albatrus*) and Threatened Steller's eider (*Polysticta stelleri*). 39p. Available from: Ecological Services Division, U.S. Fish and Wildlife Service, 605 W 4th Ave., Anchorage, Alaska 99501.

# MATERIALS AND METHODS

## Description of the Electronic Monitoring System

Archipelago Marine Research Ltd. developed EM systems to supplement at-sea observer programs, particularly in applications where data collection is routine and the vessel is inadequate to host an observer. EM systems have been successfully used in a variety of fishery applications (http://www.archipelago.ca/em-projects.htm) and the EM systems were easily adaptable for use in this study.

The EM system integrates an assortment of available digital video and computer components with a proprietary software operating system to create a unique and powerful data collection tool. The system can operate on either DC or AC voltage to log video and vessel sensor data during the fishing trip. The EM system automatically restarts and resumes program functions following power interruption. The instrumentation can be configured to start recording video at power up or the software can be set to automatically activate video collection whenever fishing activities are recognized in the sensor data. The system components are graphically depicted in Figure 1 and described in the following text.

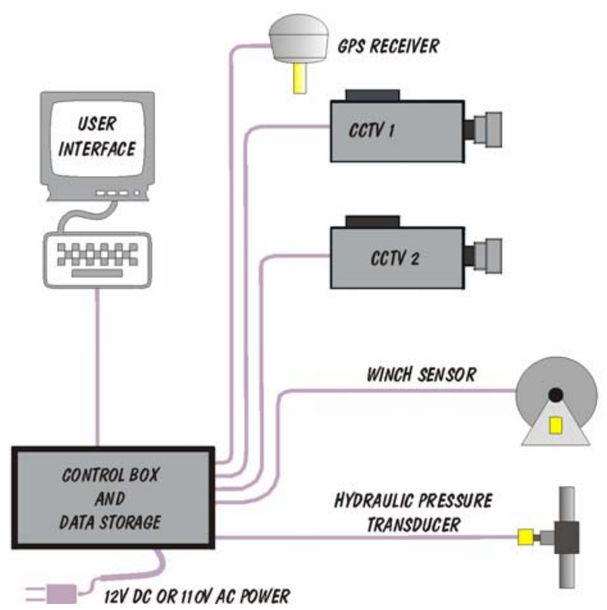


**Figure 1.** Schematic of electronic monitoring system.

## Control Box

The control box contains the operating system, data storage components, and power supplies for the video cameras and peripheral vessel sensors. The control box is a robust aluminum container approximately the size of a briefcase. It is spill-and-splash resistant but not adequately weatherproof for on-deck deployment. The box has about 0.5 cubic feet of dry and ventilated interior space for storage. The space must also be reasonably accessible to service technicians. On larger fishing vessels the monitoring system is usually powered by the onboard 120-volt AC supply although it can also be powered by a 12-volt DC source. Video camera and sensor cables are routed from the external devices to the internal control box through cable glands or compression fittings to maintain the hermetic integrity of the deckhouse structures.

The two core components in the control box are the data-logging and video computers. The data-logging computer captures and records sensor data to provide a digital time series record of the vessel activities. Post-processed sensor information can be used to detect specific actions on the vessel, such as setting or hauling fishing gear. The chronology of fishing activity derived from the time series is used to identify time-matched video segments for review. The data-logging computer can also activate the video computer whenever fishing activity is evident in the sensor data stream. In pilot programs, software control of the video computer is generally not used.

The video computer digitizes the incoming analog camera signal and stores the video imagery on removable computer hard disks. The video computer can be set to collect imagery at a wide selection of timelapse frame rates and digital compression ratios. Video frame rate and compression settings are optimized to deliver the highest quality image with the lowest storage space requirement.

## Closed Circuit TV (CCTV) Cameras

An EM system can have up to four analog CCTV cameras connected to the control box. An armored dome camera was chosen for installation on fishing vessels and has proven reliable in extreme environmental conditions on long-term deployments. The camera is lightweight, compact and easily attached to the vessel’s standing structure with a universal stainless steel mount and band straps. The camera electronics inside the sealed case are attached to a rotary gimbal mount that allows quick directional adjustment of the fixed lens camera. A choice of lenses from fisheye to telephoto enable the service technician to optimally adjust the field of view and image resolution for each application.

**Figure 2.** An example view from the twin camera system mounted on each vessel. The left view is a black-and-white image and the right is in color.

Two types of cameras were selected for deployments: a high resolution (570 TV lines), black-and-white camera and a standard resolution (350 TV lines) color camera. The black-and-white camera is considerably more sensitive to light (0.16 Lux @ f/2) than the color camera (1.0 Lux @ f/2) and thus has enhanced image resolution during low light conditions.

Initially, camera positions were targeted for the trawl deck where the trailing third-wire and flying seabirds could be viewed in greater contrast against the lighter background of the sky. However, most mounting locations on the net deck are exposed to heavy equipment and were thus deemed unsuitable for camera placement. To avoid damage to cameras and possible obstruction to net and line handling activities, cameras were placed near the third-wire winches, one deck level above the trawl deck. At this level, there were several safe mounting locations, either on the third-wire tow davit or nearby handrails; however, the higher camera position compromised image quality with the trailing third-wire and airborne seabirds appearing against the darker background of the sea. Figure 2, shown above, displays the two views provided by the cameras. It is important to note that a reduction in image quality occurs when taking still images from video imagery (image grabbing).

## Global Positioning System

An independent global positioning system (GPS) receiver was installed with each EM system. The GPS receiver delivered a digital data stream to the data-logging computer that provided an accurate time base as well as data on vessel position, speed, and heading. The GPS information was updated and stored on the data logger at a 10-second sample rate and was also captioned at the bottom of the digital video image to provide a geo-reference for each video image.

## Hydraulic Pressure Transducer

A hydraulic pressure transducer was installed on the input side of the third-wire winch. When the winch was activated to deploy the trawl net the corresponding pressure increase is recorded in the data set. Pressure variance at the third-wire winch, when displayed graphically, can provide a repeatable digital signature of the trawling activities.

Vessel engineers were consulted during sensor installation to identify the location on the winch where working pressure was accessible. Most of the winches were Bratvaag models with welded steel hydraulic supply lines that were difficult to tap into. The winches lacked standard pipe thread gauge ports or hose connections for attachment. On two of the vessels, winch fittings had to be drilled and tapped to accept the sensor pipe thread. This was accomplished with crew support.

## Winch Rotation Counter

The third-wire winch setups on many vessels of the three fleets (see following section on field program design) were generally similar. Most vessels were equipped with two winches: one primary winch, in use more than 90% of the time, and a second winch that served as a backup. On most of the vessels the third-wire cables were steel armored and were spooled through blocks mounted on short davits overhanging the stern. The winch controls and displays were located on the bridge.

Third-wire winch rotation was detected by a magnetic switch and used to detect vessel fishing activity. The simple device consisted of a drum-mounted magnet that, on each drum revolution, activated a micro-switch mounted on the winch frame. Drum rotation counts per 10-second interval were stored with the GPS and hydraulic pressure records on the data logger hard disk. Only the primary winch was outfitted with the magnetic switch for this study.

## Field Program Design

The project design called for pilot-scale testing of EM systems on trawl vessels operating out of Dutch Harbor, Alaska. Three categories of Alaskan trawl vessels were the target for the pilot tests:

- *Shoreside Delivery Vessels (Shoreside)* **-** Vessels in this fleet range in size from 60 to 140 feet length overall (LOA). These vessels make 2 to 5 day fishing trips, supplying shore-based plants with pollock.

- *Head and Gut Bottom Trawl Vessels (H&G)* **–** This fleet consists of 22 catcher/processor vessels that target a variety of groundfish other than pollock. The vessels range in size from 110 to 160 feet LOA and make 2 to 4 week fishing trips. All fish are processed aboard and are usually headed and gutted.

- *American Fishery Act Catcher/Processors (AFA)* **-** This fleet consists of about 17 vessels that target pollock. The vessels make 2 to 4 week fishing trips and all fish are processed aboard, primarily into surimi and fillets. Vessels in this fleet range in size from 180 to 350 feet LOA.

By the start of the project in September 2002, all three fleets were near the end of their fishing season and it was anticipated that about a month remained. The option of postponing the field program was dismissed given the urgency of the seabird interaction issue. It was therefore decided to promptly initiate field action and work with the available fleet rather than delaying the field program by several months. The field program occurred over a one-month period, beginning mid-September 2002. It was understood at the onset of the field program that EM testing of the AFA catcher/processor fleet was unlikely.

NMFS personnel in Seattle made initial contact with the Shoreside and H&G fleet representatives, who, in turn, put Archipelago program staff directly in contact with fleet representatives in order to arrange vessels and schedules. Information on the departure and arrival schedules of vessels was necessary for planning of EM installation and service routines. This information was obtained by various means including: questioning the vessel operators at install or service time, calling the fish plant managers, and visiting the plants to check the dockside vessel rotation. Vessel schedules varied and sailing plans often changed however, due to weather delays and to offload or processing plant delays.

## Shoreside Delivery Vessel Installation and Setup

The initial EM installations and tests were planned for the Shoreside delivery vessels which provide shore-based plants with a steady supply of fish to maintain 24-hour processing operations in port. Shoreside vessels were the most suitable test platform for project startup due to their short trips and rapid turnaround periods, offering rapid data production for the EM system trials. EM equipment was tested on three Shoreside vessels. When an instrumented Shoreside vessel returned to port, the EM service technician would visit the vessel, check the EM system, assess the data quality, and retrieve the data. If the onboard data inspection revealed any system setup parameters or equipment that required attention or modification, these tasks were completed during the service visit. After the initial data quality check was concluded, the hard drive was removed and replaced with an empty one so that the sensor data could be offloaded to a data-logging computer. A final power-on test of the onboard system was performed before the technician returned to the NMFS office in Dutch Harbor for a more detailed inspection of the retrieved video and sensor data.

Following completion of a Shoreside vessel fishing trip, Archipelago staff, using the Dutch Harbor NMFS office, forwarded data and imagery samples via the Internet to Archipelago’s office in Victoria, B.C., and the AFSC in Seattle. After reviewing the initial video data from the Shoreside vessels, a better understanding was gained of camera settings, seabird activity, background contrast, and lighting. On the next service visit to each vessel, adjustments were made to the camera angles and lenses to address any problems uncovered during the data review process. The rapid turnaround of the vessels meant that the next fishing trip was usually underway while preliminary data analysis occurred and any issues identified would usually not be implemented until the following trip.  Thus, problems identified on the first Shoreside vessel trip could not be corrected until the third trip.

The initial viewing of the imagery also served to help conserve storage space. Selective portions of video were archived so that hard drives could be reused on subsequent trips.  If the imagery for a trip was not saved in its entirety, portions that were useful for further analysis were saved.  The criteria used to select imagery to be saved included, but were not limited to: imagery that occurred during fishing operations, imagery with sufficient light available for viewing, and imagery with seabirds present. Other portions of imagery may also have been saved, but would not be included in the analyzed imagery (Fig. 3).

EM systems were installed 24, 25, and 27 September, respectively, on three Shoreside delivery vessels: *SS 1*, *SS 3,* and *SS 2*.  Over the following 3 weeks, field staff maintained and serviced the EM systems deployed on these vessels.   Installations usually required 6 hours to complete.  During first time installations for pilot projects, it was expected installations could take an entire day to ensure correct customization of the EM system.  Crew support was necessary to complete the installation and to perform system tests.  EM system servicing and removal were usually accomplished in less than an hour. EM installation specifications for this fleet are noted below.

EM control boxes were installed in protected locations near the cameras on the afterdeck.  On the *SS 1* there was no nearby protected location so the control box was sealed in a waterproof tote and placed on the stern gantry work platform.

Timelapse image recording on the three Shoreside vessels was set to four fields (i.e., still images) per second and at a medium resolution compression ratio of 20:1 (digital video systems use a data compression algorithm to compress file size and rates ranging from 10:1 to 35:1 correspond to increasingly reduced image detail and smaller file size).  The conservative timelapse settings and the relatively short turnaround time for the Shoreside vessels reduced the video storage requirement.  With reserve disk capacity available, continuous video image recording was chosen to maximize image capture.  The vessel crew was directed to turn the control box on at departure and leave it on until the vessel returned to dock.  The vessel would return with several days of video data that would include the fishing and third-wire imagery as a subset.  The chronological location of fishing imagery on the disk could be defined in the sensor time series by the pressure signal from the third-wire winch.

Only one Shoreside vessel (*SS1*) had a winch rotation counter installed. Installation of the winch counter required a magnetic switch mounting in close tolerance to the magnet mounted on the winch drum. Archipelago's installation technique, developed for aluminum longline drums, was not suitable for the steel third-wire drums. The vessel had a steel mount welded onto the winch support frame that could serve as a switch mount. Archipelago is developing a photoelectric winch sensor that will not require special mounting structures.

## Head and Gut Bottom Trawl Installation

The experience gained in the Shoreside vessel tests was applied to the installation and configuration of the systems installed on the H&G fleet. As mentioned, vessels in this category were larger and make much longer fishing trips. Deployment of EM equipment on this fleet was therefore delayed until after the Shoreside fleet testing was complete in order to ensure that these would be successful. Given this delay, only two H&G vessels (*H&G 1* and *H&G 2*) were identified for pilot testing of EM equipment. We coordinated with industry representatives who provided the contact information for the two catcher/processors that were preparing to depart on their final trips of the season. Discussions with the vessel operators indicated that they would fish for an indeterminate period of up to 20 days, then return to Seattle by the end of October. The vessels were serviced in Seattle during the first week of November. An EM technician collected the video and sensor data and removed the EM systems from the ships at that time.

Given the length of the fishing trip and the uncertainty of the amount of fishing time, there was concern that the image storage capacity could be exceeded. To address this potential disk capacity problem, two modifications were made to the H&G vessel installations. The EM systems were outfitted with an additional hard disk for a total capacity of 120 gigabytes. The second modification was a change from the continuous video capture used on Shoreside fleet to manual control, operated by the onboard groundfish observer (both vessels required 100% observer coverage). To limit EM operation to daylight fishing periods, the groundfish observer was instructed to power the

EM system during the day when the net was set and turn the system off when it was recovered. This procedural change ensured that there was more than enough storage capacity on each vessel to cover the uncertainty of the trip duration.

The EM installations and observer briefings on the H&G vessels were completed just before departure with limited notice. The system setups on the Shoreside vessels were used as templates for these vessels. Control boxes were mounted positioned in protected storage areas in the aft section of the vessel and cameras were mounted on the third-wire davits. The amount of time available for installation of EM components was very limited due to eminent departure schedules. Thus, the EM installation occurred quickly and included only the essential components. The hydraulic pressure transducer and winch sensor were not installed. Omitting these components reduced the installation time and allowed the vessels to sail on schedule.

## American Fisheries Act Catcher/Processor Fleet

The timing of the 2002 field program precluded pilot testing of EM systems on the AFA fleet. In early January 2003, Archipelago project staff traveled to Seattle to meet with the AFA vessel operators and to evaluate suitability of several AFA ships for EM installation. Archipelago and NMFS staff also attended the AFA vessel skippers meeting on 6 January 2003 and gave a short presentation about the project. As well, several of the AFA vessels owned by American Seafoods were boarded for examination of layout and discussion with vessel officers. The discussions and observations provided information useful for planning future EM tests on this fleet.

The third-wire equipment on the AFA ships was structurally similar to the gear on the Shoreside and H&G trawlers that participated in the Dutch Harbor experiments. On some vessels, the winches were located on the upper afterdecks and were Bratvaag models. Some of the winch cables were spooled through blocks mounted on davits extending behind the vessels. In other installations the winches were mounted outside the stern handrails and the cables were deployed directly from the level-wind rollers on the winch. The winches were connected to the vessel hydraulics with welded steel pipes. Some of the winches had pressure gauge ports that could be used for hydraulic pressure sensor installation.

On all of the vessels that were inspected there were rails and other structures near the third-wire winches suitable for mounting cameras. While a trawl deck level camera provides a preferable image, it is unlikely that the cameras can be safely installed at this level. The mounting points, with a clear view astern, showed signs of impact by the heavy trawl doors. All of the ships had protected spaces close to the stern that could be used to house the EM control boxes, thus reducing the wire distance from the cameras and sensors. If the vessel engineer was available to support the installation and testing of the pressure sensor, an EM system installation on an AFA catcher/processor vessel should proceed without difficulty.

## Data Analysis Procedures

In addition to the preliminary analysis performed on the data set in the field, a secondary analysis was conducted in the Dutch Harbor NMFS office. The data set was initially inventoried according to completeness and quality. Initial analysis of sensor data was completed shortly after each trip. The output of the analysis illustrated the general activity of the vessel, as well as a timeline of fishing events. This timeline would then be used to view the video imagery more efficiently. Detailed analysis of the imagery was conducted after the field season by Archipelago staff at its Victoria, B.C. office.

### Data Set Inventory Process

Data sets from EM deployments were inventoried to assess the overall success of data capture and to identify elements of the fishing trip for more detailed analysis of the imagery. The inventory process is outlined in a flowchart in Figure 3, showing the categories used to separate the EM data set. The first tier in the process was to distinguish successful EM trips from those that were unsuccessful. Within the successful EM trips, the data set was further subdivided into fishing and non-fishing components. Lastly, within the fishing component of the data set, the data were divided between what could and could not be analyzed. The reasons for and the criteria used to create these separations are described in more detail in the following sections.

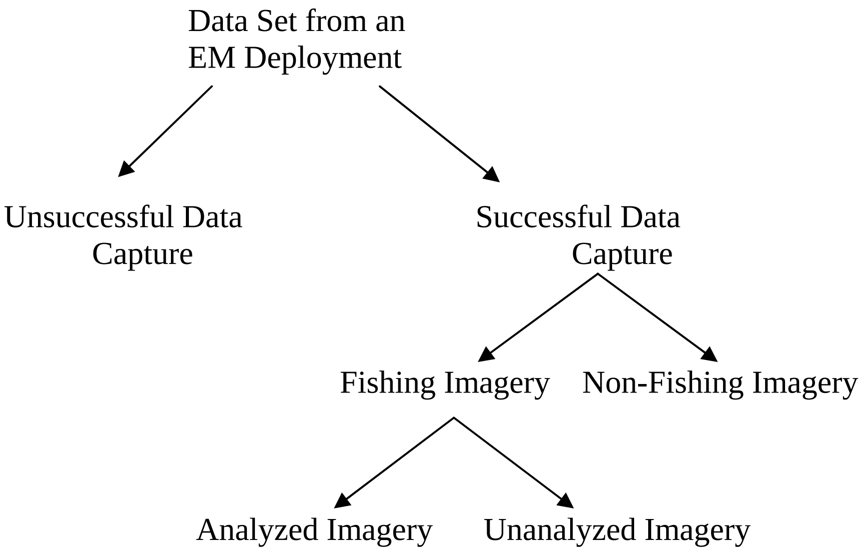


**Figure 3.** Flowchart showing the data set inventory categories.

## Sensor Data Analysis

Although sensor data was collected, in whole or in part on all vessels, detailed analysis was necessary for only the Shoreside vessels, where sensor data was recorded for the entire trip and the particular focus was on detection of fishing events. The sensor data analysis included an assessment of the data quality, an evaluation of completeness of the data set, and interpretation of sensor data to identify fishing events. This analysis was facilitated using the following software tools and data presentation techniques:

- *Relational Database* – The raw ASCII sensor data was imported into a relational database application to perform a variety of tasks including reformatting data and examining related records for anomalies in the data series (e.g., power interruptions or poor GPS signal quality).

- *Time Series Plotting* – Selected variables from the monitoring system data were displayed in a time series graph. The sensor data presented in this format clearly distinguish vessel activities including transit, anchor, fishing, and periods when the system power was off.

- *Geographic Plotting* – Selected variables from the data set were also displayed using a geographic information system (GIS) software tool. These plots enable the geographic positioning of fishing activity with a hydrographic chart and fishing boundaries.

Once the database application processed the data, anomalies in the data set could be identified. The most important anomalies to identify were the time gaps, or breaks in the data logging time series usually caused by power interruptions. Minimal time gaps indicated that the data series was complete. Other data set anomalies investigated included GPS reading lockups, which indicated a temporary GPS data stream loss, usually caused by a poor GPS signal or interference from other vessel electronics.

The time series graphs displayed information such as hydraulic pressure, winch rotations, vessel speed and heading, and data logging interval plotted over time in order to more easily identify fishing activities (e.g., setting, hauling, and towing) and other vessel activities such as transiting, departing, and landing times. The data-logging interval, the time between adjacent data records, was used to more easily identify data set time gaps.

A GIS plot of the fishing trip was used to provide a spatial representation of the vessel's cruise in relation to the hydrographic chart. Towing, setting, and hauling events, recognizable from the sensor data, could be highlighted in distinctive colors. Interpretation of both time series graphs and GIS plots facilitated the detection of fishing events. These events, referenced by date and time, were then used to directly access the imagery. The ability for direct access of imagery was facilitated by digital images stored on a hard drive.

## Image Data Analysis

All imagery was examined after the field program for inventory and analysis purposes. The inventory process was carried out in the same manner as in Dutch Harbor. Imagery subject to more detailed analysis included all fishing imagery that was suitable. Examples of fishing imagery of every trip from each vessel are provided in the Appendix.

Imagery from fishing activity was analyzed in order to evaluate overall image quality, fishing conditions, and seabird interaction information. A database was created to log these qualitative assessments while reviewing the images. Image quality was assessed as follows:

- *High Quality* - Horizon was visible, the lens was properly focused, and the third wire was clearly seen and seabird activity was easy to assess.

- *Medium Quality* - Some loss of resolution, but the ability to view the third wire and assess seabird activity was not greatly hampered.

- *Low Quality* – Images affected by conditions such as reduced light, water spots on the lens, poor focus, or loss of horizon. In this case, the third wire was difficult to resolve, or was often out of sight so seabird activity was difficult to describe.

- *Unusable Quality* – Light levels too low for analysis.

Weather conditions and ambient light levels were also recorded in relation to quality. Weather was recorded in a qualitative fashion using the following indicators:

- *Good Weather* – sunny or partially sunny, zero precipitation, and relatively calm seas.

- *Moderate Weather* – light overcast clouds, light rain, and choppy seas.

- *Poor Weather* – heavy overcast clouds, heavy rain, and stormy seas.

Light levels were described as either adequate or too low to see various events of interest. Weather and light levels were the main external factors that affected video quality, while internal EM system-related factors affecting quality included lens focus, camera configuration (color or black-and-white, field of view), and image recording specifications (frames recording rate and image compression ratio).

Seabird activity observations were divided into two categories: seabird abundance and seabird behavior. Because the relative abundance of seabirds around fishing vessels could be related to interaction rates, the viewer first described the number of seabirds entering and leaving the field of view. Secondly, he or she described the behavior of the seabirds in terms of how likely they were to interact, or come in physical contact with the third wire. Seabird abundance was classified in four levels as follows:

- *Infrequent* **-** less than 1 seabird seen per minute.

- *Low Abundance* - 1 to 4 seabirds seen per minute.

- *Medium Abundance* - greater than 4 seabirds seen per minute.

- *High Abundance* - seabirds continually present. This category could be further divided into levels of abundance, but it was determined to be unnecessary for the purposes of this study.

Seabird interaction with the trawl third-wire was described in terms of zones of proximity to the third wire (Fig. 4). Each zone represents an increasing level of potential interaction between seabirds and the third wire:

- *Absent* – No seabirds were visible in the image.
- *Zone 1* – Seabirds were in transit. Seabirds flew into and out of the field of view in a short period of time. They did not travel near the third wire, and did not appear to be staying in the area. The level of potential interaction with the third wire was low.
- *Zone 2*– Seabirds were flying close to the third wire, often in a circular, or figure-eight pattern. The level of potential interaction was moderate.
- *Zone 3* – Seabirds were on the water in the vicinity, but not in the immediate path of the third wire. The level of potential interaction was moderate.
- *Zone 4* – Seabirds were on the water in the immediate path of the third wire. Particular attention was paid to the seabirds close to this point of entry. The level of potential interaction with the third wire was high.

If seabird interaction was in more than one zone of proximity for a given period of time, the highest zone was recorded. For example, if seabirds were seen on the water and in transit the viewer would record Zone 3, and the level of potential interactions would be considered moderate. As more information is obtained about the behavior of seabirds around the third wire, these zones could be further divided to more accurately reflect potential physical contact with the third wire.

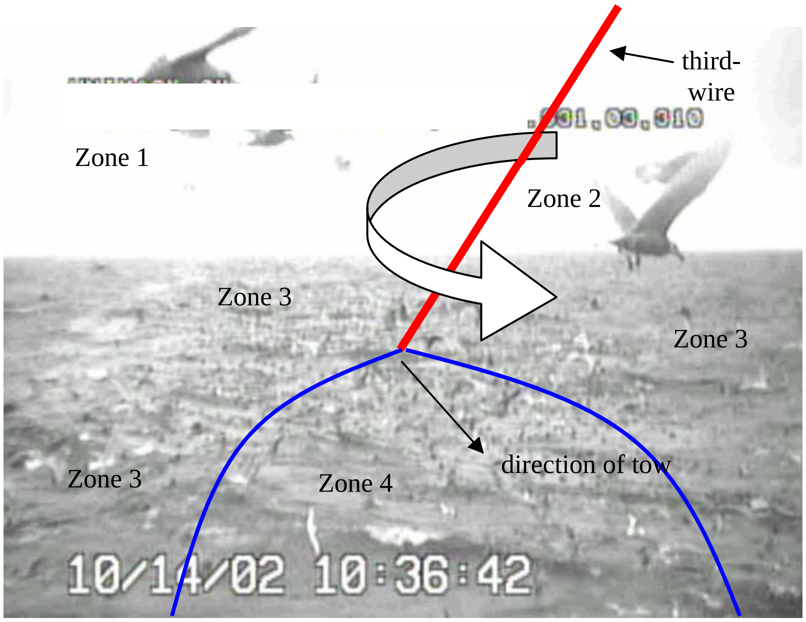


**Figure 4.** Zones of proximity in relation to the trawl third-wire (See text for definition of zones).

Direct contact with the third wire was described as an interaction. There were two types of interactions interpreted from the imagery:

- *Seabird Strikes* - As the seabirds approached the third wire (from the air or on the water), the viewer would describe any seabird strikes witnessed, as well as the resultant condition of the seabird. The species (or species group) was recorded if known.

- *Seabird Third-wire Entanglements* - Special attention was paid to the third-wire during hauling events to watch for seabirds tangled on the third wire.

During image analysis the viewer also recorded the time spent in order to determine the level of effort required to process fishing imagery. A real-time to analysis-time ratio could then be calculated. Finally, sample video and still imagery was captured for each trip, highlighting events of interest. The sensor and image data was then gathered and summarized in a trip report.

## Detection of Fishing Events

EM installations on all vessels in this study did not use automatic control of image recording. On Shoreside vessels, EM systems were powered continuously during the fishing trip, recording imagery continuously. On the H&G vessels, the groundfish observer activated the EM system only during daylight fishing operations to decrease unnecessary video capture to maximize media storage capacity.  Reliance on human involvement to start the EM system, however, for fishing events is at risk to error and possible information loss.  The EM system is designed to automatically control image capture to avoid these problems.  However, initial sensor data must be collected from the target fleet in order to identify the sensor data signatures that correspond to fishing activity.

# RESULTS

Electronic Monitoring deployments carried out in the field program occurred on five vessels in the Shoreside and H&G fleets for a total of 14 fishing trips and 86 fishing events (Table 1). The EM deployments took place from 27 September until 18 October 2002, during which time the vessels were based in Dutch Harbor, Alaska, participating in fishing operations.

**Table 1.** Summary of EM deployments by fleet category. The reason for unsuccessful EM deployments is shown (sensor or video data).

| Fleet | Trip No. | Date Start | No. of Sets | Deployment Result<br>Successful | Deployment Result<br>Failure Reason |
|---|---|---|---|---|---|
| **Shoreside Fleet (SS)** | | | | | |
| *SS 1* | 1 | 9/27/2002 | 3 | Y | |
| *SS 1* | 2 | 9/29/2002 | 3 | Y | |
| *SS 1* | 3 | 10/2/2002 | 4 | | video |
| *SS 1* | 4 | 10/11/2002 | 4 | | video |
| *SS 1* | 5 | 10/14/2002 | 4 | Y | |
| *SS 2* | 1 | 9/28/2002 | 6 | Y | |
| *SS 2* | 2 | 10/4/2002 | 6 | Y | |
| *SS 2* | 3 | 10/10/2002 | n/a | | sensor/video |
| *SS 3* | 1 | 9/28/2002 | 4 | Y | |
| *SS 3* | 2 | 10/4/2002 | 3 | Y | |
| *SS 3* | 3 | 10/7/2002 | 4 | Y | |
| *SS 3* | 4 | 10/12/2002 | 3 | Y | |
| **Subtotal** | **12** | | 44 | **9** | |
| **Head-Gut Fleet (HG)** | | | | | |
| *HG 1* | 1 | 10/10/2002 | 32 | Y | |
| *HG 2* | 1 | 10/14/2002 | 10 | Y | |
| **Subtotal** | **2** | | **42** | **2** | |
| **TOTALS** | **14** | | **86** | **11** | |

## Unsuccessful Data Capture

Three of the 14 EM deployments were unsuccessful in data capture, resulting in unusable data sets (see Table 1). All EM failures occurred on the Shoreside fleet and two were with a single vessel. Both H&G vessels equipped with EM systems were successful in collecting data from the fishing trips. Among the unsuccessful EM deployments, one was due to user intervention and the other two were due to technical malfunction of the

EM system. The former was the result of a vessel crew change and the new skipper not wishing to participate in the EM pilot study. EM equipment was already installed for two previous trips, but the system was intentionally disconnected for the third and final fishing trip on the vessel.

For the two unsuccessful EM trips caused by technical failure, both were the result of faulty recording of video imagery. On the third trip of the *SS 1*, the video computer operating system suffered a boot failure on startup, which locked the video control software. This type of problem is uncommon and usually resulted in the system locked for the entire fishing trip. The fourth trip of the *SS 1* lost all video data, very likely for the same reason. It is difficult to confidently draw that conclusion, however, due to an accident that happened during system service. While the EM technician was checking the data quality on the outdoor control box, rainwater that had collected on the cover tarp poured into the open box and onto the electronics. The box had to be removed from the vessel and returned to the NMFS office for repair. During this process the digital system log on the video computer was damaged and the disk boot error could not be confirmed. A spare EM control box was installed on the *SS 1* and a complete video data set was retrieved from the fifth and final trip of the vessel. Subsequent to the field program, control box software revisions were made to detect video computer lockup problems and automatically reboot the systems.

## Successful Data Capture

Electronic Monitoring systems performed properly for 11 of the 14 fishing trips. Table 2 provides a summary of the total hours of imagery collected by fleet and vessel category. Overall, there were 694 hours of imagery from all successful EM deployments, among which 410 hours were during fishing operations where the trawl net was deployed and fishing. Over 80% of all EM data was collected on the Shoreside vessels, of which there were 289 hours of fishing imagery. EM deployments on the two H&G vessels resulted in about 130 hours of data, nearly all of which was during fishing operations. The discrepancy between the proportion of fishing and non- fishing imagery for the two fleets was due to the manner in which the EM system was operated: the system was powered continuously on Shoreside vessels whereas on H&G vessels the NMFS-certified groundfish observer turned the system on only during daylight fishing operations.

The EM deployment on the second trip of the *SS 2* was successful but the results are not shown in Table 2, as the data set was inadvertently lost due to an operational error. The disk drive for this trip was accidentally taken from archive storage and used for EM deployment on the *H&G* 1. The mistake was the result of the field crew having to equip the *H&G 1* on short notice. The result of this error was to implement more structured video and data handling procedures in the field, making this kind of error less likely.

**Table 2.** Summary of total hours of EM imagery for all vessels with successful data capture.

| Fleet | Trip No. | No. of Sets | Fishing Imagery | | Total Fishing Imagery | Non-Fishing Imagery | Total Imagery |
|---|---|---|---|---|---|---|---|
| | | | Analyzed | Not Analyzed | | | |
| **Shoreside Fleet (SS)** | | | | | | | |
| *SS 1* | 1 | 3 | 0.0 | 25.7 | 25.7 | 24.6 | 50.3 |
| *SS 1* | 2 | 3 | 13.8 | 19.4 | 33.2 | 18.5 | 51.7 |
| *SS 1* | 5 | 4 | 34.1 | 0.0 | 34.1 | 23.4 | 57.5 |
| *SS 2* | 1 | 6 | 11.6 | 53.8 | 65.4 | 46.7 | 112.0 |
| *SS 3* | 1 | 4 | 0.0 | 34.2 | 34.2 | 26.5 | 60.7 |
| *SS 3* | 2 | 3 | 8.6 | 33.5 | 42.1 | 18.9 | 61.0 |
| *SS 3* | 3 | 4 | 14.9 | 14.2 | 29.0 | 45.8 | 74.8 |
| *SS 3* | 4 | 3 | 25.6 | 0.0 | 25.6 | 70.5 | 96.1 |
| **Subtotal** | **8** | **30** | **108.6** | **180.7** | **289.3** | **274.8** | **564.1** |
| **Head-Gut Fleet (HG)** | | | | | | | |
| *HG 2* | 1 | 10 | 0.0 | 25.5 | 25.5 | 0.0 | 25.5 |
| *HG 1* | 1 | 32 | 95.0 | 0.0 | 95.0 | 9.6 | 104.6 |
| **Subtotal** | **2** | **42** | **95.0** | **25.5** | **120.5** | **9.6** | **130.1** |
| **Totals** | **10** | **72** | **203.6** | **206.2** | **409.8** | **284.4** | **694.1** |

## Imagery Analysis

The imagery associated with fishing activities was grouped into two categories: analyzed and not analyzed. The former category included all the imagery used in subsequent analysis while the latter included imagery that was either not suitable or available for further analysis due to the following reasons:

- *Technical Failure* – EM data from the *H&G 2* was lost during the analysis process as a result of a hard drive failure. Imagery from the fishing trip was previewed for inventory and preliminary analysis; however, a hard drive failed which resulted in lost data for the detailed analysis. Some sample imagery and video stills were copied from the drive before the failure occurred. Initial observations of the imagery indicated similar conditions and seabird activity as was observed in *H&G 1* imagery.

- *Data Archiving* – Early in the field program, a sample of daylight fishing operations from two fishing trips (*SS1*, trip 1 and *SS3*, trip 1) was archived to CD. There were concerns over storage space that led to the decision to reuse hard drives before a complete analysis was conducted on the imagery. Most of the imagery not saved was during nighttime fishing operations. However, portions of video where no seabirds were visible were also not saved for detailed analysis.

- *Night Fishing* - Generally, light levels at night (roughly, between 21:00 and 09:00 Alaska time) were insufficient for viewing the third wire and such imagery was not included in the analyzed data set. If the vessel's stern lights illuminated the third wire the data set was included for analysis. Imagery from night fishing was only recorded on Shoreside vessels and, among the 290 hours of total fishing activity, 51% of the time was night fishing, although the individual trips ranged from 35% (*SS 3*, trip 4) to 64% (*SS 3*, trip 1) night fishing.

## Analysis of Fishing Imagery

Among the set of imagery used for detailed analysis there was over 203 hours, from 4 vessels, 7 fishing trips, and 53 fishing events, 21 of which were from the Shoreside fleet. The level of effort required to analyze the imagery was just over 25% of real time. That is, for every hour of video, about 15 minutes of viewing time was required to interpret the imagery and record these results in a database. The average analysis time of the Shoreside vessels and the H&G vessels was 13 and 18 minutes, respectively, per hour of imagery. The higher level for the latter was due to the number of seabirds present in the imagery and the extra time required to assess interactions with the third-wire. While several factors affected analysis times including analyzer experience, image quality, and level of seabird activity, these values represent averages that could be used in planning image analysis effort required for fishing imagery.

### Image Quality

An assessment of overall quality is presented in Table 3. About 83% of the analyzed imagery was considered usable. Imagery was unusable where light levels were insufficient, due to evening and/or dawn fishing times. These hours are separate from the night fishing hours that were not analyzed. There were about 22 hours of insufficient light levels, most of which came from trip 4 of the *SS 3*. Imagery was also considered unusable if the third wire was not in the field of view for periods of greater than 5 minutes. The third wire was not in view for the majority of the first trip of the *SS 1*, a consequence of aiming the cameras when the vessel is dockside and using narrow field of view lenses. These problems were corrected on subsequent trips with this vessel. The general goal of the camera configurations was to keep the third wire in view, however, nearly all Shoreside vessel image sets had some periods where this did not occur, such as when the vessel made a sharp turn, or when heavy seas displaced the third wire position relative to the vessel stern. The longest period of time that the third wire remained out of view was 1.25 hours; however, the wire usually left the field of view for only short periods of time, less than 15 minutes. The third wire remained in view for the duration of the *H&G 1*'s imagery. In total, there were about 4 hours of analyzed imagery where the third wire left the field of view.

Among the usable imagery, almost 82% was of medium quality. Low quality accounted for 14% and the remaining 4% was high quality. The image quality from the Shoreside fleet was slightly better than the one H&G vessel, although variability between individual trips was high. The quality assessment was usually the same for the entire fishing (net deployment) event.

**Table 3.** Summary of the analyzed image quality and weather condition by fleet and vessel.

| Fleet | Trip No. | No. of Sets | Usable Hours | Quality (%) | | | Weather (%) | | | Unusable Hours | Total Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | High | Medium | Low | Good | Moderate | Poor | | |
| **Shoreside Fleet (SS)** | | | | | | | | | | | |
| *SS 1* | 2 | 3 | 12.2 | 0.0% | 67.5% | 32.5% | 96.6% | 3.4% | 0.0% | 1.6 | 13.8 |
| *SS 1* | 5 | 4 | 23.9 | 0.0% | 100.0% | 0.0% | 24.6% | 75.4% | 0.0% | 10.2 | 34.1 |
| *SS 2* | 2 | 5 | 9.3 | 31.6% | 64.3% | 0.0% | 96.0% | 0.0% | 0.0% | 2.4 | 11.6 |
| *SS 3* | 2 | 2 | 6.8 | 0.0% | 100.0% | 0.0% | 26.6% | 5.9% | 67.5% | 1.7 | 8.6 |
| *SS 3* | 3 | 4 | 12.9 | 0.0% | 71.6% | 28.4% | 71.6% | 0.0% | 28.4% | 1.9 | 14.9 |
| *SS 3* | 4 | 3 | 12.9 | 0.0% | 89.4% | 10.6% | 35.4% | 62.5% | 2.0% | 12.8 | 25.6 |
| **Subtotal** | **6** | **21** | **78.0** | **3.7%** | **84.2%** | **11.5%** | **54.1%** | **34.5%** | **10.9%** | **30.6** | **108.6** |
| **Head-Gut Fleet (HG)** | | | | | | | | | | | |
| *HG 1* | 1 | 32 | 90.4 | 4.5% | 79.3% | 16.2% | 55.9% | 22.0% | 22.1% | 4.7 | 95.0 |
| **Subtotal** | **1** | **32** | **90.4** | **4.5%** | **79.3%** | **16.2%** | **55.9%** | **22.0%** | **22.1%** | **4.7** | **95.0** |
| **Totals** | **7** | **53** | **168.3** | **4.2%** | **81.6%** | **14.0%** | **55.1%** | **27.8%** | **16.9%** | **35.3** | **203.6** |

### Weather Conditions

Weather conditions during fishing events are summarized in Table 3 by vessel and fleet category. Overall, about 55% of the usable fishing imagery occurred in good weather, followed by about 28% in moderate and 17% in poor weather conditions. This pattern was quite variable among the seven fishing trips assessed, ranging from 100% good (*SS 2*, trip 2) to mostly moderate (*SS 1*, trip 5) or poor (*SS 3*, trip 2). It was only during poor weather conditions that detection of events of interests became limited. Heavy rain and stormy weather conditions usually resulted in a low image quality rating and it was difficult to view the third wire and sea surface astern of the vessel.

## Analysis of Seabird Trawl Third-Wire Interactions

The imagery available for detailed analysis amounted to 168 hours, representing four vessels, seven fishing trips and 53 fishing events (Table 3). However, imagery analyzed in the field totaled 37 hours and were included in this portion of the analysis, bringing the total imagery to 206 hours (Table 4). These hours represented daylight hours where no seabirds were seen. The majority of the 37 hours of imagery came from two trips; 18 hours from trip 2 of the *SS 3* and 20 hours from trip 1 of the *SS 2*. All of the imagery from the H&G vessel was analyzed.

The single H&G vessel provided about half of the usable imagery and 62% of the fishing events. The remainder was from the six Shoreside vessel trips, providing from 13 to 29 hours of imagery per fishing trip. These results and seabird interaction observations are summarized in Table 4. Seabird abundance estimates provided a relative index of the presence of seabirds during fishing events. The Shoreside fleet had very low abundance levels of seabirds for the majority of the fishing imagery. Occurrences of seabirds were infrequent for 86% of the imagery. For 9% of the imagery, a low abundance of seabirds was seen and for 5% of the time, a medium abundance of seabirds was seen. There was no time during which seabird abundance was high while the third wire was deployed; however, a high abundance of seabirds was evident during most setting and hauling events. Seabirds quickly disappeared after the net sank below the water and just as quickly returned once it resurfaced at the end of the tow.

Seabird abundance was also examined during different weather conditions for the Shoreside fleet. There was a noticeable increase in abundance levels during poor weather. Although the total hours of poor weather were low (8.5 hours), abundance levels of low and medium during this period were 51% and 45%, respectively, as compared with 9.4% and 5.1% for the Shoreside fleet overall. Further, 65% of the total time seabird abundance was recorded as medium was during poor weather.

Imagery for *H&G 1* showed an opposite overall seabird abundance pattern to that observed for the Shoreside vessels. Over 94% of the total imagery examined for seabird abundance was recorded as high and the remaining levels were 3%, 1%, and 2% for medium, low and infrequent abundance. The imagery from the *H&G 2* when viewed during the preliminary analysis was similar to that of the *H&G 1* where abundance levels were high and seabirds were continually present for the majority of the time.

Seabird proximity to the third wire was also markedly different between the two fleets. For the Shoreside fleet, during 66% of the imagery there were no seabirds present. Seabirds were seen in transit, occupying Zone 1, for 26% of the imagery. Seabirds were flying near the third wire for about 6% of the time and on the water for about 3% of the time (Zones 2 and 3, respectively). Seabirds were not seen on the water ahead of the third wire in Zone 4, the highest level of potential interaction. Concentrations of seabirds were highest during setting and hauling events.

In contrast, for 89% of the *H&G 1*'s imagery, seabird potential interactions with the third wire were in Zone 4 on the water ahead of the third wire. Seabirds elsewhere on the water and flying near the third wire each accounted for 4%, while seabirds in transit made up the remaining 3%. Again, the initial analysis of fishing imagery from the *H&G 2* showed a similar pattern to that of the *H&G 1*. Seabird interactions with the third wire consisted mainly of flying near the third wire and on the water, around and in front of the third wire.

While video imagery clearly established when seabirds were in the vicinity of the trawl third wire, direct interactions with the third wire were uncommon and difficult to fully interpret. There were two incidences when it appeared as though a seabird struck the third wire, once on the *H&G 1* and once on the *SS 3*. In both instances, while it was difficult to confirm direct contact with the third wire, seabirds abruptly changed direction, and then flew away after the incident. In one case the directional change was nearly 180°, making it appear that the bird had struck the cable and rebounded off. This bird was identified as a black-legged kittiwake (*Rissa tridactyla*). Also during the *H&G 1* fishing trip, during three separate fishing events, seabirds tangled on the third wire were seen as the trawl net was being retrieved. In one instance, there were at least two seabirds tangled on the third wire. The imagery was not clear enough to identify the seabirds. Upon examination of the complete imagery for these fishing events, it was difficult to determine how the seabirds became tangled, or determine the specific behavior that would lead to a seabird getting entangled.

Interaction rates (No. of seabirds/hour) were calculated for both strikes and entanglements based on these results. For the three shoreside vessels we observed, there was a strike rate of 0.009/hour. If the hours of no seabirds present were not included in the total, the strike rate was 0.03/hour. The entanglement rate was 0/hour. The strike rate for the single H&G vessel that we had imagery from was 0.01/hour and the entanglement rate was approximately 0.04/hour. These interaction rates are based on very few observations on very few vessels during a limited time period. Given these limitations, the results should not be extrapolated to a fleet average.

**Table 4.** Summary of analyzed imagery and seabird interaction observations by vessel and fleet category.

| Fleet | Trip No. | No. of Sets | Total Hours | Seabird Abundance (%) | | | | | Zone of Proximity (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Infrequent | Low | Medium | High | Absent | 1 | 2 | 3 | 4 |
| **Shoreside Fleet (SS)** | | | | | | | | | | | | |
| *SS 1* | 2 | 3 | 13.5 | 98.5% | 1.5% | 0.1% | 0.0% | 83.6% | 14.7% | 1.6% | 0.0% | 0.0% |
| *SS 1* | 5 | 4 | 23.9 | 98.3% | 1.7% | 0.0% | 0.0% | 85.9% | 11.5% | 2.6% | 0.0% | 0.0% |
| *SS 2* | 2 | 5 | 29.4 | 94.7% | 4.8% | 0.5% | 0.0% | 78.3% | 21.3% | 0.0% | 0.5% | 0.0% |
| *SS 3* | 2 | 2 | 22.8 | 71.4% | 20.3% | 8.4% | 0.0% | 70.1% | 13.1% | 16.2% | 0.7% | 0.0% |
| *SS 3* | 3 | 4 | 12.9 | 71.5% | 0.0% | 28.5% | 0.0% | 37.9% | 33.5% | 7.5% | 21.0% | 0.0% |
| *SS 3* | 4 | 3 | 12.9 | 66.0% | 33.0% | 0.9% | 0.0% | 0.0% | 88.7% | 10.4% | 0.9% | 0.0% |
| **Subtotal** | **6** | **21** | **115.3** | **85.5%** | **9.4%** | **5.1%** | **0.0%** | **65.6%** | **25.8%** | **5.9%** | **2.7%** | **0.0%** |
| **Head-Gut Fleet (HG)** | | | | | | | | | | | | |
| *HG 1* | 1 | 32 | 90.4 | 2.2% | 0.7% | 3.0% | 94.1% | 0.0% | 3.0% | 4.0% | 4.4% | 88.6% |
| **Subtotal** | **1** | **32** | **90.4** | **2.2%** | **0.7%** | **3.0%** | **94.1%** | **0.0%** | **3.0%** | **4.0%** | **4.4%** | **88.6%** |
| **Totals** | **7** | **53** | **205.7** | **48.9%** | **5.6%** | **4.2%** | **41.3%** | **36.8%** | **15.7%** | **5.1%** | **3.5%** | **38.9%** |

## EM System Control

An excerpt of sensor data from a Shoreside fishing trip is shown in Figures 5 and 6. The time series presentation in Figure 5 clearly identifies fishing activity, most notably by the distinctive patterns in the hydraulic pressure signal, the winch rotation counter, and vessel speed. The corresponding fishing activity associated with these sensor indications were verified with the video imagery.

Figure 6 is an example GIS plot showing the cruise track of the vessel overlaid on a hydrographic chart. The GIS plot corresponds to time series data graphed in Figure 5. The vessel cruise track is blue and the second tow of the trip, captioned in the graph in Figure 5, is highlighted in red. The vessel transited from Dutch Harbor to the entrance of Unimak Pass to complete a short tow there before beginning a long tow to the west (highlighted). The overnight tow duration was approximately 17 hours. The 180$^o$ turns near the tow midpoint and endpoint are visible in the four sensor signals plotted in the graph.

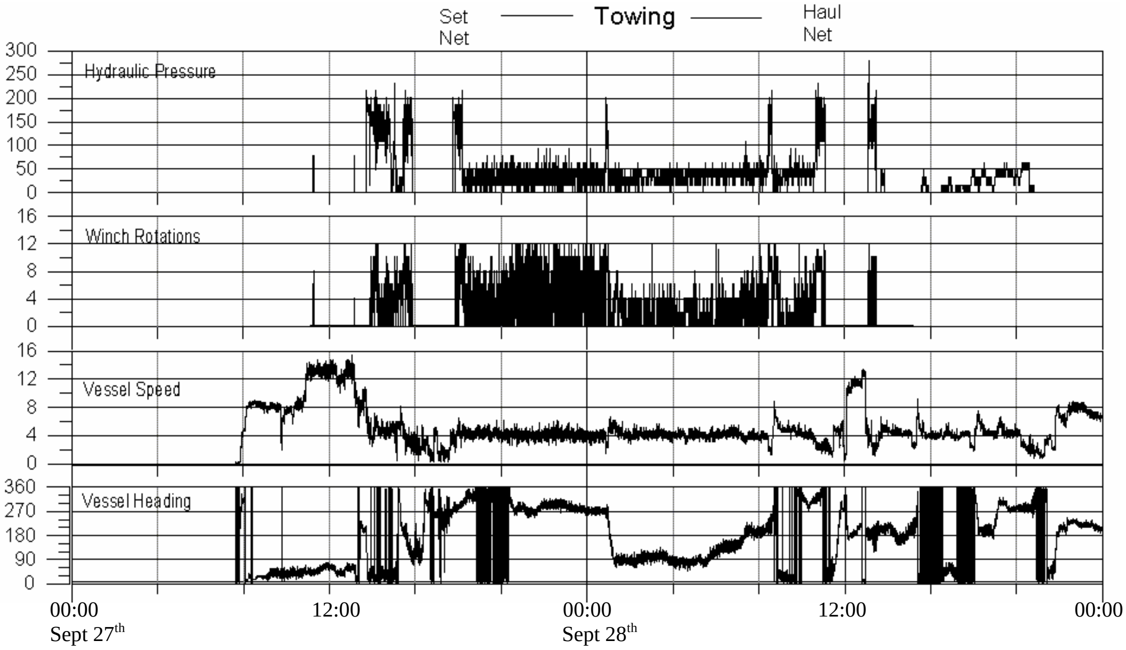


**Figure 5.** Time series graphs showing a 2-day fishing trip segment on a Shoreside vessel. Pressure spikes to 200 psi define the set and haul of the trawl net (top). The winch drum is active and vessel speed is steady for the duration of the tow. Lesser pressure spikes during the tow are related to winch tension changes when the vessel turns (see Vessel Heading). Each graph has the following units: pressure: psi, winch: count per 10 second, speed: knots, heading: degrees.

The most revealing sensor indication was with the third-wire winch sensor, which appeared to be constantly in motion whenever the trawl net was in the water. Vessel engineers stated that the amount of the third-wire deployed is continually adjusted to align with trawl-door cable settings and to maintain preset line tension. This process shows up as continual motion of the drum. Whenever the trawl net was not in the water, little or no third-wire winch sensor activity was recorded. Hydraulic pressure readings were also descriptive of fishing activity, but did not always give as clear picture of fishing activity as the third-wire winch sensor.

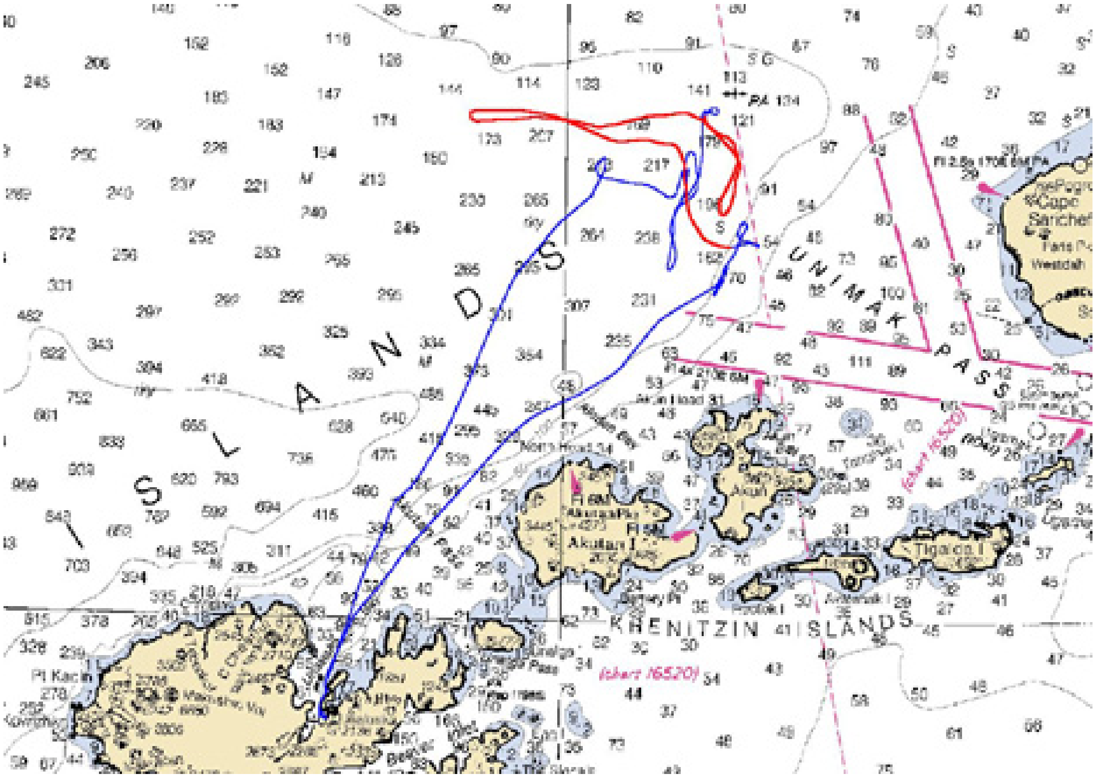


**Figure 6**. GIS plot of a fishing trip, corresponding to time series graphs in Figure 5. The vessel cruise track is shown in blue. The tow, denoted in the time series graph above, is highlighted in red. (North is up)

# DISCUSSION

## Technical Assessment of EM System

Electronic Monitoring offers a practical approach for assessing seabird interactions with trawl third-wire, although its utility will depend on the specific monitoring objectives. From a practical standpoint, the lengthy amount of time that fishing vessels spend with gear in the water fishing makes continuous monitoring by an at-sea observer impractical. The video imagery collected by the EM system is more efficient as many hours can be recorded and the imagery can later be replayed at a controllable viewing speed.

In terms of specific seabird interaction issues, EM imagery obtained during this study was useful in determining the presence of seabirds, their orientation with respect to the trawl third-wire, their general behavior, and relative abundance. While there were instances where certain seabirds could be identified, in general, image quality was not sufficiently clear to allow consistent seabird identification to the species-specific level. Seabird identification from video imagery depends on the birds' proximity to the camera, uniqueness of the species, taxonomic level of identification required, and experience of the analyst. Birds that are closer to the camera and to the third wire were easier to identify than those farther away. From the imagery, we could categorize birds near the third wire by broad species groups according to size. In some imagery viewed by an experienced seabird observer, it was obvious most birds in the area were northern fulmars (*Fulmaris glacialis)*, black-legged kittiwakes, and shearwaters (*Puffinus* spp.*)*. A few larger gulls were present in much lower numbers, and there were no albatross in the field of view. Some individual birds could be easily identified when a diagnostic character was captured in the imagery.

Electronic Monitoring was successful in documenting seabird entanglements on the third wire although careful study of the associated fishing event imagery did not reveal causes for the entanglement, but it is likely that these were seabirds that had been sitting in the water ahead of the third wire. The entanglement may actually have occurred while the third wire was out of the field of view. This occurred when the vessel turned, which may have brought the third wire across the offal stream behind the vessel. We did not analyze the interactions where birds changed their behavior in response to the third wire without actually encountering it. This was difficult to judge for flying birds and easier to determine for birds on the water.

The quality of imagery directly affected the nature of seabird interaction information possible. Image quality could be improved with higher data capture settings (e.g., higher frame rates and a lower data compression ratio) although the most significant factors influencing image quality were related to the environment such as:

- *Distance Between Camera and Third Wire* – In most installations, the distance between the CCTV cameras and the point where the third wire entered the water was 50 -100 m. Image resolution degrades over this distance, particularly in stormy wet weather where visibility is restricted.

- *Camera Field of View* – The camera setting must balance between providing sufficient resolution of the third-wire entry point to clearly see seabirds and providing overall coverage of the stern area so that the third wire is in view during vessel maneuvering and various sea states. These requirements were achieved by pairing a wide-angle view and narrow field view cameras. Partitioning the view area with more cameras would provide better results than by a single wide-angle camera.

- *Vessel Motion* – The use of cameras fixed to the vessel results in imagery that pitches and rolls with the motion of the vessel. Imagery with such constant movement is difficult to interpret, particularly with higher lens magnifications and rougher sea conditions. Image interpretations were much easier when the camera field of view was positioned low and included the horizon for a frame of reference.

- *Ambient Light* – The cameras used in this study were useful for monitoring daylight fishing operations. Imagery from fishing at night was not useful for analysis. While the stern area of many vessels is well lit, resolution of the third-wire entry point was poor or absent. The backscatter on rain at night or lowlight conditions also reduced image quality.

The utility of EM would depend on the type of monitoring being considered. Below are three possible monitoring applications:

- *Mitigation Monitoring* - The goal of the EM system for monitoring mitigation measures would be to document the use of the mitigation measure and the resulting effect on seabirds. Mitigation measures could include keeping the third wire within a certain distance from the stern, the use of streamer devices (i.e., the New Zealand “Bird Baffler”), and offal discharge controls. In our view, EM would be ideally suited for this application.

- *Seabird Presence and Absence* – The goal would be to evaluate whether birds are at risk for a fleet using a specific fishing mode, or in certain areas or times of the year. If very few birds were present while the third wire was being towed, it is unlikely that they would be put at risk. Therefore, any mitigation requirements resulting from future work might not be applied to all trawl vessels at all times when using third wires.

- *Seabird Interaction Monitoring* – The EM goals would be similar to the mitigation monitoring but would include more direct assessments of species interactions, species identifications, specific interaction behavior, and estimates of takes. While the existing technology would be useful for gross observations (i.e., discerning basic differences between fleets), in our view, EM would not be suitable for this application without more specific technological development. Ideally, this could be achieved with concurrent EM and seabird observer monitoring. Such monitoring could mesh these two data sets and set up decisional matrices for establishing species identifications, reactions to the third wire, and validation of encounters. Such work would prove valuable in addressing the broad range of vessel activity and seabird abundance in Alaskan waters.

In addition to the imagery for seabird interactions, the EM systems were successful in providing other information about the fishing trip. When sensors were used, the resulting data provided a clear description of the fishing trip, including the time and location of fishing events. This information is useful in relation to analysis and interpretation of the imagery and setting the monitored events into a fishery context. As well, the sensor data can be reliably used by the EM control software to more strategically control image capture. In this way, image capture for 100% of fishing events would be possible even for long catcher/processor fishing trips.

Image analysis conducted in this study took place at about one-fourth the actual fishing time. Analysis time was governed by the presence of seabirds and the kind of image interpretations desired. In this study, image playback speed was selected to discern seabird strikes with the third wire. The lower proportion of time when seabirds were present among Shoreside fleet fishing trips resulted in a small amount of image time. In contrast, the nearly constant presence of seabirds in relation to the single H&G fishing trip observed resulted in image interpretation for nearly 100% of the fishing time. In either case, the labor requirement for image interpretation was considerably less than what would be required using an at-sea observer *in situ.* Using the H&G fishing trip as an example, the observer labor would be the trip duration (10 days), compared with approximately 25 hours of EM labor.

EM suitability for the monitoring application also depends upon the reliability of the equipment. In this study, there were 14 EM deployments on five separate vessels that resulted in six fishing trip data sets that were usable for analysis of seabird interaction issues. Among the unusable fishing trips, most failures were related to the nature of a pilot program where the application is new, and sampling activities are opportunistic and spontaneous. There were three fishing trips where data losses were due to technical failure of the equipment. One technical problem was related to a hard drive failure, which is generally uncommon and difficult to anticipate. The remaining two problems were on the same vessel where the control box was mounted on deck within a waterproof tote. This mounting location provided limited protection from the weather during servicing and, as a result, the technician was not able to properly diagnose the problem and prevent it from reoccurring on the second trip. Since the field program, modifications to the control software have been incorporated to detect and correct this type of problem.

The uncertainties that accompany pilot projects usually results in loss of data. However, with increased use of EM in a fleet monitoring application, the level of data capture will increase, as start-up issues are resolved. As an example, Archipelago provides EM-based monitoring on a 45-vessel crab fleet in northern British Columbia. The monitoring program is in its third year of operation and experienced a data capture rate of 99.6% in over 2,500 vessel days at sea (Archipelago, unpublished data).

Obtaining reliable winch activity information is important to detect fishing gear deployment. This information could be used to activate image recording or, in the case of this study, to distinguish between fishing and non-fishing imagery. In pilot projects, such controls are usually not implemented unless the data signatures are easily identifiable. In the automatic operation mode, the control box would be continuously powered such that the data-logging computer always monitors and records sensor data. When the control software detects sensor data relating to fishing activity, the image computer would initiate recording. When control software detects the completion of fishing, there would be a preset time delay to ensure fishing has actually halted. The video image recording would then cease. In order to consider this type of control on image recording, sensor signatures were analyzed to determine the characteristics relating to fishing imagery.

Unfamiliarity with the design of the winches in this pilot study hindered the correct choice of sensor type and placement location. The results of hydraulic pressure tests at dockside were often unrepresentative of the operational pressures recorded during tows. There was also little time available during the EM service routines to experiment with hydraulic pressure sensor relocation. A better understanding of the third-wire winch design and operation would have to be acquired to use the pressure signal as a source for automatic activation.

## Feasibility of EM for Monitoring Seabird Interactions with Trawl Third-Wire

Electronic Monitoring would be useful for gathering more information about seabirds and trawl third wire. Seabird presence was detected in both the Shoreside and H&G fleets. However, their abundance was quite different with respect to one another. The imagery from the Shoreside fleet revealed that seabirds were present mainly during setting and hauling operations and generally absent while the vessel was fishing. However, during poor weather conditions, seabird abundance increased. In contrast, among the H&G fleet, seabird abundance was high for the entirety of fishing activity, regardless of weather. The most likely reason for such a high abundance of seabirds was the offal discarded from the vessel during processing.

The EM imagery also successfully detected interactions with the third wire. In addition to the general description of increasing levels of interaction, specific incidents of contact were documented. Strikes or near strikes of seabirds with the third wire were witnessed on two occasions. Capturing imagery with a higher frame rate would no doubt improve the ability to detect this type of interaction. Seabird takes, incidents where seabirds became entangled on the third wire and brought in during a haul, were witnessed in 3 of the 32 sets from one H&G vessel.

From the analysis, it is clear there were seabird interactions with the third wire. In our view, further baseline work is needed to more specifically understand the nature of seabird interactions with the trawl third wire. Some of this information may be available from literature sources. Specific deployments of at-sea observers would also be useful to provide more detailed interpretations of seabird behavior that may lead to third-wire entanglements. This information, combined with EM-based observations where significant seabird interaction (i.e., catcher/processors) occurs, would be useful in developing appropriate mitigation measures. Once these measures are in place, EM would be a useful tool to monitor compliance and effectiveness of mitigation measures.

Fishing vessels examined from all three fleets are ideal platforms for EM equipment. As compared with our experience with other fleets, all vessels in this study were relatively straightforward for installation of the equipment, with excellent electrical power and adequate dry storage for the EM control box. In the future, EM installations on these fleets should involve more discussion with vessel owners and operators to ensure successful installation and to convey mutually beneficial opportunities. In our brief discussions with AFA skippers, a few expressed a desire for camera imagery to be displayed on the bridge, improving safety and providing the opportunity for vessels to more directly influence seabird interactions with their fishing gear. Improved performance of the EM equipment would also occur with more significant involvement by vessel personnel. All installations in this study were done between fishing trips where time was tight or access to the vessel personnel was limited. In future studies, as much as a day per vessel should be allotted for setup and testing during the initial installation of EM equipment as basic issues such as wire runs, mounting locations for cameras and sensors, and access points to power and hydraulics must be established. The availability of vessel personnel, in particular the skipper and chief engineer, greatly aids in this process. Following the initial installation, EM equipment can be removed and re-installed more quickly with less involvement by vessel personnel.

The use of an EM system for this application would occur with the basic equipment used in this study and some specific modifications. Most importantly, the EM system must operate with automatic software control to trigger activation of image recording during fishing operations. The information gathered in this study would enable the specific software modification although the third-wire winch sensor and hydraulic pressure transducer would be necessary for all applications. The magnetic switch winch sensor used in this study would not be practical given the difficult mounting requirements. We have experimented with an optical sensor that has simpler mounting requirements and would be better suited for this application. The hydraulic pressure transducer used in this study would be appropriate, although more discussion with vessel engineers is necessary to determine appropriate mounting locations.

Another modification for consideration is camera placement. Positioning the cameras lower on the vessel would be more ideal as seabird and third-wire images that contrast against the sky are easier to interpret. As was discovered in this study, a trawl deck mounting location would be difficult without a sufficiently armored camera mounting system. Discussions with the vessel owners and operators would be necessary to develop this further.

# CONCLUSIONS

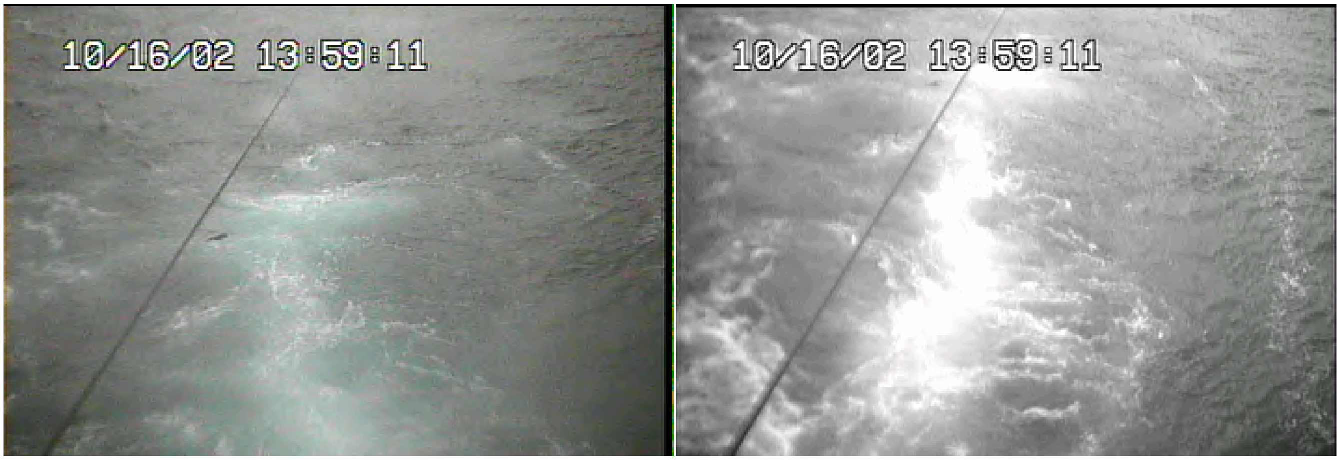
Results from this study demonstrated that EM could be an effective tool to monitor seabird interactions with trawl third-wire cables. The EM system used in this study provided imagery of sufficient quality to detect the presence, relative abundance, and general behavior of seabirds during most daylight fishing events. As well, EM-based imagery was also able to detect third-wire entanglements of seabirds although it was not possible to determine the cause of these entanglements. In our configuration, EM imagery was useful for enumeration of seabirds by broad categories directly astern of the vessel, but not for specific counts of birds either directly astern or in attendance around the vessel. Species identification depended on several factors. Birds that were near the stern, and often near the third wire, could at least be categorized by general form and size class. Differences could be seen between small, medium, and larger birds such that albatross could likely be enumerated (none were seen in this study). Diagnostic features of some birds were seen, and some black-legged kittiwakes and northern fulmars were identified to species. We were not able to identify the entangled birds to species. In regard to monitoring seabird interactions with trawl third-wire, EM would be very suitable for monitoring the use and effectiveness of mitigation measures.

# ACKNOWLEDGEMENTS

The authors would like to thank the captain and crews of the Shoreside and H&G vessels for their cooperation in the project, as well as the industry representatives that assisted in arranging these trips.  NMFS staff in Dutch Harbor, Ms. Jennifer Watson and Mr. Rob Swanson, were very helpful with the field aspects of the program.  We also thank the Groundfish Observers who assisted in this project in the field.  Funding for this study was supplied by the NMFS National Observer Program Office, with additional support from the Alaska Fisheries Science Center.

# APPENDIX – Sample Imagery From Each Vessel

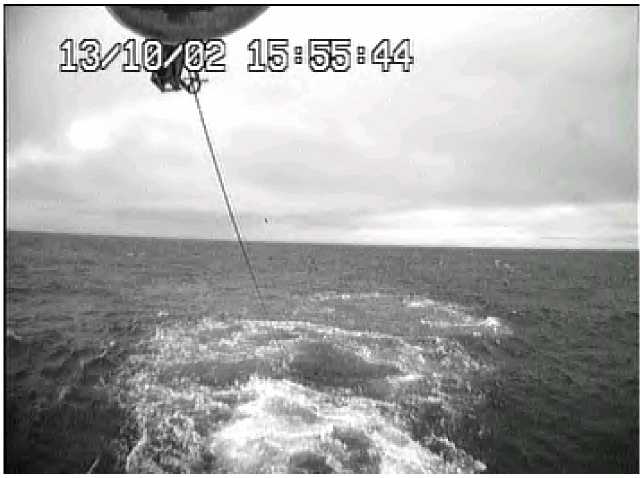
SS 1



SS 2

(hauling event)

SS 3


13/10/02 15:55:44


09/10/02 17:10:07

H&G 1


10/12/02 10:21:02


10/12/02 13:40:04

H&G 2


16/10/02 09:28:13


16/10/02 12:04:54

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