

Trials on F/V Sea Mac
To Evaluate the Use of Electronic
Monitoring for the Kodiak, AK Rockfish
Pilot Program

Prepared by

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Introduction

The management of the rockfish fishery in the Central Gulf of Alaska has shifted from open access to fishing cooperatives. Under the new Rockfish Pilot Program (RPP), fishing cooperatives track individual allocations of target and bycatch species, and NMFS oversees program management and allocations as appropriate. In its implementation of the new program, NMFS has increased observer coverage from 30% to 100% for participating shore-side rockfish catcher vessels. An issue for RPP participants is the cost increase for observer coverage relative to the expected increase in revenues from the rockfish fishery and concerns over the accuracy of halibut bycatch amounts based on present North Pacific Observer Program sampling methods which were not designed for estimating haul-specific catches on individual vessels.

In the west coast domestic whiting fishery and several west coast of Canada fisheries, electronic monitoring (EM) is used on fishing vessels for a variety of purposes including: fishing time and location, gear deployment and retrieval methods, catch estimation, and bycatch mitigation practices. For the Rockfish Pilot Program, it was proposed that catch monitoring could be achieved through a combination of catch sampling at shore-side plants and the use of EM while the vessel is at sea to fully census discards of halibut and ensure that all other catch is retained aboard the vessel. In addition to assessing its utility in fishery monitoring, it has also been proposed that EM may have use in monitoring marine debris. For the purposes of this study, marine debris is defined as any anthropogenic material brought aboard the vessel or material originating from the vessel and discharged overboard. The range of items likely include fishing gear or parts thereof, trash, plastics or other discarded items.

To test these ideas, the Alaska Groundfish Data Bank (AGDB), NOAA and Archipelago Marine Research Ltd. carried out a study with a vessel chartered to operate under conditions similar to those encountered under the RPP. The objectives of the study were:

- Assess the haul level accuracy and precision of estimates of the number and weight of halibut discarded (using published tables of length/weight regression) on a trawl vessel based on data from EM and standard observer sampling using a complete census of halibut in each haul as a known standard reference. This assessment will include appropriate statistical tests of whether there are differences between the estimates and the known haul amounts. This aspect of the work is being contracted through a separate contract with a qualified statistician and Archipelago is not directly involved in this aspect of the research.
- Provide an assessment of the utility of EM for monitoring discards on deck and estimating halibut discards. In addition to providing the estimates of halibut discards for this part of the work, Archipelago will contribute to the overall assessment of the extent to which error in the EM estimates of number and length of halibut is a function of the equipment and its placement, pace of discards and liveliness (viability) of halibut passing by the cameras, ambient conditions affecting the ability of cameras to obtain length data on halibut, technique used

for reviewing EM data (including individual reviewer bias), and other important factors associated with estimating halibut discards with EM.

- Evaluate the suitability of EM in monitoring gear loss or damage, and monitoring the retrieval of lost gear or other debris of anthropogenic origin.
- Assess the costs associated with collecting and reviewing EM data. Cost and scale of operations information provided by Archipelago will be used to help inform this aspect of the overall project.

Archipelago's role in the project was to equip the charter vessel with EM equipment, conduct an analysis of EM data collected during the field trials, provide an overall assessment of the utility of EM to support the monitoring requirements of the RPP and evaluate the utility of EM for monitoring marine debris, as described above. This report provides a description of these aspects of the study.

Methodology

Field Study

AGDB obtained an Experimental Fishing Permit to charter the commercial fishing vessel *F/V Sea Mac* (Figure 1) to carry out rockfish fishing for about a four - week period in the fall of 2007, making 6 trips and 27 tows. The vessel was required to retain onboard all catch except halibut, under simulated conditions of the RPP. Observers were to carry out the standard basket sampling method for each tow to assess halibut catch. In addition, halibut were whole-haul sorted from each tow, counted and measured. Prior to measuring, halibut were passed across a 'pre-discard chute', simulating the discarding that would occur under the RPP. The pre-discard chute was graduated with 5cm marks to enable camera-based measurements of 'discarded' halibut.

Prior to the charter commencement, the *F/V Sea Mac* was equipped with an EM system. The EM system consisted of four closed circuit television cameras, a GPS receiver, a hydraulic pressure sensor, a winch sensor, and system control box (See Appendix I). The EM system and observers were simultaneously in place for all fishing trips in an effort to collect a duplicate data set for all fishing events. There were two EM system data recording configurations used. The first recorded imagery for 100% of the time, once the vessel left port and the second recorded imagery only during fishing events, as triggered by hydraulic or winch sensors. Image recording rates were set to six frames per second (fps) for the main halibut discard chute, four fps for the overview of halibut discard chute area, and two fps each for the deck and stern view cameras. Sensor data was recorded 100% of the time while the EM system was powered. Following completion of the field study, the EM system was removed from the vessel and shipped to Archipelago for analysis of collected data.



Figure 1. Photograph of F/V *Sea Mac*.

EM Data Analysis

Sensor data (GPS, hydraulic and winch rotation) were analyzed to interpret the geographic position of fishing operations and distinguish key vessel activities including transit, gear setting, and gear retrieval. EM sensor data interpretation was facilitated using a relational database as well as time series and spatial plots. Raw data were first imported to an MS Access database where an analysis was performed to determine the completeness of each data set by checking for time breaks in the data record, as indicated by the duration between records exceeding the expected 10-second time interval. Time breaks in the data record were the result of loss of power to the EM system, system lockup, or GPS signal failure.

The objectives of image interpretation were to firstly assess whether all the intended imagery was recorded properly, then to analyse imagery for specific events of interest.

The fishery monitoring elements of the project required the following of the image analysis:

1. Measurement of lengths of halibut on pre-discard chute - EM viewers reviewed imagery from catch stowage operations of all fishing events to enumerate and measure halibut passing across the pre-discard chute (Figure 2). Fish lengths were determined by measuring the fish in millimetres and scaling this measurement to the reference provided by the 5cm graduation marks on the pre-discard chute. All halibut were measured by fork length. Two independent viewers examined all fishing events.

2. Assessment of discard events – Imagery of the whole fishing deck was examined from a sample of fishing events to verify that all catch was being stowed and that no discarding was occurring. For this analysis ten sets were randomly selected from the first five trips and all fishing events from the last trip were selected.



Figure 1. EM camera views from F/V *Sea Mac* showing pre-discard chute and fishing deck.

The marine debris components of the project were carried out differently. It was recognized that marine debris encounters could occur at any time during a fishing trip but were more likely during the haul back catch stowage operations. Therefore a two-phased approach was taken for image analysis:

1. Assessment of marine debris in association with fishing events – Imagery from fishing deck cameras was examined from about half the fishing events (same events as #2 above) to look for marine debris that occurred in the catch.
2. Assessment of marine debris in general – An entire fishing trip was selected for complete viewing. The deck view cameras were examined for the entire fishing trip, including fishing events to determine if marine debris was either taken aboard or discharged.

At the completion of the marine debris investigation, the viewer involved provided an assessment of the usefulness of imagery for detecting certain types of marine debris encounters.

Image analysis times were recorded for all aspects of EM data analysis in order to measure the amount of time required to analyse imagery in relation to the real time of the fishing event.

Results

EM System Performance

The EM system collected data over the course of six trips. There were 27 sets made, ranging from three to seven sets per trip. EM system performed well for all fishing trips with no system error caused data loss (Table 1). Out of a total of nearly 340 hours of operation, there was 8 minutes of lost sensor data due to a system wide GPS signal failure. This signal failure was also detected in other EM systems operating in British Columbia. Among the image data, the initial plan was to record imagery for 100% of the first trip and fishing events only thereafter. With some initial set up errors encountered during the first trip, image recording was set to fishing events only. All trips except trip 3 thereafter were set to record for the entire fishing trip. In total there were over 245 hours of imagery recorded with no data loss experienced.

Table 1. Summary of EM data collected, summarized by fishing trip.

Trip #	Departure Date	Total # of Sets	Sensor Data		Setting	Image Data	
			Hours	% Success		Hours	% Success
1	16-Sep-07	4	41.95	99.7%	FE	9.42	100.0%
2	19-Sep-07	4	40.93	100.0%	Trip	40.93	100.0%
3	23-Sep-07	4	76.54	100.0%	FE	15.86	100.0%
4	28-Sep-07	3	47.87	100.0%	Trip	47.87	100.0%
5	7-Oct-07	5	69.47	100.0%	Trip	69.47	100.0%
6	11-Oct-07	7	62.28	100.0%	Trip	62.28	100.0%
Totals		27	339.04	100.0%		245.82	100.0%

Table 2 summarizes fishing events carried out in this study by time and duration of each event. A total of 79 hours was spend on the 27 fishing operations with the duration of each event ranging from about an hour to eight and most taking less than three hours. Fishing time (doors out and net deployed) made up a little over half the total time while stowage time (net retrieval and stowage of catch) makes up the balance. Image analysis activities focussed on the stowage interval when fish are on deck being sorted, processed and stowed.

Table 2. Summary of EM data collected, summarized by fishing events.

Trip	Set	Fishing Event Start	Fishing Time	Stowage Time	Total Duration
1	1	9/16/07 5:35 PM	2:00	1:55	3:55
1	2	9/17/07 7:52 AM	1:06	0:44	1:50
1	3	9/17/07 10:56 AM	1:19	0:32	1:51
1	4	9/17/07 1:32 PM	1:00	0:48	1:48
2	1	9/20/07 8:16 AM	1:27	3:18	4:45
2	2	9/20/07 12:48 PM	0:55	0:57	1:52
2	3	9/20/07 3:44 PM	1:21	1:06	2:27
2	4	9/20/07 7:12 PM	2:56	0:49	3:45
3	1	9/24/07 1:30 PM	0:29	0:33	1:02
3	2	9/24/07 6:43 PM	1:59	0:49	2:48
3	3	9/25/07 12:40 PM	0:33	7:44	8:17
3	4	9/26/07 7:46 AM	0:46	2:57	3:43
4	1	9/28/07 8:53 PM	3:12	0:37	3:49
4	2	9/29/07 9:47 AM	2:43	1:13	3:56
4	3	9/29/07 6:59 PM	1:39	1:19	2:58
5	1	10/8/07 1:18 PM	0:54	1:37	2:31
5	2	10/8/07 6:25 PM	0:44	0:39	1:23
5	3	10/9/07 8:01 AM	1:03	0:44	1:47
5	4	10/9/07 10:48 AM	1:34	1:06	2:40
5	5	10/9/07 2:38 PM	1:36	1:01	2:37
6	1	10/12/07 9:06 AM	2:12	0:51	3:03
6	2	10/12/07 1:02 PM	2:36	0:53	3:29
6	3	10/12/07 7:12 PM	0:56	0:18	1:14
6	4	10/13/07 8:57 AM	2:18	0:32	2:50
6	5	10/13/07 12:43 PM	1:32	0:28	2:00
6	6	10/13/07 3:23 PM	2:23	0:16	2:39
6	7	10/13/07 7:24 PM	2:42	1:18	4:00
Total			44:04	35:04	79:08

Image Data – Fish Monitoring Issues

Two viewers examined imagery from all 27 fishing events, providing independent counts and measurements of halibut. The viewers had the same count of halibut on all but three fishing events. Among the three mismatched sets, each differed by one piece and the net difference for the total halibut recorded on all fishing events was also one piece, with total counts of 775 and 776 pieces for the two viewers, respectively.

Halibut size measurements were compared between the two viewers and were found to be very consistent across the full size range of halibut encountered. These results are shown in Figure 3 comparing the two EM viewer data sets.

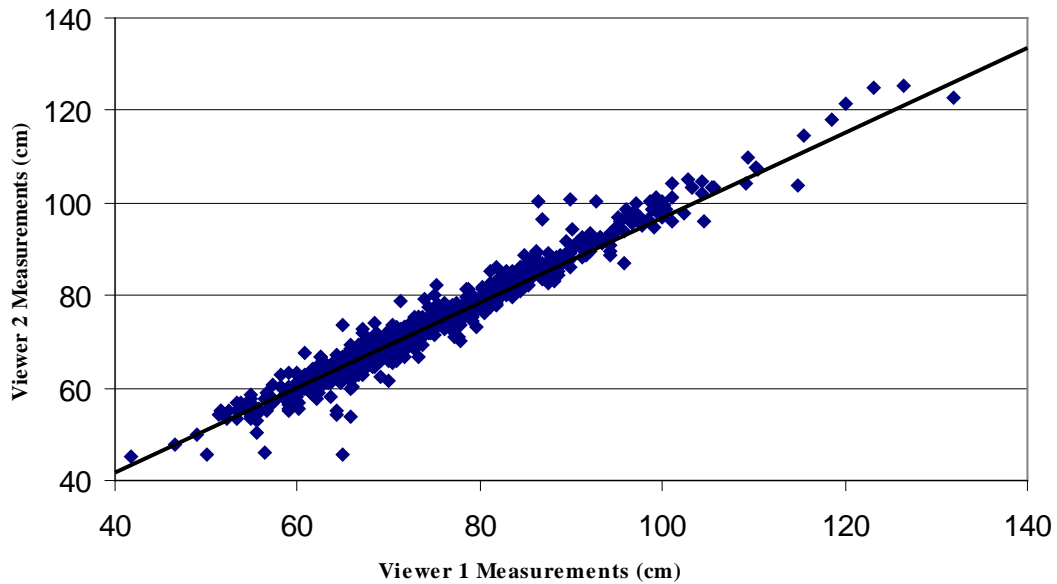


Figure 3. Scatter Plot showing the relationship between two image analysis viewers for measurements of halibut.

After the halibut measurements were completed, the imagery was examined for other discarding events and the discarding of halibut by means other than through the pre-discard chute. There were eight incidents of discarding from the imagery examined (Table 3). In all but one case, the fish discarded were those that were tangled in the net and either discarded or left in the net when the net was wound back onto the drum. The number of pieces for these eight incidents ranged from one to eight. The last discarding incident involved an estimated 40 pieces of red rockfish that appeared to be discarded after the holds were filled.

Table 3. Summary of discard observations made from examination of a sample of fishing events.

Trip	Date	Set	Time	Species	#	Comment
6	11-Oct-07	1	9:01	Unknown	4	When setting net, 4 pieces of fish fell out of net onto deck and were discarded.
6	11-Oct-07	2	15:58	Flatfish /roundfish	7	Wrapped in net and wound around drum as it is coming onboard. Two fall out as net is reset for next haul and kicked overboard. The other 5 are assumed to be in the net as it is reset.
6	11-Oct-07	4	8:55	roundfish	1	Fell out of net as it was being set - thrown overboard
6	11-Oct-07	5	12:44	Flatfish	8	Fell out of net as it was being set - thrown overboard
6	11-Oct-07	6	15:19	Flatfish	5	Caught in net from previous set, and were in net as it was re-set
6	11-Oct-07	7	21:56	Flatfish	4	Caught in net from previous set, and were in net as it was re-set
6	11-Oct-07	7	22:21	Flatfish /roundfish	6	Wrapped in net and wound around drum as it is coming onboard. Net is not re-set, so assumed that fish remained in net until cleaned.
3	23-Sep-07	4	11:46	Red Rockfish	40 ap.	Unable to positively determine due to camera angles, but appears as though crew member discarding through scupper due to vessel overloading.

Image Data – Marine Debris Issues

The marine debris analysis included a total of 17 fishing events and all imagery for the last fishing trip. There were no incidents of marine debris encountered during periods other than during fishing operations. On three fishing events there were incidents observed as summarized in Table 4. In the first instance, the net was in the process of being retrieved and the crew were seen working on the portion of net wound on the net drum. A coil of cable was seen being carried away as a result of this operation. It is not known whether this was cable brought up while fishing or simply third wire cable from the trawl net. The second object observed appeared on the trawl deck while the codend was being emptied. The object was large, possibly a dark rock. The third object observed was a small piece of rope that was pulled from the catch and was set aside by crew on the deck. All items except the rock were apparently retained onboard.

Table 4. Summary of marine debris observations made from EM imagery.

Trip	Date	Set	Activity	Time	From Net?	Discarded?	Item Description	Comment
6	11-Oct-07	3	Hauling gear	21:34	Yes	No	Cable in a coil	Possibly vessel's own gear.
6	11-Oct-07	4	Sorting fish	11:48	Yes	Yes	Round black object (possibly a big rock)	Discarded off vessel stern.
6	11-Oct-07	7	Sorting fish	23:23	Yes	No	Piece of rope	

Image Data – Analysis Ratios

Table 5 provides a summary of image analysis time associate with carrying out the two main types image review at the set level: halibut counting and measurement and discard and marine debris assessment. Overall, halibut monitoring review activities were carried out at about 70% of real time with individual events ranging from about 0.25 to over 2.5 (time real time). The main variables affecting analysis ratio would be image quality, catch volume, number of halibut, and the manner which halibut pass across the measurement chute. The discard and marine debris analysis was less time consuming, with an overall average of 0.38, about half that of the halibut analysis requirement. Again, variability in the time required per fishing event was high, ranging from 0.03 to 1.6. The main variables affecting marine debris and discard assessment were image quality, volume and composition of catch, and the manner which crew handle catch.

The analysis ratios for whole fishing trip (trip 6) review included vessel transit time and time for fishing operations. The total duration of trip six was 63.3 hours, of which 4.6 hours was stowage time. The analysis ratio was 0.08 overall, 0.6 during fish operations and 0.04 during other periods.

Table 5. Summary of analysis ratios from fishing event level image viewing.

Trip	Set	Image quality	Stowage Time	Halibut	Review	Discard and Marine Debris		Comments
				Analysis Hours	Analysis Ratio	Analysis Hours	Analysis Ratio	
1	1		1.92	0.50	0.26			
1	2	High	0.73	0.75	1.02	0.12	0.16	
1	3		0.53	0.50	0.94			
1	4	High	0.80	0.75	0.94	0.13	0.17	
2	1		3.30	2.00	0.61			
2	2		0.95	1.00	1.05			
2	3	High	1.10	1.00	0.91	0.17	0.15	
2	4		0.82	1.25	1.53			
3	1	High	0.55	0.50	0.91	0.12	0.21	
3	2		0.82	0.75	0.92			
3	3	High	7.73	1.25	0.16	0.27	0.03	
3	4	Medium	2.95	0.75	0.25	0.38	0.13	Sun Glare
4	1		0.62	0.25	0.41			
4	2		1.22	2.00	1.64			
4	3	High	1.32	0.75	0.57	0.17	0.13	
5	1	Very low	1.62	1.50	0.93	0.22	0.13	Sun/ Shadows
5	2		0.65	0.50	0.77			
5	3		0.73	0.25	0.34			
5	4	High	1.10	0.75	0.68	0.13	0.12	
5	5	High	1.02	0.50	0.49	0.12	0.11	
6	1	High	0.85	1.00	1.18	0.50	0.59	
6	2	High	0.88	2.25	2.55	0.78	0.89	
6	3	High	0.30	0.25	0.83	0.48	1.61	
6	4	High	0.53	0.50	0.94	0.20	0.38	
6	5	High	0.47	0.25	0.54	0.18	0.39	
6	6	High	0.27	0.50	1.88	0.27	1.00	
6	7	High	1.30	1.50	1.15	0.35	0.27	
Total			35.07	23.75	0.68	4.58	0.38	

Conclusions and Recommendations

General

Results of this pilot study show promise for both areas of investigation. It is important to point out that the utility of EM for these monitoring applications in a commercial fishery setting may vary according to vessel configuration and level of cooperation by the crew. Success of EM is highly dependent upon camera placements and those available on the *F/V Sea Mac* were ideal. Some vessels may need to make structural modifications for camera placements.

The level of industry cooperation strongly affects the success of an EM-based monitoring program. In this study, cooperation was high and the equipment was attended on all trips by two observers. In a broader fleet-wide application involving EM, the motivation for EM success may not be as high. An EM system is not tamper proof and crew can interfere with it in various ways such as shutting off the power, disconnecting or diverting certain sensors, interfering with CCTV cameras, etc. While an EM system is designed to operate autonomously and be tamper evident, a tamper-proof design is likely not practical. The level of cooperation and support for EM-based monitoring should be considered prior to implementation as part of the RPP.

Fish Monitoring Issues

EM system performed very well in detecting halibut at the pre-discard chute. In this study, the 5cm graduations on the chute worked very well and should be continued provided they meet precision requirements. The placement of the pre-discard chute in relation to cameras is very important. Ideally, the chute should be fixed in a specific location so that the camera can be aimed at the chute and immediate surroundings. The pre-discard chute changed position slightly during the course of the project due to weather and vessel motion. The accuracy of halibut measurement is influenced by several factors. Firstly, image distortion is inevitable with the telescopic image, resulting in a 'keystone' affect (i.e., the top of the grid was a different dimension than the bottom of the grid). This distortion made it more difficult to calibrate screen measurements of fish, particularly if the chute location changes. Secondly, the speed at which fish were passed across the grid also influenced measurement accuracy. In most cases there were 2-3 frames recorded per fish, which would enable a few opportunities for selecting the best image to measure. A rough estimate of the speed that fish were moving along the chute is about 0.5 metres per second. Increasing the speed of fish movement reduces the number of pictures available while increasing the recording rate provides more pictures at the expense of higher data storage requirements. The two chute cameras recorded four and six fps for the general and specific views, respectively (See Appendix I). As most measurements were taken from the former camera, a higher frame speed should have been used. The pre-discard chute generally worked well in keeping fish properly aligned with the grid. Infrequent instances where the fish was not aligned with the chute graduation marks or very actively moving resulted in more difficult and less accurate measurements. In most instances halibut were clearly distinguishable on the pre-discard chute although small halibut may not be as easy to identify.

The influence of weather and other ambient conditions on image quality is difficult to quantify because such measurements were not systematically recorded. Image quality was assessed as excellent of all but two of the fishing events. In these instances image quality was degraded because of sun glare. Image quality was the same with natural and artificial light (day versus night), cloud cover and precipitation. Vessel motion also has little affect on image quality since the camera position is fixed relative to the vessel. Rough weather conditions could provide difficulty in making accurate counts of halibut if the rocking motion of the vessel causes fish to slide backward and forward across the measurement chute.

The second part of the fish monitoring involved examination of discard activities other than through the pre-discard chute. The analysis conducted revealed nine instances involving minor quantities of fish, which were mostly caught in the trawl mesh. Net cleaning is a normal part of trawl fishing and discards from such activities is generally not considered discarding. However, it would be useful to establish guidelines to more precisely distinguish the two activities. In this study, cameras were not trained aft so it was not possible to monitor spillage of fish prior to the net being brought aboard. Net

bleeding is likely rare but could occur in cases where the net is overfull or the net has unwanted catch. The importance of including stern monitoring should be considered.

Marine Debris

The utility of EM for marine debris monitoring is difficult to fully assess. Marine debris events appear to be relatively rare; very few incidents were encountered in this study despite the high level of image analysis (one full trip and 60% of the fishing events). Of the three incidents listed in Table 4, very likely only one was marine debris according to the definition provided in the Introduction. The incidence of marine debris would vary by fishing location and it would appear low where this study was carried out. The size of marine debris is also a factor influencing detection by EM. The wide field of view cameras used in this study provided imagery for the entire fishing deck but would poorly resolve small items such as plastic bags, small net fragments, cans, etc. We feel confident that large items such as crab pots, cable and large pieces of net would be easily detectable while small items such as rope or plastic trash would escape detection unless there was an associated activity such as a crewmember picking up the item. Small items may be difficult to identify and clearly establish as marine debris such as the rock like item in this study. During transit operations, imagery can be viewed at high speed (about 25 times real time) and events are detected by change such as crew walking on deck. During fishing operations, imagery is viewed at about 40% of real time, as there is so much activity to take in. With several crew working actively during the catch stowage operation it can be difficult to monitor each person. Thus, we believe that EM shows promise in monitoring encounters of large marine debris and has limitations with the detection of smaller items.

Cost Issues

Pilot projects have limitations in their ability to predict overall costs of using EM in a true fishery application. On the basis of cost per day in this study, observers would likely be a less expensive option than EM when all factors are considered. However, pilot programs are often more costly than developed programs. The cost elements for an observer includes briefing, deployment, time at sea, debriefing, and observer travel expenses. An EM program involves provision of EM equipment, field services for EM deployments on vessels, and office services for EM data interpretation, analysis and reporting. On most levels of scale, the labour requirements for an EM program will be less than an observer program. As well, a significant component of EM labour is office based which would have a much lower unit cost than observers or EM field technicians. If activity levels are high enough to justify EM equipment acquisition and installation costs, EM-based monitoring may be a less costly option. In Canadian fisheries with fully established EM-based fleet monitoring, the cost ranges from 20-35% of the cost of monitoring using observers.

The six fishing trips in this study required about 20 observer days at sea, for a total of 22-24 days overall while the basic EM labour requirement was about 10 days (excluding EM technician sea time, duplicate viewing, and other special activities). We would expect the EM labour requirement to decline significantly in an operational program as a result of economies of scale and established methodologies. Field service requirements achieve significant economies of scale in terms of effort per sea day with the number of vessels and duration of activity. Office-based data processing activities are less affected by scale but the analysis effort per sea day is already a compelling argument for EM. In this study the 20 days at sea (27 fishing events) resulted in about 35 hours of catch stowage time, the critical activity of monitoring interest. Basic image analysis work required about 21 hours to assess stowage operations, inventory halibut and monitor for discards. Including other time for data handling, quality assessment, sensor data interpretation, the total labour requirement would still be less than 30 hours. Data processing requirements for the marine debris issues would be considerably less.

The historic ‘Olympic style’ Kodiak rockfish fishery was intense in nature with several vessels actively fishing over a short duration. In this instance EM would have been more practical than observers because fewer people were needed to service the fleet and the level of activity was high making it easier to justify the EM field service infrastructure. Under a rationalized fishery fewer vessels fishing are expected but their fishing activity will extend over a longer time period. Fleet monitoring for this style of fishery would be simpler for both EM and observer monitoring but the low activity may make it harder to provide EM field services. The specific fishery context needs to be more fully examined in order better assess the viability of EM.

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APPENDIX I – EM System Description

Overview of the EM System

The EM system supplied by Archipelago for this project was operated on the ship's power to record imagery and sensor data during each fishing trip. The software was set to automatically activate image recording based on preset sensor indicators (e.g. winch activity). The EM system was configured to automatically restart and resumes program functions following power interruption. EM system components are described in the following sections.

Control Box

The heart of the electronic monitoring system is a metal tamper-resistant control box (approx. 15x10x8" = 0.7 cubic feet) that houses computer circuitry and data storage devices. The control box receives inputs from several sensors and up to four CCTV cameras. The control box is generally mounted in the vessel cabin and powered with either DC or AC electrical power. In the case of AC power, the control box may be also fitted with a UPS, to ensure continuous power supply. The user interface provides live images of camera views as well as other information such as sensor data and EM system operational status. The interface has been designed to enable vessel personnel to monitor system performance.

EM systems use high capacity video hard drives for storage of video imagery and sensor data. The locked drive tray is removable for ease in replacement. Depending upon the number of cameras, data recording rates, image compression, etc., data storage can range from a few weeks to several months. The four camera set up in this study (combined total of 14fps) and a 500-gigabyte hard drive would provide continuous recording for about 63 days.



Figure A1. EM control box and user interface installation.

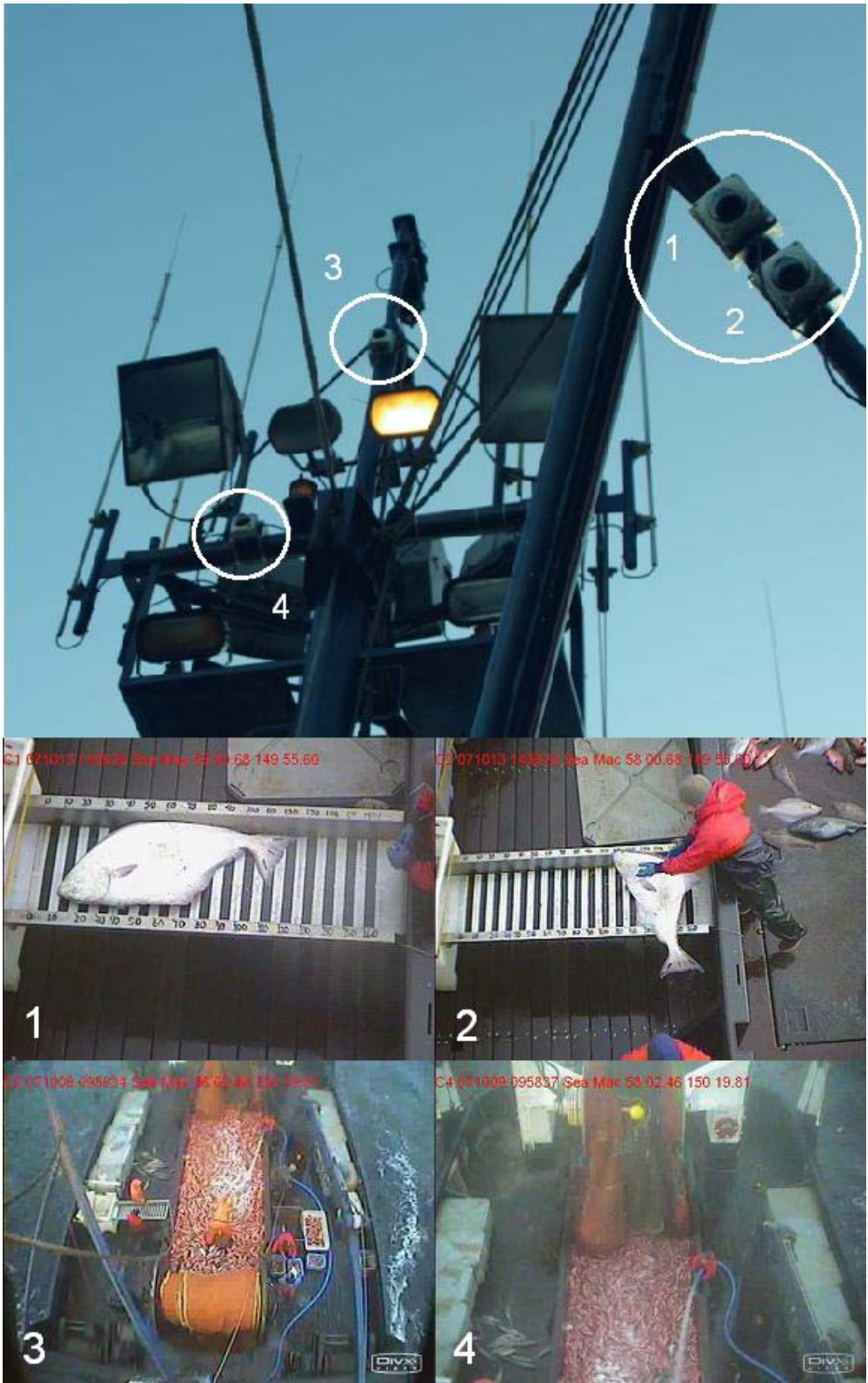


Figure A2 CCTV camera installations on three different fishing vessels. Each camera has a mounting bracket and stainless steel mounting straps.

CCTV Cameras

Waterproof armoured dome cameras were used as they have been proven reliable in extreme environmental conditions on long-term deployments on fishing vessels. The camera is lightweight, compact and quickly attaches to the vessel's standing structure with a universal stainless steel mount and band straps. In general, three or four cameras were used to cover general fish and net handling activity and areas around the vessel.

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

GPS Receiver

An independent Garmin 17N GPS receiver is installed with the EM system. The GPS receiver and antenna are integrated into a single plastic dome that is wired directly to the control box, there is no attached display interface. The GPS receiver is fixed to mount on top of the wheelhouse away from other antennae and radars (Figure A3).

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

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

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

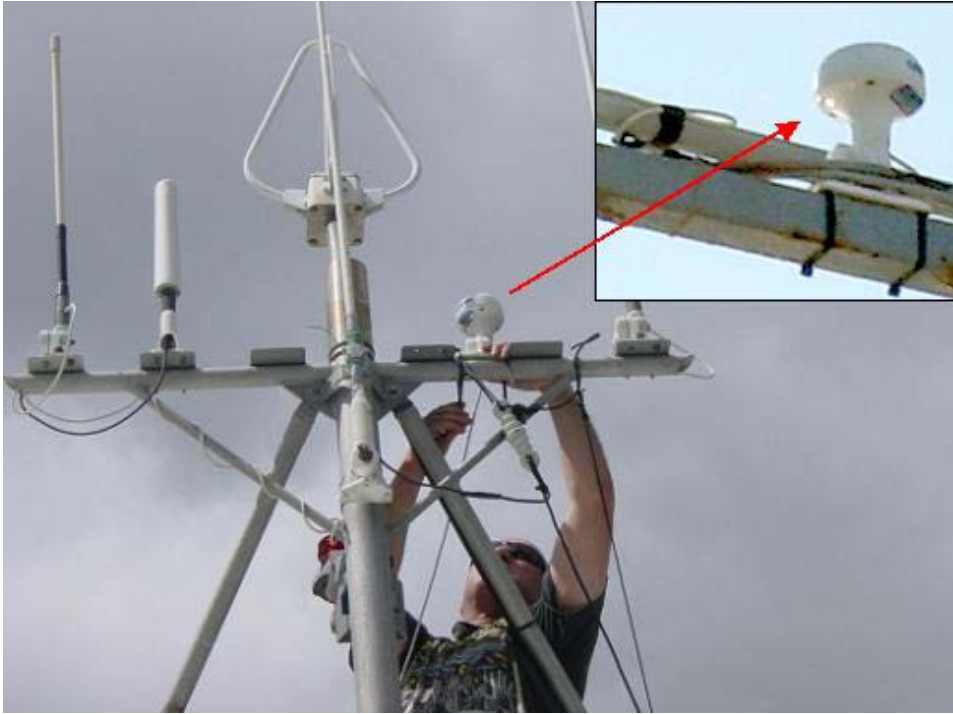


Figure A3. GPS receiver installed in the rigging of a vessel and a close up photograph of the mounted GPS.

Hydraulic Pressure Transducer

An electronic pressure transducer was attached to the hydraulic system (Figure A4) of each vessel to provide a record of fishing activity. The sensor has a 0 to 2500 psi range, high enough for most vessel hydraulic systems, and a 15,000 psi burst rating. The sensor is fitted into a ¼ inch pipe thread gauge port or tee fitting on the pressure side of the hauler circuit. An increase in system pressure signals the start of fishing operations such as longline retrieval. When pressure readings exceed a threshold that is established during system tests at dockside, the control box software turns the digital video recorder on to initiate video data collection.



Figure A4 Hydraulic pressure transducer installed at trawl warp winch.

Drum Rotation Sensor

A photoelectric drum rotation sensor is usually mounted on either the warp winch or net drum of each vessel (Figure A5). The small waterproof sensor is aimed at a prismatic reflector mounted to the winch drum to record winch activity and act as a secondary video trigger.



Figure A5. Drum rotation sensor mounted on trawl warp winch, showing optical sensor and reflective surface.