Continued Assesment of an Electronic Monitoring System for Quantifying At-sea Halibut Discards in the Central Gulf of Alaska Rockfish Fishery

EFP 08-01 Final Report

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Introduction

During 2007, a pilot study was conducted to determine whether electronic monitoring (EM) could be used to improve estimation of halibut discard in the Central Gulf of Alaska rockfish fishery (the Phase I study)(Bonney and McGauley, 2008). Based on results from a single vessel in an experimental setting, the study indicated that EM had the potential to produce more reliable and precise estimates of halibut discard when compared to current observer sampling methodologies. However, the study stressed that performance of an EM system in a commercial setting could be quite different and recommended further research into its broader utility. Specifically, the pilot study was unable to:

- reasonably assess the costs associated with large scale EM under different regulatory scenarios;
- determine the extent to which different vessel configurations, sizes and fishing methods would impact the practicability of EM;
- investigate the flow of data from an EM system at-sea to data available for the management of actual quotas;
- investigate the extent to which vessel crew would cooperate with the required halibut discard only policy necessary for accurate halibut accounting.

In order to more fully answer these implementation questions, the Alaska Groundfish Data Bank (AGDB) in cooperation with staff from NMFS, developed a second phase project to qualitatively investigate these outstanding pre-implementation questions.

Background

Amendment 68 to the Fishery Management Plan for the Groundfish of the Gulf of Alaska (FMP) established a rockfish pilot program (RPP) for quota-based management of the rockfish fisheries in the Central Gulf. Under the shoreside component of this program, catcher vessels with historic participation in the rockfish fisheries may form cooperatives. Each cooperative is allocated a share of the total allowable catch (TAC) for various rockfish species, sablefish and Pacific cod. The cooperatives are also allocated a limit of halibut prohibited species catch (PSC) to allow the prosecution of the quota fisheries. Under the program, all quota species must be retained by the vessel and delivered to a shoreside processor where they are weighed and debited from the cooperative's quota. Halibut PSC, however, must be discarded at-sea. At this time, halibut can only be effectively accounted against the cooperative's PSC limit if there is an observer onboard to estimate the amount of halibut catch in each haul.

When Amendment 68 was implemented, observer coverage for the participating catcher vessel fleet was increased from 30% to 100%. This increase was necessary to ensure that all quota species were retained and to allow for trip-specific estimation of halibut bycatch. RPP participants are concerned about the cost increase for observer coverage relative to the expected increase in revenues from the rockfish fishery. They are also concerned with the precision of halibut bycatch estimates based on present North Pacific Observer Program sampling methods which were not designed for estimating haul-specific catches of rare species such as halibut on individual vessels.

NMFS seeks to account for quota-catch based on full census accounting, rather than expanded estimates. This has not been possible for halibut PSC, which must be discarded at-sea and cannot be accounted for shoreside under the current system. While this issue was identified in the Environmental Assessment developed prior to implementation of the RPP (NMFS 2006), no better method for estimating halibut bycatch was available and the program was developed with reliance upon standard observer sampling protocols.

Description of the Fishery

Traditionally, the rockfish catcher vessel fishery took place in early July when the trawl fisheries were opened. Though all trawl fisheries opened at the same time, effort was focused on the Pacific Ocean Perch (POP) fishery, which generally closed after approximately one week. Following this closure, most vessels shifted effort into the northern rockfish fishery which normally closed about two weeks later. The rapid pace of the fishery created economic inefficiencies that reduced the value of the delivered rockfish. In response to these inefficiencies, congress granted NMFS specific statutory authority to manage Central GOA rockfish fisheries in Section 802 of the Consolidated Appropriations Act of 2004. This section required the North Pacific Fishery Management Council to establish a pilot rationalization program that recognized the historical participation of rockfish participants (the RPP). NMFS published a Final Rule implementing this program in November of 2006 (71 FR 67210). In brief, the shoreside component of this program allows catcher vessels with historic participation in the rockfish fishery to form cooperatives around a processor that has a history of taking rockfish deliveries. Based on the amount of rockfish harvested by coop vessels during the qualifying years, the cooperative is then given a fraction of the allowable catch for primary rockfish species (POP, Northern rockfish and pelagic shelf rockfish) and secondary species (sablefish, Pacific cod, rougheye rockfish, shortraker rockfish, and thornyhead rockfish). Additionally, each cooperative is given an allocation of halibut mortality proportional to the rockfish quotas which may not be retained on board the vessel and must be discarded at sea. Vessels belonging to the cooperative are allowed to harvest species managed under the program between May 1 and November 15.

Vessels fishing for primary and secondary species incidentally catch halibut. The amount of halibut caught varies depending on the gear used, the species targeted, and the location fished. In general, vessels targeting POP or using midwater gear will catch less halibut than vessels targeting northern rockfish or using bottom contact gear. Under the RPP, cooperatives and the vessels that fish for them have a strong incentive to reduce halibut bycatch to the extent that not doing so may limit their full harvest of primary and secondary species. Because of this incentive, vessels targeting POP have switched to almost exclusive use of midwater nets and bycatch rates for halibut have been very low. However, some level of halibut bycatch is unavoidable, especially when a vessel is targeting those species, such as northern rockfish, that live near the bottom in close association with halibut.

Catch Accounting in the Rockfish Fishery

Most catcher vessels participating in the rockfish fishery prior to rationalization were required to carry an observer 30% of the time, and NMFS accounted for catch in the fishery using two primary data sources: observer data when available from observed trips, and landings data submitted by processors receiving the catch. These data were sufficient for managing a “limited access” type fishery, but were inadequate for monitoring a quota fishery where catch of all quota species is allocated to an entity (one or more cooperatives). In order to manage a quota based rockfish fishery, NMFS implemented new catch accounting procedures. Quota species (primary as well as secondary) may not be discarded at sea and are accounted for on a delivery by delivery basis at the time of each offload. Halibut PSC however, may not be retained on board the vessel so it is not possible to account for halibut at the time of delivery and it must be accounted for at-sea. Under the regulations implementing the RPP, NMFS increased observer coverage requirements for catcher vessels from 30% to 100%. There were two primary reasons for this increase. First, without at-sea observer coverage, it is not possible to account for halibut PSC on unobserved trips without using halibut rates from other vessels; which would make quota holders effectively responsible for the fishing behavior of other quota holders. Second, it is not be possible to ensure that less valuable or limiting quota species are not being discarded at-sea.

NMFS uses shoreside data to manage the quotas of all rockfish and secondary species, but uses at-sea estimates made by observers to manage halibut PSC. In general, at-sea estimation of species composition, and estimation of halibut bycatch specifically, is problematic. When a codend comes on board, the observer on a rockfish trawl catcher vessel estimates the volume of fish in the net. The observer then takes a density sample to estimate the weight of fish per unit volume and multiplies the two estimates to obtain an estimate of the total catch. If conditions do not allow an observer to obtain a volumetric estimate, then the captain's hail weight is used to estimate official total catch.

Using a random sampling methodology, the observer obtains a sample of approximately 300 kg of fish. Fish within the sample are identified to species and weighed. This sample is then expanded by the estimated weight of the haul to give an estimate of the weight of each species in the haul.

Because the observer cannot work 24 hours a day, not all hauls are sampled. When it is not possible for an observer to sample a given haul, the species composition estimate from other hauls is applied to the unsampled haul and expanded based on the skipper's hail weight for the unsampled haul.

There are several potential sources of imprecision in this methodology. First, the estimation of the volume of fish in a net is imprecise. Second, the observer must estimate the weight of their sample as well as the weight of the individual species using fairly simple scales that are neither as precise nor as accurate as the electronic scales that are used to weigh catch shoreside. Third, the average tow in the rockfish fishery is approximately 13 mt, so less than 2% is actually sampled. Fourth, not all hauls can be sampled. Because halibut is a comparatively rare species, the estimate of species composition is especially imprecise at the haul level though it may be accurate when the estimates are aggregated across deliveries, vessels and the season.

Results of Phase I

Phase I of this EM study (Bonney and McGauley, 2007; McElderry et al, 2007; Haist, 2007) focused on the feasibility of using EM in the RPP and the accuracy and precision of video-based estimates of halibut discards. The study took place on the F/V Sea Mac and had two primary goals: (1) determine whether EM could monitor for 100% retention of non-halibut catch using two overview video cameras; (2)

determine the accuracy and precision of EM estimates of halibut length and number when compared against an actual census of halibut discard. Secondarily, halibut bycatch was also estimated using standard observer methodology and this estimate was compared against the EM and census data.

The results of Phase I indicated:

- There was no statistically significant bias in the EM or observer estimate of halibut length or number when compared against a census.
- The precision of the observer estimate of halibut bycatch was low compared to the EM estimate of halibut discard.
- EM was able to monitor for discard other than through the marked discard chute. However, the EM system could not monitor for discard behind the stern (net bleeding).
- The exclusion of unclear images of halibut from the EM system did not significantly improve the accuracy or precision of the estimate of halibut discard.
- There was no apparent difference in the accuracy of EM measurement based on time of day (ambient light condition), number of halibut per haul, or reviewer-perceived image quality.
- The EM system was reliable and no significant data were lost as a result of equipment failure.

It should be noted that this was an experimental study with 3 project staff on board to monitor adherence to the project design and sampling protocols. This included ensuring a thorough sorting of halibut from the catch, and discarding those halibut through the single point of discard (across the measurement grid) in a manner that facilitated subsequent shoreside video review (i.e. discarded singly at a reasonable pace and in a unidirectional, tidy manner). Crew and skipper cooperation were high and the vessel was an ideal platform for the study. At 90' LOA with a 33' beam, the vessel had ample space for the discard chute and obstruction of the camera views was not an issue.

Phase I concluded that applying EM at the co-op level would require the vessels electing to participate to cooperate fully and comply with the EM system requirements: (1) install a secure and well-marked discard chute of suitable size (at least 3 feet long and 1.5 feet wide); (2) limit all at-sea discards to this single point of discard; (3) discard halibut at a reasonable pace in a manner that would facilitate the subsequent video review; (4) if necessary, make structural adjustments for camera and sensor installation.

Goals of Phase II

Phase I demonstrated on a quantitative level that EM was a viable method for generating sufficiently accurate and precise haul-level estimates of halibut discard under comparatively controlled conditions. However, prior to considering actual large-scale implementation, we believed that it was important to further investigate the use of EM under real-world conditions and to explore the regulatory, cost, fleet management, catch accounting, and infrastructural issues that need to be addressed prior to effective implementation. Phase II was envisioned as a primarily qualitative project designed to test larger scale implementation in a real world environment and to inform industry, Council and NMFS staff on how best to implement a cutting-edge program with many regulatory unknowns. The use of an EFP for pre-regulatory implementation of an EM program is not new. Beginning with a pilot study in 2002 (McElderry et al, 2002) and expanding to the entire fleet in 2004, EM has been used to monitor discard in the West coast hake fishery under an EFP. This has allowed the development of a more effective monitoring program as knowledge of EM systems has accrued over the years.

Specific goals for the phase II study were to:

1. Determine the time lags between vessel arrival in Kodiak and data available to quota managers under different scenarios (analysis of the data in Kodiak vs. analysis of the data in an off-site location).
2. Develop NMFS catch accounting data base infrastructure for handling EM data and linking EM data to the source delivery.
3. Determine whether crew behavior is different when scientific staff or observers are not present. Specifically, whether the no discard of non-halibut and single point of halibut discard rules will be followed.
4. Determine whether EM systems can be effectively deployed on a wider variety of vessels fishing under real world conditions.
5. More fully assess the costs associated with various components of an EM program (equipment, support, and analysis).
6. Assess the qualitative effectiveness of EM for quantifying halibut and ensuring compliance with no discard rules.
7. Determine whether vessel self reporting could be used to acquire halibut discard numbers for preliminary management by the co-op.

Methods

Experimental fishing

The project took place during the entire 2008 RPP fishing season and involved all of the vessels fishing for a single RPP co-op. Based on funding constraints, we decided that the fishing co-operative best suited to participate in the project would have 3 -5 member vessels, which limited the choice of RPP co-ops to either the North Pacific (NP) Fisheries Rockfish Co-op with 3 active member vessels or the Ocean Beauty Seafoods, Inc (OBSI) Rockfish Co-op with 4 active RPP participants. NP declined to participate because their processing plant (Alaska Pacific Seafoods in Kodiak) was scheduled to undergo major renovations and would not be ready to accept harvests until well after the start of the season. The OBSI members consulted with each other and agreed to participate in the EFP and to comply with the permit's requirements. The four participating Kodiak-based catcher vessels are listed in Table 1.

Table 1. OBSI Co-op vessels participating in the EM Phase II EFP project.

Vessel	Length (ft.)	Beam (ft.)
Excalibur II	92	30
Pacific Star	79	31.5
Laura	92	24.5
New Life	80	27

Vessels fishing under the EFP agreed to retain all catch with the exception of halibut which were to be sorted and discarded at sea. All halibut were to be discarded at a single location, and crew members were instructed to discard them one at a time across the discard chute. The discard chute was pre-marked with a measurements grid 5 cm wide bars spaced 5 cm apart, and shunted the halibut into a scupper area where halibut could be discharged overboard. Figure 1 depicts the 4 styles constructed and utilized by the co-op vessels.

Under the conditions of the EFP, participants were exempted from the 100% observer coverage requirements and maximum retainable allowances (MRA's). The four vessels were subject to 30% observer coverage with the added precondition that an observer be onboard for all sablefish and Pacific cod target trips.

Figure 1. Clockwise from upper left, halibut discard chutes on the F/V Laura, F/V Pacific Star, F/V Excalibur II and the F/V New Life.

The vessel operators voluntarily agreed to complete halibut tally sheets. They were requested to tally discarded halibut by size category (>24 inches, 24-32 inches, >32 inches) and to submit the tally sheets to AGDB after each trip.

Project personnel conducted two calibration trips per vessel. During these trips, project staff observed the discard practices of the crew and measured the halibut in consecutive order of discard to allow for direct comparisons to the length estimates generated by the video reviewers. The trip totals (based on EM estimates plus the weights of the halibut landed at the processing plant) were also compared to the observer's total trip estimates of halibut weight posted on the NMFS Co-op ledger website.

Project staff kept note of all trip departure dates, times and dates of vessel arrival, hard drive retrieval, transmission of sensor and video files to Archipelago, and receipt of final EM data.

EM Equipment and Operations

Archipelago Marine Research, Ltd. (AMR) of Victoria, B.C., was contracted for the installation and maintenance of EM equipment and for video review. This company has extensive experience in electronic monitoring of fisheries in Canada and around the world (AFSC, 2008). For this project, Archipelago provided and installed the four EM systems, each of which consisted of three closed circuit television cameras, a GPS receiver, a hydraulic pressure sensor, a winch/drum sensor, a system control box, hard drives and a user interface (monitor and keyboard) (Appendix I, *EM System Description*). Archipelago technicians travelled to Kodiak prior to the start of the RPP season to install the systems on all four vessels and, when required, returned to Kodiak for equipment repair, system troubleshooting and gear re-installation or removal.

The data recording configuration recorded imagery 100% of the time, starting once the vessel left port. Image recording rates were set to eight frames per second (fps) for the close-up of the discard chute (camera 1, Figure 2), three and two fps for the deck and stern view cameras (cameras 2 and 3, respectively, Figure 3). Winch and pressure (hydraulics) sensor data were recorded 100% of the time while the EM system was powered.

Figure 2. Clockwise from upper left, video snapshots (from camera 1) of halibut discards on the Laura, Pacific Star Excalibur II and New Life.

Figure 3. Example of overview (left) and stern view (right) camera angles.

Upon arrival in Kodiak after each RPP trip, the vessel operator was instructed to inform project staff that the vessel had arrived in port. Staff then met the boat at the dock to: ascertain that the equipment had functioned properly during the trip; switch out the hard drive to ready the vessel for a subsequent fishing trip; and collect halibut tally sheets. The video files were then previewed for completeness; video and sensor data files were archived to a portable external hard drive; and staff emailed the sensor data (GPS, hydraulic and winch rotation) to Archipelago. Hard drives containing accumulated video files were shipped to Archipelago via the U.S. Postal Service or Federal Express for data review on an as-needed basis.

Archipelago's staff in Victoria, B.C. analyzed the video data files upon receipt of the hard drives in Victoria or, on occasion, in Kodiak if a video analyst happened to be in port. Sensor data were analyzed to interpret the geographic position of fishing operations and to detect and describe key vessel activities including transit, setting and retrieval of gear.

The objectives of image interpretation were to first assess whether all the intended imagery was recorded properly, then to analyze the video files for 100% retention and to estimate the length of each halibut discarded across the measurement grid painted on the discard chute. All video files were analyzed by a single EM reviewer.

Results

EM System Performance

The four EM systems collected video and sensor data over the course of the season, from the start of Excalibur's first trip on May 8 to the end of the New Life's last trip on September 26. All four systems were installed in May prior to the start of the season. The equipment was removed from the Excalibur II on June 3rd (the vessel went fishing in the Bering Sea) and re-installed on August 18th. The final gear removal for the Excalibur II occurred on August 26th. The system remained on the other vessels until the end of their respective seasons. The systems were removed from these vessels on July 13th (Pacific Star), July 21st (Laura), and September 27th (New Life).

There were several EM system malfunctions over the season (Table 2):

- Excalibur II Trip 1. May 7th. Runtime error occurred before the vessel left the dock. The hard drive was replaced and the system appeared to working properly, but it failed again just before the vessel arrived on the fishing grounds on May 8th. The skipper called an EM technician from sea and together they attempted to troubleshoot the problem, but were ultimately unable to do so. All files from Trip 1 were corrupted and could not be recovered (3 hauls). A technician travelled to Kodiak on May 13: he replaced the V4 computer system box and installed a port-appropriate version of the operating software. No further problems were encountered.
- Pacific Star Trip 3. May 29th. Runtime error. The hard drive from trip 3 was corrupted but Archipelago was able to recover data from hauls 1-7; data from hauls 8-15 were lost. An Archipelago technician arrived in Kodiak on May 30th and replaced the hard drive. A system check confirmed that everything was working properly.
- Pacific Star Trip 4. June 4th. The system shut down again during trip 4 on June 4th while at sea. Archipelago was able to recover hauls 1-5 of the 6 hauls from the corrupted hard drive. An AMR technician arrived in Kodiak on June 19th: she replaced the V4 system box and winch sensor. No further problems.
- Laura Trip 2. June 12th. System shutdown before last haul. Hauls 1-9 of the 10 hauls were recovered from the corrupted hard drive. System appeared OK after re-initialization.
- Laura Trip 3. June 15th. System shut down when the GPS feed stopped prior to vessel arriving on the fishing grounds. Problems from both trip 2 and 3 likely due to a short from the drum sensor because of a wire rubbing against the drum. No data for the 16 hauls. An AMR technician arrived in Kodiak on June 19th and replaced the V4 system box, GPS unit, winch/drum sensor and power cord. No further problems.
- New Life. Faulty drum sensor. This sensor never functioned and was not replaced because it was not considered to be a priority for the project. Set and retrieval information was obtained from the pressure/hydraulic sensor.
- New Life Trip 6. Unexplained camera 3 failure during hauls 2 and 3. No further problems.

Table 2. Total number of RPP trips and hauls by OBSI co-op vessel.

Vessel	RPP start fishing date	RPP end fishing date	Total fishing and transit days	Total no. 2008 RPP Trips	Total no. RPP Hauls	No. hauls lost due to EM equipment failure	Failure Rate
Excalibur II	5/8/2008	8/23/2008	17	5	20	3	15.00%
Pacific Star	5/16/2008	7/10/2008	19	6	46	9	19.57%
Laura	6/6/2008	6/28/2008	18	6	39	17	43.59%
New Life	6/9/2008	9/26/2008	50	17	72	0	0.00%
Total			**104**	**34**	**177**	**29**	**16.38%**

The technical problems all occurred within the first 6 weeks of the season and, except for the New Life drum sensor and camera 3 failures, all were related to the system control box ("V4 box"). The problems were all resolved when the older, well-used rental boxes were replaced with the newer model boxes and the operating software was updated.

EM Data Review

All uncorrupted video files were successfully reviewed by Archipelago staff in Victoria, B.C. However, the EM reviewers did note that they had difficulty estimating the lengths of numerous halibut, particularly those on the Laura and New Life (Table 3), mostly due to camera view obstruction by crew members. The crew and discard chute on the Pacific Star clearly performed the best, although this manner of discard is a bit more labor-intensive. The discard chute (Figure 1) was well out of the way of the sorting area and the crew placed each halibut on the grid with the head positioned against a wooden barrier at the top of the grid (as one would do on a measuring board) for ease of measurement before rotating and sliding the fish into the scupper area and overboard (Figure 2). The discard chute on the Excalibur II also did not impede traffic or cause camera view obstructions and halibut was discarded as on the Sea Mac during Phase I. On the Laura, one crew member was assigned the task of tallying the halibut: she frequently used the bottom portion of the grid on the discard chute to obtain a length before discarding the halibut over the side or letting the halibut slide the very short distance to the scupper and so often inadvertently blocked the camera view (Figure 2). Sliding the fish from the upper portion of the chute would have given the video reviewer more opportunities to obtain a quality length estimate. The New Life had the poorest performance: in haul 1, trip 13, 87 of the 99 estimates contained the reviewer remark "fisherman in the way". Camera view obstruction was clearly an issue on this vessel – almost entirely due to the crew getting halibut measurements for the project (Figure 2) (an unintended consequence of the study) and, possibly, in part, to the style of the New Life's discard chute (Figure 1). Unlike those on the other vessels, the New Life's chute was not raised off the deck – it was a piece of removable laminated plywood positioned flat on the deck (or, at times, leaned up against a tote, Figure 4) leading from the trawl alley wall to the scupper. It proved to be in an area of high traffic volume and was frequently moved aside so the crew could access the RSW hatch which was directly underneath.

Table 3. The number of "difficult" estimates and sample comments for each of the four OBSI Co-op vessels.

Pacific Star	*1 out 176 length estimates classified as "difficult" (0.57%)*
	difficulty getting length
Excalibur II	*15 out of 129 difficult (11.6%)*
	Fish not flat on grid
	Fish head and tail not laying flat on grid - very much a guess.
	Fish sideways on grid
Laura	*106 out of 585 difficult (18.1%)*
	Observer blocking view. Very rough estimate
	hard to determine the size
	very hard to determine the size
	Fish is slid down grid. Difficult to get an accurate measurement
	Observer blocking view. Very rough estimate as viewer could not see fish at all.
	Fish bent on grid
	Fish head blocked by rail.
	Fish not flat on grid
	fish sideways on grid
	Fish partially out of camera view
	fish head blocked by rail
New Life	*140 out of 324 difficult (43.2%)*
	87 "fisherman in the way " comments for haul 1, Trip 13 (99 total halibut). See figure 2.
	very rough estimate fish is perpendicular to the lines
	Estimate: observer blocking view of fish.
	Fish not put on grid or measured by observer before being kicked out scupper. This is a guess of the size.
	halibut was on an angle
	Fisherman foot in the way.
	fisherman in the way.
	VERY FOGGY lens.
	planks in the way
	bucket in the way.
	fisherman in the way and fish on an angle.
Total "difficult":	*262 out of 1,214 estimates (21.6%)*

Figure 4. Halibut discard on F/V New Life. The chute has been moved from deck level and propped up against a tote.

EM monitoring of discard events

The participating vessels were required to retain all groundfish in accordance with the conditions of the EFP. During review, 7 discard events were detected on the video files collected over the course of the project (Table 4): all involved discards of lingcod, except for one flatfish from haul one on Laura trip 6 and one halibut that was discarded from the New Life on trip 11 (haul 3) without having passed across the discard chute. Note that the video reviewer did record a guesstimate for this halibut. The crew properly discarded 103 halibut from this haul and no other improper discards were detected. There were no non-halibut discards from the Pacific Star or Excalibur II.

Lingcod became an issue when the New Life (trip 3), abiding by the 100% retention requirement, delivered lingcod to the processor in Kodiak on June 19th. Lingcod are managed by the State of Alaska and retention is prohibited prior to July1st with a 3% MRA after July 1. After consultation with ADF&G and NMFS, the vessels were instructed to discard any further lingcod bycatch in excess of State retention allowances.

Table 4. Discard events detected by EM reviewer by vessel, trip and haul.

Vessel	Discard Event
Laura	
LA5 haul 4	4 Lingcod
LA6 haul 1	1 flatfish and 8 Lingcod
New Life	
NL4 haul 1	~200 Lingcod
NL6 haul 1	11 Lingcod
NL7 haul 1	41 Lingcod
NL7 haul 2	9 Lingcod
NL11 haul 3	1 unmeasured halibut

Data Summary and Review

The halibut data collected over the course of the project from EM, vessel tally sheets, plant deliveries and observer data are summarized by trip in Table 5. Sixty percent of trips were observed. For observed trips, the observer estimate and the NMFS estimate are the same. For unobserved trips, NMFS uses the best available data from other observed vessels to estimate halibut bycatch.

Table 5. Halibut data collected during Phase II by source, vessel and trip.

		EM		At-sea Tally		Plant		Observer estimate[1]	NMFS estimate[2]
Delivery Date	**Trip**	**No.**	**Kg.**	**No.**	**Kg.**	**No.**	**Kg.**	**Kg.**	
19-May	PS1	7	27.7	7	25.2	0	0.0	----	138.
22-May	PS2[3]	15	80.1	15	79.4	11	17.9	----	360.6
29-May	PS3[4]	17	204.7	88	481.5	8	43.1	0.0	0.0
5-Jun	PS4[3,4]	40	302.3	56	367.9	7	58.1	----	41.2
6-Jul	PS5	48	499.1	53	336.9	0	0.0	494.2	494.2
10-Jul	PS6	49	557.8	46	327.5	0	0.0	167.4	167.4
Pac Star Total		**176**	**1,671.7**	**265**	**1,618.4**	**26**	**119.0**		**1,101.5**
10-May	EX1[4]	no data: system failure		30	53.4	21	80.3	----	71.4
18-May	EX2[3]	0	0.0	0	0.0	1	3.6	0.0	0.0
20-May	EX3	0	0.0	0	0.0	0	0.0	0.0	0.0
30-May	EX4	55	547.3	42	203.1	82	545.2	----	75.7
23-Aug	EX5[3]	74	605.5	76	512.2	0	0.0	516.1	516.1
Ex II total		**129**	**1,152.8**	**148**	**768.72**	**104**	**629.1**		**663.2**
9-Jun	LA1[3]	13	117.5	13	86.7	3	13.6	138.4	138.4
13-Jun	LA2[4]	130	949.1	139	849.2	39	299.8	----	264.6
18-Jun	LA3[4]	no data: system failure		51	324.5	3	18.1	----	74.2
22-Jun	LA4[3]	397	565.9	398	565.0	1	1.4	0.0	0.0
27-Jun	LA5	26	44.7	35	52.2	0	0.0	----	205.9
28-Jun	LA6	19	35.5	22	42.7	0	0.0	0.0	0.0
Laura total		**585**	**1,712.7**	**658**	**1920.28**	**46**	**332.9**		**683.0**
12-Jun	NL1	4	78.1	5	44.9	1	4.5	0.0	0.0
16-Jun	NL2	3	16.9	3	14.3	4	31.3	0.0	0.0
19-Jun	NL3	6	25.7	6	23.6	6	35.8	0.0	0.0
23-Jun	NL4	0	0.0	0	0.0	0	0.0	----	42.6
26-Jun	NL5	1	10.0	1	9.0	0	0.0	----	15.5
28-Jun	NL6	27	31.3	25	36.1	0	0.0	0.0	0.0
1-Jul	NL7	43	88.4	44	69.5	0	0.0	0.0	0.0
4-Jul	NL8	0	0.0	0	0.0	0	0.0	0.0	0.0
7-Jul	NL9	3	30.8	4	25.9	0	0.0	0.0	0.0
10-Jul	NL10	0	0.0	0	0.0	0	0.0	----	20.9
14-Jul	NL11	103	1,193.2	102	735.1	2	5.4	100.2	100.2
17-Jul	NL12[3]	35	399.7	36	288.3	0	0.0	----	71.6
21-Jul	NL13	99	972.3	100	708.0	0	0.0	400.2	400.2
23-Jul	NL14[3]	0	0.0	0	0.0	0	0.0	0.0	0.0
22-Sep	NL15	0	0.0	0	0.0	2	15.0	0.0	0.0
24-Sep	NL16	0	0.0	0	0.0	0	0.0	0.0	0.0
27-Sep	NL17	0	0.0	0	0.0	0	0.0	0.0	0.0
New Life Total		**324**	**2846.4**	**326**	**8**	**16**	**107.1**		**651.9**
Grand Total		**1,214**	**7,383.5**	**1,397**	**6,262**	**192**	**1,188**		**3,099**

1. Observer estimate is only provided for observed trips.
2. NMFS accounting system estimate based on expanded observer data. This was the amount of halibut PSC that was debited from the co-op's PSC limit. During this project, when an observer was not on board, the PSC estimate was derived from PSC catch observed on other vessels participating in the RPP fishery.
3. Denote census trips.
4. Trips with EM equipment malfunctions.

At-sea census vs. EM reviewer: halibut weight and count comparisons by haul

Table 6 summarizes the halibut data collected on the at-sea "census" trips by project personnel and the associated EM values generated for those hauls. Haul 6 from Pacific Star trip 6 was dropped for lack of EM data (corrupted hard drive). Excalibur II trip 2 and New Life trip 14 were census trips with zero halibut bycatch and are not shown in Table 6.

EM errors were calculated as proportional differences ((*EM-census)/census*)). The error in the EM weight estimates on the haul level ranged from -31% to 37% and the error in count estimate ranged from -7% to 25%, with means of 5% and <1% respectively. Using the same methodology as Phase I (two tailed t-test, $(\alpha = 0.05)$), the null hypothesis that the mean errors are equal to zero is not rejected for either weight or count across hauls.

During Phase I, researchers attempted to target halibut on all hauls, and out of the 27 hauls made during the study, halibut were present in 26. Because of the nature of the Phase II design, it was not possible to target halibut and there were a far larger number of hauls on census trips where no halibut were discarded (20 out of 45 census hauls). Further, a qualitative examination of the distribution of the number of halibut discarded on census trips during Phase II indicates that the number of discarded halibut per haul is probably not normally distributed, even when hauls where no halibut were discarded are excluded, thus the assumptions of the parametric hypothesis test may be violated. However when the null hypothesis that errors in the estimation of biomass are evenly distributed around zero is tested using the Wilcoxon ranks test (p=.09) the null hypothesis also can not be rejected. Because only four hauls had errors in the estimation of count, the null hypothesis that errors in the estimation of count are evenly distributed around zero was not tested.

The standard deviations of the errors in the EM halibut biomass and count estimates provide an indication of the expected precision of EM estimation. On a haul basis, the standard deviation of the error in biomass estimation was 15%, which was comparable to that obtained during phase I (11.9% and 5.6% for the two reviewers). The standard deviation of the error in count estimation was 5.3%, which was also comparable to Phase I (5.3% and 1.3% for the two reviewers).

Table 6. Halibut numbers and weights from at-sea census and EM by haul. EM errors are calculated as proportional differences ((EM-census)/census).

		At-sea Census		EM		Error	
Trip	Haul	No.	Kg.	No.	Kg.	No.	Kg.
EX5	1	22	105.3	22	118.8	0.00	0.13
EX5	2	1	13.1	1	13.9	0.00	0.07
EX5	3	17	161.7	17	169.2	0.00	0.05
EX5	4	36	310.1	34	303.5	-0.06	-0.02
LA1	1	3	30.5	3	32.8	0.00	0.08
LA1	2	0	0.0	0	0.0		
LA1	3	7	50.3	7	57.2	0.00	0.14
LA1	4	0	0.0	0	0.0		
LA1	5	0	0.0	0	0.0		
LA1	6	3	24.0	3	27.6	0.00	0.15
LA1	7	0	0.0	0	0.0		
LA4	1	6	14.5	6	20.0	0.00	0.38
LA4	2	392	444.4	391	545.9	0.00	0.23
LA4	3	0	0.0	0	0.0		
LA4	4	0	0.0	0	0.0		
NL12	1	1	9.0	1	10.7	0.00	0.19
NL12	3	4	42.3	4	49.6	0.00	0.17
NL12	4	1	18.2	1	22.8	0.00	0.25
NL12	6	13	138.3	12	156.4	-0.08	0.13
NL12	7	17	145.7	17	160.1	0.00	0.10
PS2	1	4	22.4	4	22.6	0.00	0.01
PS2	2	1	6.6	1	6.6	0.00	0.00
PS2	3	7	35.1	7	35.4	0.00	0.01
PS2	4	0	0.0	0	0.0		
PS2	5	1	5.7	1	6.1	0.00	0.08
PS2	6	1	4.8	1	4.8	0.00	0.00
PS2	7	1	4.6	1	4.6	0.00	0.00
PS4	1	4	39.0	5	43.7	0.25	0.12
PS4	2	5	68.4	5	47.1	0.00	-0.31
PS4	3	7	92.7	7	70.8	0.00	-0.24
PS4	4	10	80.5	10	61.9	0.00	-0.23
PS4	5	13	91.0	13	78.8	0.00	-0.13
Total All hauls		577	1957.75	574	2070.92		
Mean over hauls						0.005	0.054
Standard Deviation						0.053	0.154
p-value (parametric)						0.68	0.10
p-value (non-parametric)							0.09

Halibut self-reporting

All four vessel operators submitted a completed halibut tally sheet at the end of each RPP trip. Three of the vessels tallied the halibut by size category (<24 inches, 24 to 32 inches, >32 inches); one vessel (New Life) actually had the crew measure (in inches) each halibut before discard. We then assigned all of the EM generated halibut lengths to the same size categories and eliminated those trips where EM technical problems were encountered or no halibut were reported by EM or skipper's tally. These data are summarized in Table 7. Skipper tally errors were calculated as proportional differences ((*skipper tally-EM)/EM*)) for the total counts.

In this case, the question was not whether tally sheets are an accurate reflection of actual halibut discard, but whether they can be used for as a proxy for EM for interim management by a co-op manager. Thus, we did not seek to determine whether the skipper's estimates were correct per se, but simply how they compared to the EM estimates. Because vessel tally sheets are not contemplated for management use at the haul level, these data were examined only at the trip level. The error in the tally sheet count estimate when compared to the EM estimate ranged from -24% to 25%, with a mean of 5%. Using the same methodology as Phase I, the null hypothesis that the mean errors in count are equal to zero, cannot be rejected.

Examining the extent of agreement in classification between skipper tallies and EM was problematic on a trip by trip level because of disagreements in count. For the entire project, skipper tallies underestimated the number of large halibut by approximately 10%, underestimated the number of medium halibut by 8%, and overestimated the number of small halibut by 11%.

Table 7. Comparison between vessel-reported halibut catch and EM. Count errors for skipper tallies are calculated as proportional differences ((skipper tally-EM)/EM). Vessel crew reported halibut discard by category, small = <24 inches, medium=24-32 inches, large=>32 inches. EM lengths were converted to the same categories based on reviewer recorded lengths in cm.

	EM				Skipper Tally				Count Error
trip	**L**	**m**	**s**	**Total**	**L**	**m**	**s**	**Total**	
L1	10	3	0	13	7	6	0	13	0.00
L4	1	23	373	397	0	12	386	398	0.00
L5	0	4	22	26	0	2	33	35	0.35
L6	0	4	15	19	0	5	17	22	0.16
N01	4	0	0	4	5	0	0	5	0.25
n02	1	2	0	3	1	1	1	3	0.00
n03	1	4	1	6	1	3	2	6	0.00
N05	1	0	0	1	1	0	0	1	0.00
N06	0	0	27	27	0	1	24	25	-0.07
N07	1	10	32	43	0	4	40	44	0.02
N09	2	1	0	3	2	2	0	4	0.33
N11	69	32	2	103	69	27	6	102	-0.01
N12	31	4	0	35	29	7	0	36	0.03
N13	71	27	1	99	62	38	0	100	0.01
PS1	0	6	1	7	0	6	1	7	0.00
PS2	3	10	2	15	5	8	2	15	0.00
PS5	29	14	5	48	31	11	11	53	0.10
PS6	36	10	3	49	31	11	4	46	-0.06
X4	28	25	2	55	13	18	11	42	-0.24
X5	43	30	1	74	43	31	2	76	0.03
Total	331	209	487	1027	300	193	540	1033	
		Mean over trips							0.05
		Standard deviation							0.137
		p-value							0.16

EM data transit and delivery timelines

Transit times for shipping the full hard drives to AMR in Victoria, B.C. from Kodiak ranged from 1-3 days using Federal Express international priory or economy (~$80) and 4-8 days using U.S. Postal Service international express mail (~$35). Rather than shipping a hard drive after every trip, the accumulated data from 5-6 trips were transferred to one hard drive which was then shipped to Victoria. For trips where data review took place in Victoria Canada, at AMR headquarters, the number of days from date of vessel arrival to receipt of final EM data ranged from 15-37 days with an average of 26.4 days. For those trips reviewed when an AMR reviewer/technician was in port (May 30 – June 12), the average was 9.7 days.

The final EM data received from AMR was in the form of an electronic spreadsheet and contained fishing information derived from sensor data (haul set and retrieval times and locations), NMFS landing report number and halibut count and length estimates by haul for each trip. These lengths were converted to weights using the IPHC length/weight conversion table and sent to NMFS Alaska Region which also had access to the second data stream of halibut delivered to the processing plant (ADF&G fish tickets).

Currently, NMFS estimates halibut bycatch, and debits co-op accounts, based on observer data. Because almost all trips are observed in the normal RPP fishery these data are, with limited exceptions, only expanded to cover unsampled hauls. When an observer arrives in Kodiak, they transmit their data to NMFS Seattle where data are integrated into the NORPAC database, a set of data integrity checks are performed, and the data are transmitted to the AKFISH database in Juneau. This process is generally completed within 1-2 days. Once each night, the catch accounting system calculates the amount of halibut to be debited from each co-op account and those numbers are made available the following day. While longer delays between delivery and quota debiting do occur, 2-3 days is the normal time lag under the current system.

Clearly even the minimal lag time of 9.7 days experienced when a technician was in port are longer than currently experienced. However, these lags may not be representative of what would be experienced if a dedicated reviewer were located in Kodiak. In order to examine how long the lags might be under such a scenario, we examined landing patterns in the RPP fishery for 2007 and 2008 and modeled what the potential lag time might be using the following assumptions:

- A single reviewer would be based in Kodiak
- Reviewing a trip requires an average of 3.14 hours, which is the average number of hours spent on review for all trips reviewed during phase II.
- The reviewer can review EM data for four hours/day and works five days per week
- All catcher vessels in the RPP participated in the EM program
- Sick days, vacation etc were not included in the model.
- EM data would be reviewed in a first in-first out manner.

Using those assumptions, and the actual landing dates for RPP deliveries during 2007 and 2008, we looked at how large of a data review backlog would potentially develop at any given point during the season. For example, following the first delivery, which occurred on a Tuesday, there were four hours worth of data to review. Because the first delivery occurred on a weekday and the reviewer could complete 3.14 hours worth of review that day, there would be 0.86 hours worth of review remaining to complete on Wednesday. If a second delivery was made on Wednesday, the reviewer would be able to complete the review of the first delivery (a lag of < 1day) and begin the review of the data from the second delivery, which would be completed on Thursday. We continued through all of the deliveries in this manner. The results of this exercise are shown in Figure 7. As can be seen, a single reviewer quickly gets behind. For 2007, the modeled estimate of lag time reached a maximum of 95 hours (or almost five weeks turnaround time) on July 24th and dropped fairly steadily thereafter. For 2008, different fishing patterns resulted in a smaller (77 hour, almost four week) turnaround, but a more protracted period of long (>two weeks) delay.

As a second exercise, we changed the assumption by adding a second reviewer. The second reviewer would be called in when the lag time reached 20 hours (a one week lag time for a single reviewer) and would analyze EM data until the lag reached zero (Figure 8). Under these assumptions during 2007, the model estimated the maximum lag time at 40 hours, or one week for two reviewers. During 2008, the lag time reached a maximum of 36 hours, or slightly less than one week for two reviewers.

Figure 7. Estimated EM data review lag time using 2007 and 2008 RPP landings. Assumes a single reviewer analyzing data 4 hours per day five days per week.

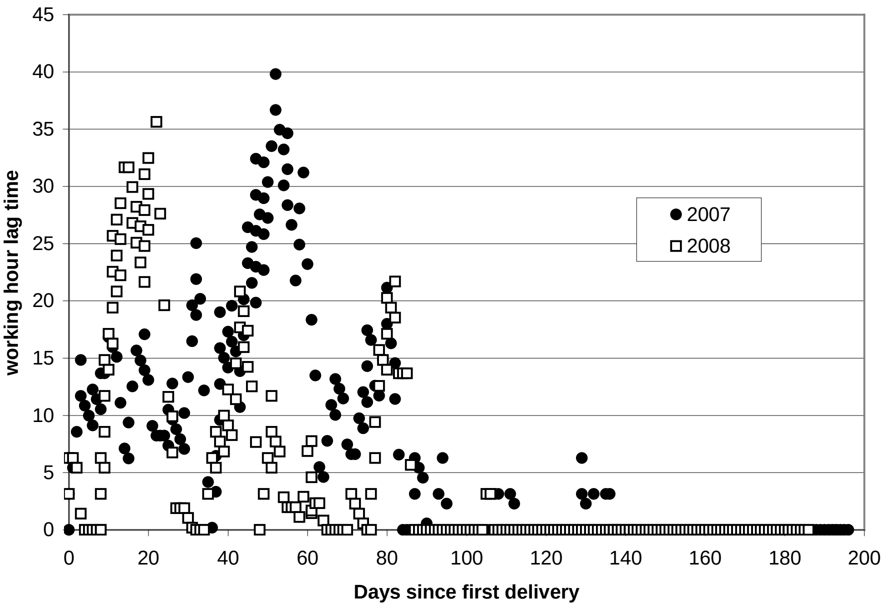

Figure 8. Estimated EM data review lag time using 2007 and 2008 RPP landings. Assumes a single reviewer analyzing data 4 hours per day five days per week and a "part time" reviewer that is brought in when lag time reaches 20 hours.

NMFS staff investigated how video data could be integrated into the current catch accounting system and determined that it would require staff time for system design, application development, and database programming, but that it would not be inherently difficult.

A mechanism for submitting data to NMFS would need to be developed. However, because only the results of the EM review would need to be transmitted and received there are several potential electronic reporting mechanisms that could be developed. Current regulations, for example, specify that any shoreside processor with a Federal Processor Permit (FPP) must use elandings to submit a landingreport. An similar online system could be developed by NMFS to enable the submission of halibut PSC data from the EM reviewer to the catch accounting system. An online application could be password protected and only available to authorized users and perform basic data validation and error checking on the data being submitted. Once submitted to NMFS, database programming would need to be completed to incorporate the data into the catch accounting system to get a total estimate of halibut PSC. An issue identified during this study was the need for an accurate and robust way to link the data from EM review, landing report (ADFG fish ticket) data, and observer data to ensure that halibut delivered shoreside becomes part of the estimate of total halibut bycatch.

Costs

Cost breakdowns for the project are shown in Tables 10 and 11. For equipment installation and service, travel time and cost to and from Kodiak are not included. Because of EM equipment malfunctions, an EM field technician had to travel to Kodiak three times to repair and service the systems. This was in addition to the first trip for the initial gear installations (two technicians) performed prior to May 1 and three additional trips to Kodiak for two EM system removals and one system re-installation on the Excalibur II.

AGDB, based in Kodiak, performed most of the hard drive retrievals and replacements, spot checked the video and sensor files, performed periodic system checks; and completed two system removals.

Review time to enumerate halibut, and hence cost, varied considerably between trips and hauls (Table 11) and were generally a function of time required to stow all hauls on a trip and the number of halibut that had to be measured. The least amount of time for video review was half an hour for New Life trip 17, a single haul trip on which no halibut were discarded. The maximum amount of time (8.25 hours) was for Laura trip four when 397 halibut were discarded.

Time to monitor for discard was not broken out separately by trip or haul. A total of 60 hours was spent on quality checking, most of which was spent on review for discard. An additional 8 hours was spent on analyzing sensor data for all hauls.

Collection of hard drives when boats arrived in port, installing new drives, a fast data check to ensure the system was working, and transmitting sensor data files to Archipelago required approximately one hour per trip.

Table 10. Equipment costs for participating vessels. Labor costs are estimated at $50.00/hr. Material costs were not separated during this study and are estimates.

	Laura	New Life	Pac Star	Excalibur II
Equipment lease	3,600	6,000	3,600	3,600
Materials	500	500	500	500
Installation Labor	350	275	375	363
Maintenance Labor	150	200	150	150
Total	**$4,600**	**$6,975**	**$4,625**	**$4,613**

Table 11. Review hours for all hauls and review times based on number of hauls and number of halibut (as estimated by EM). Hours to review for discard are not included.

Trip	EM halibut count	hauls	review hrs	hrs/haul	hrs/halibut
PS1	7	9	6.75	0.75	0.96
PS2	15	7	5	0.71	0.33
PS3	17	8	1.5	0.19	0.09
PS4	40	6	3.25	0.54	0.08
PS5	48	4	3.76	0.94	0.08
PS6	49	4	2	0.50	0.04
Total PS	**176**	**38**	**22.26**	**0.59**	**0.13**
EX1	no data				
EX2	0	9	6.6	0.73	--
EX3	0	2	5	2.50	--
EX4	55	5	3.5	0.70	0.06
EX5	74	4	3	0.75	0.04
Total EX	**129**	**20**	**18.1**	**0.91**	**0.14**
LA1	13	7	3	0.43	0.23
LA2	130	9	4.5	0.50	0.03
LA3	no data				--
LA4	397	4	8.25	2.06	0.02
LA5	26	1	2	2.00	0.08
LA6	19	1	1	1.00	0.05
Total LA	**585**	**22**	**18.75**	**0.85**	**0.03**
NL1	4	11	4.25	0.39	1.06
NL2	3	5	2.25	0.45	0.75
NL3	6	5	2.75	0.55	0.46
NL4	0	5	2	0.40	--
NL5	1	5	2	0.40	2.00
NL6	27	3	1.5	0.50	0.06
NL7	43	2	4	2.00	0.09
NL8	0	8	2	0.25	--
NL9	3	5	2.5	0.50	0.83
NL10	0	3	0.5	0.17	--
NL11	103	6	6	1.00	0.06
NL12	35	7	4	0.57	0.11
NL13	99	1	2.75	2.75	0.03
NL14	0	4	1	0.25	--
NL15	0	4	2.25	0.56	--
NL16	0	2	1.25	0.63	--
NL17	0	1	0.5	0.50	--
Total NL	**324**	**77**	**41.5**	**0.54**	**0.13**
Grand Total	1214	157	100.61	0.64	0.08
average			3.14	0.82	0.33

Cost Projections

Prior EM investigations out of Kodiak have been small scale and experimental and trying to accurately assess costs for large scale implementation has been problematic. This study, however, focused on a larger scale implementation across a range of boats and cost estimation for a full scale implementation is more valid.

Costs can be classified in several ways. In brief:

- **One time startup costs for vessel equipment.** These costs include equipment installation, crew training, and materials. These costs are dependent on the number of program participants to the extent that skilled labor for system installation is unavailable in Kodiak. Based on this and prior projects, these costs can be estimated fairly accurately and would probably be borne by industry.

- **Ongoing equipment costs (either lease, or replacement and maintenance).** Maintenance costs are dependent on the number of program participants to the extent that skilled labor for system installation is unavailable in Kodiak; since such skilled labor would need to be brought in from off-island and travel costs would be spread among all program participants. Lease costs or equipment replacement costs are independent of the number of program participants. These costs can be estimated fairly accurately if based on leasing rather than owning the equipment and would likely be borne by industry.

- **Data collection, routine vessel support, and transmittal costs.** This must be done by someone local and involves a small amount of time over an extended period. These costs are problematic to estimate without knowing the program structure (who collects the data) and the number of participants. However, these costs are fairly low. Depending on program structure these costs may be borne by industry, NMFS, or indirectly by industry via fee collection.

- **Data review costs.** These costs can be estimated fairly reliably for any given level of review. To a great extent they are independent of the number of program participants. Local review would increase the speed of review turnaround and may not be feasible without sufficient program participation. Also, technology to automate data review is rapidly improving so these costs may be expected to decrease with time. Depending on program structure these costs may be borne by industry, NMFS, or indirectly by industry via fee collection. Review encompasses several tasks:
    - intensive review of chute mounted camera footage to obtain halibut lengths
    - extensive review of deck and stern view cameras to ensure compliance with discard rules
    - review of ancillary data (GPS and sensor data)
    - preliminary review to ensure data adequacy

- **Cost to NMFS for developing infrastructure.** Several months of full-time effort by staff would be required to design and develop the infrastructure and complete the database programming to receive the results of the EM review and incorporate the data into the catch accounting system. Additional data that may be needed for program monitoring (lengths and counts of individual halibut, non-text data, and vessel location data) would need to be effectively accessible to NMFS staff and would potentially require the development of new infrastructure and storage capacity and might require outside contractors. These costs would be borne by NMFS.

- **Data maintenance and storage costs.** These costs are highly dependent on the program structure and cannot be determined in advance. However, it is reasonable to assume that all EM data would be retained for some period of time and that specific EM data would be retained for a longer period of time. These costs would likely be borne by NMFS.

In order to better assess whether the cost of EM is competitive with 100% observer coverage, we used landings data from 2007 and 2008 to model costs on an individual vessel level. We made a number of assumptions.

- Labor cost for all activities is $50/hr.
- Review and enumeration of halibut discard requires 3.14 hours/trip.
- Review for discard outside of the discard chute requires ½ hour per fishing day.
- Hard drive collection and preliminary QC review requires one hour per trip.
- Equipment lease costs $40/day and equipment is installed two days before leaving for the first trip and removed two days after returning from the last trip.
- Installation costs $700 per year.
- Travel and per diem costs for a technician are not included. We assumed that full fleet participation would create sufficient economy of scale to make it economically feasible to train a local technician.
- Observer costs are $355/day (NMFS 2007).
- Costs for equipment leasing, maintenance and installation and data review would be borne by industry. This assumption was made simply for comparative purposes. As stated above, depending on program structure, these costs could be borne in several different ways Assuming that data review is an industry cost versus agency cost is a large policy decision and drives up the cost substantially. This decision needs to be highlighted for the reader.
- Costs for data maintenance, storage and additional infrastructure would be borne by NMFS and are not included. However, these costs could be potentially born by industry in the form of a cost recovery program.

For the 28 vessels that had at least one RPP landing in 2007 or 2008, we estimated the number of RPP observer days assuming 100% coverage. We then subtracted the final delivery date from the first fishing day and added four days to estimate the number of rental days. Using the actual number of fishing days and deliveries for each vessel, we estimated the number of review hours. This allowed us to project the cost of EM for each vessel by year and estimate the cost of observer coverage.

The graphic result of that projection is shown in Figure 9 where the projected savings or cost of EM relative to 100% observer coverage is plotted against the percent of rental days where the vessel was fishing. Under this model, EM savings would range from $6,870 per year to an additional cost of $5,400 per year. On average, EM under this scenario would cost an additional $237 per boat per year. However, as Figure 9 shows, cost declines quickly as the vessel fishes during more of the rental period. For vessels that would have been fishing more than 30% of the rental days, the model shows net savings for 27 of 32 observations. In most cases, observations where fishing took place during less than 30% of the rental period had a single large gap between fishing periods. To the extent that removing and reinstalling leased equipment is cost effective, one would expect to see these vessels remove the EM equipment during non fishing portions of the year. For those vessels that would have fished more than 30% of the days in the rental period, we also looked at the relationship between the number of RPP fishing days and the net cost or savings from using EM (Figure 10). Because of the fixed cost of installation and before/after fishing rental, it is clear that savings are greatest under the model assumptions for vessels that fish more days each RPP season.

Vessels requiring observer coverage pay a daily rate for an observer. The vessel also pays a prorated share of the cost of the observer's travel and debriefing expenses. When an observer is efficiently deployed over a long period of time, these costs are lower. When an observer must be sent for only a brief period, these costs represent a significant portion of the total cost of observer coverage. As stated above, we assumed that daily observer costs do not vary across time or between vessels. While this assumption simplifies the model, it represents an over-simplification of the true cost of observer coverage. In the case of a fishery such as the RPP, that is spread out in short pulses over a long period of time and takes place in a comparatively remote port, observer costs may be considerably higher (ie in the range of $355 to $500 or more per day). To the extent that the true cost of observer coverage is greater than $355/day, EM becomes more cost effective. For example, if the average cost of observer coverage is $500/day (a higher end estimate of potential daily observer cost in the RPP), EM would save the average vessel $1,165/season, with savings ranging from $7,764 per year to an additional cost of $4,948. However, irrespective of the daily rate used to estimate observer cost, the result remains the same—at current lease rates, EM would reduce costs for some vessels and increase costs for others.

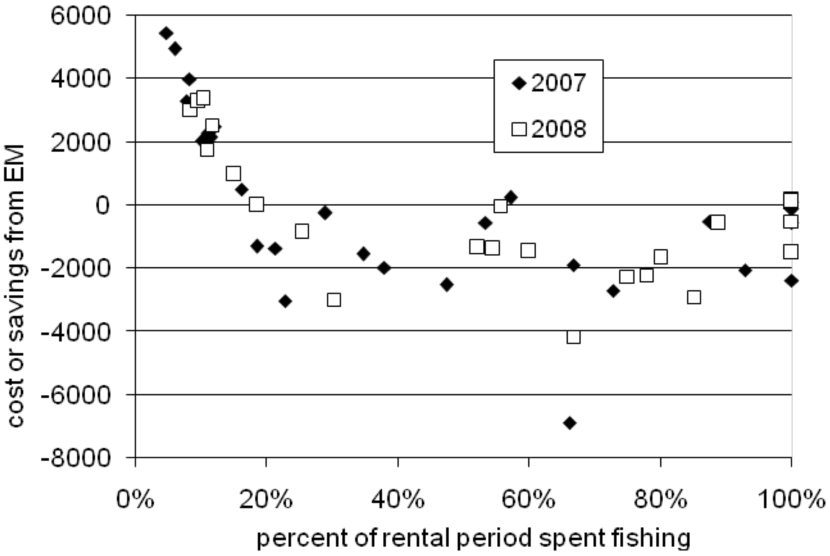

Figure 9. Estimates of per vessel cost savings or additional cost for using EM based on the number of rental days compared to 100% observer coverage. Each point represents a catcher vessel that participated in the RPP fishery. The number of rental days was estimated using landings data and the number of fishing days in the RPP for 2007 and 2008. Positive y axis value represent the projected additional annual cost (compared to 100% observer coverage) had EM been used in that year. Negative values represent projected savings.

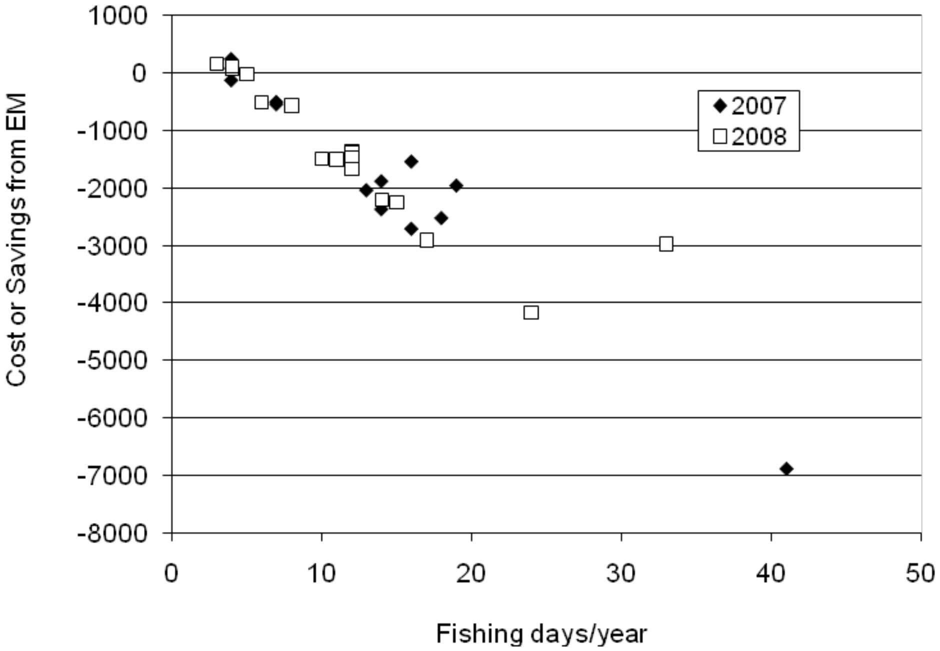

Figure 10. Estimating per vessel cost/savings for using EM vs RPP fishing days/year based on landings data in the RPP for 2007 and 2008 for vessels that would have fished during >30% of the rental days under the model assumptions. Positive y axis value represent the projected additional annual cost had EM been used in that year. Negative values represent projected savings.

Discussion

System Performance and Quality of EM Data

The results, similar to those of Phase I in 2007, indicate that EM can monitor for 100% retention and provide consistent and acceptable estimates of halibut discarded at sea in the RPP over one co-op and one RPP season. The system failure rate experienced during this study was higher than that seen during previous studies and would clearly be unacceptable in a full scale implementation. However, we do not believe that this is a serious long-term issue. The at-sea components of EM monitoring use reasonably mature technology that, in other applications, has proven to be quite reliable. Perhaps the best analog in current regulations is the use of at-sea scales in the catcher/processor fleet where, with limited exceptions, all catch must be weighed on NMFS approved scales. NMFS currently approves flow scales on 40 vessels and the failure rate is very low, yet the technology involved in accurate at-sea weighing of large volumes of catch (up to 100 mt/hr) is far more complex than the technology used for this EM application. . Because vessels required to use scales may not continue to fish if the scales are not working, the program vessel owners and operators have a strong incentive to ensure that the catch weighing equipment operates reliably. While such a rigid approach may not be suitable for this application, some, incentives must be built into any large scale implementation program to ensure equipment reliability.

Because a primary goal of Phase II was to determine how well EM systems could account for halibut bycatch under a variety of conditions, we did not attempt to constrain the design of discard chutes unduly and the four vessels had different approaches to chute design. The consistency of the EM results over all at-sea census trips on the four vessels indicates that EM performs well despite the diverse styles of discard chutes , crew members and their manners of discard, weather and lighting conditions, amount of halibut per trip and other unknown variables. Nevertheless, some crew training may be necessary to encourage discard methods that facilitate video review (including not blocking the camera view). The results do highlight that it will not be possible to fully anticipate how well an installation will perform until it can be tested at-sea.

Halibut Self-Reporting

The vessel halibut tally sheet trip totals collected in this study agreed fairly well with the EM system in terms of the number of halibut discarded and there was no evidence that these numbers were biased. Because of differences in count, we were not able to fully examine how well EM and skipper categorization by size agreed. Clearly, to the extent that vessel-reported halibut discard numbers are used for interim or actual quota accounting, more research into appropriate categories and the extent to which skipper self reporting is reflective of an EM based census is warranted. Acquiring an estimate of halibut bycatch from a vessel after each trip gives the co-op manager the essential tool she needs to monitor and manage a PSC cap that has the potential to shut down the co-op. With immediate feedback, the co-op can implement bycatch reduction incentives and/or penalties for non-compliance in the membership agreement.

Data Turn-around and Integration with the NMFS Catch Accounting System

There appear to be no inherent obstacles to the integration of EM data into the catch accounting system. However, the data turn-around times experienced during this project would clearly hamper the management of halibut PSQ by quota managers. There are three potential solutions to this problem. The turn-around time could be decreased by using local reviewers. However, unless the current average review time of slightly more than three hours per trip can be decreased, time lags of more than a week could still be an issue unless several part-time reviewers could be trained locally. The review could be either fully or partially automated. Video analytic software is currently used for more difficult tasks than determining the length of an object laying on a surface of known size and the current methodology used by Archipelago reviewers is robust but labor intensive. In the future analytic software may be used to speed up the review process by flagging only those frames where a halibut might be present, or by automatically determining the length of halibut in frames chosen by the reviewer. It may also be possible to automate the process entirely and human review would only be required for auditing. This is an area worthy of further investigation but it is unavailable now. Finally, managers could rely on an alternate data source (industry self reported halibut numbers) either for interim management or, if a formal and robust auditing structure could be developed, for actual quota debiting. A similar program using audited vessel logbooks is in place for the Canadian multispecies longline groundfish fishery (Koolman et al 2007).

EM Costs and Economies of Scale

Industry envisions EM as a voluntary, high quality and less expensive alternative to 100% human observer coverage for the RPP. Phase I and II indicate that EM can provide accurate estimates of halibut bycatch that are less variable on the haul or delivery level than current observer derived estimates. It would also provide for halibut catch accounting more in-line with NMFS goals for using census-level data for catch accounting in quota fisheries. But for EM to be seen as a viable option for vessel owners, it must be less expensive. Based on the cost data collected during this study and the rental-based scenarios explored in the results, it appears that EM is currently only cheaper for vessels that would be fishing during more than 30% of the rental period and for vessels that would be using EM in lieu of an observer during more than seven fishing days a year.

While EM appears to be an appropriate mechanism for accounting for halibut bycatch, it cannot replace a human observer for collecting catch data that must be spatially explicit at the haul level. Presently, vessel observers collect haul-specific species composition and biological data such as sexed length frequencies, otoliths, maturity assessments, stomach samples and tagged fish information. Marine mammal and seabird sightings and fishery interactions are also noted. If EM replaces all or part of the at-sea observer coverage, some of this at-sea and haul-specific data from catcher vessels will be lost because the shoreside observer would sample the catch at the trip level. Thus replacement of human observers with EM is a trade off: potentially improved accounting for halibut bycatch, but a loss of other observer-collected data. Fishing days where an observer is required in addition to EM would, under our model assumptions, be the equivalent of “unused” rental days and it would appear that at current costs, even 30% coverage would result in a very small subset of vessels that would find it cost effective to participate in the EM program. Those are vessels that fish a large number of days/year, so requiring EM participation could, under some scenarios, result in undesirable fleet consolidation. The level of at-sea observer coverage for this fleet necessary to provide these data has not been carefully examined by biologists and other alternatives for collecting haul-explicit data may exist (relying on the catcher/processor fleet, sampling deliveries where all fishing took place in a small area, etc). Clearly as part of the development of a future larger-scale EM program, the level of required observer coverage for other purposes must be addressed.

One of the outcomes of this project was the realization that an effective EM program for this application will require locally available support. At a minimum, such support is necessary for data collection, routine troubleshooting, and monitoring the status of EM systems. Costs for installation and repair would be markedly reduced if technical staff is available locally, and review times can be reduced significantly if data do not need to be shipped off-island. However, this requires a certain economy of scale. While the exact number of vessels that would have to participate in an EM program to make it cost effective to have local support staff is unknown, the protracted nature of the season and the patchy distribution of fishing effort would indicate that a fairly large number of vessels would have to participate. Industry envisions participation in an EM program as a potential option rather than a requirement and a number of researchers have indicated that EM programs tend to be most effective when they are either voluntary or have received broad industry buy in (Alaska Fisheries Science Center, 2008). Thus, neither NMFS nor the industry is contemplating a required-participation program. In addition to the need for vessel owners to realize cost savings, the use of EM in other fisheries will increase the economy of scale. Already some vessels participating in the RPP also participate in the hake catcher vessel fishery and would realize savings by using the same equipment in both fisheries. Increasing demands on monitoring for salmon discard by the catcher vessel fleet in the Bering Sea may be another, similar, application for EM that would have significant vessel overlap with the RPP fishery.

Finally only once the regulatory structure of an EM program can be developed will it be possible to determine the exact distribution of costs for the program.

Future Research

Improved reliability of at-sea equipment. Based on the results of this and earlier studies, it appears that EM technology can provide better data for the management of RPP halibut prohibited species quota and that it can do so at a comparable price. Similar technology is used to remotely monitor hundreds of oil wells scattered across vast areas of the Saudi Arabian desert; the damage caused by hurricanes in the Caribbean, and conditions inside Hawaiian volcanoes. Given these applications as well as other successful high technology programs currently in use by the fishing industry off Alaska, we assume that reliability issues experienced during this project can be resolved. One avenue of investigation would be to use an operating system (such as Linux) that is less prone to failure from unexpected shut-down and start-up cycles caused by unreliable vessel power sources. A second would be to investigate what technology is in use in other non-fishery but still analogous programs (harsh environmental conditions, minimal technical support, need to store and integrate multiple data sources, changing light conditions, etc).

Increased speed and accuracy of data review process. The field of video analytics is complex and the technology is evolving far more quickly than the technology for actually capturing EM data. Quite probably the ability to reduce the cost of the EM data collection equipment is minimal, but it may be possible to reduce the cost of data review significantly. While programs designed to automatically identify fish by species using EM have not been developed sufficiently for actual use in an ongoing fishery, the measurement of halibut passing across a marked grid is a comparatively simple application.

Continued trials in a flexible environment. The inflexibility of the federal regulatory process tends to fossilize technology at the point in time where the regulations were developed. The flexibility of operating an entire fishery under an EFP, as is used for the west coast hake fishery, may not be available to Alaska. However, it may be possible to continue large-scale but still pre implementation investigations of the use of EM prior to full regulatory implementation.

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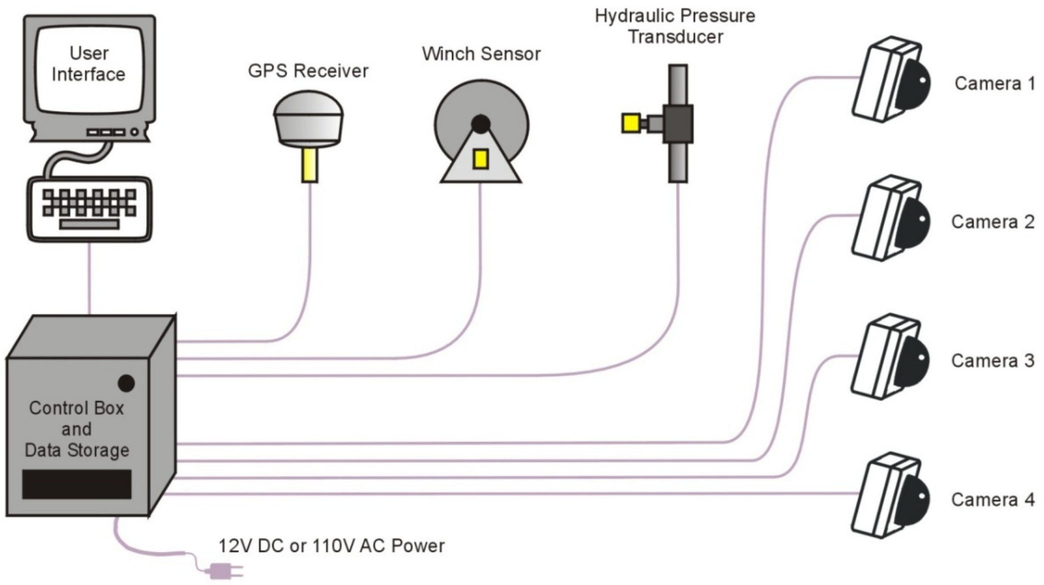
APPENDIX I – EM System Description *(Courtesy of Archipelago Marine Research, Ltd.)*

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 upon departure from Kodiak. The EM system was configured to automatically restart and resume program functions following power interruption. EM system components are described in the following sections.

Archipelago's EM system is shown schematically below and consists of the following components:



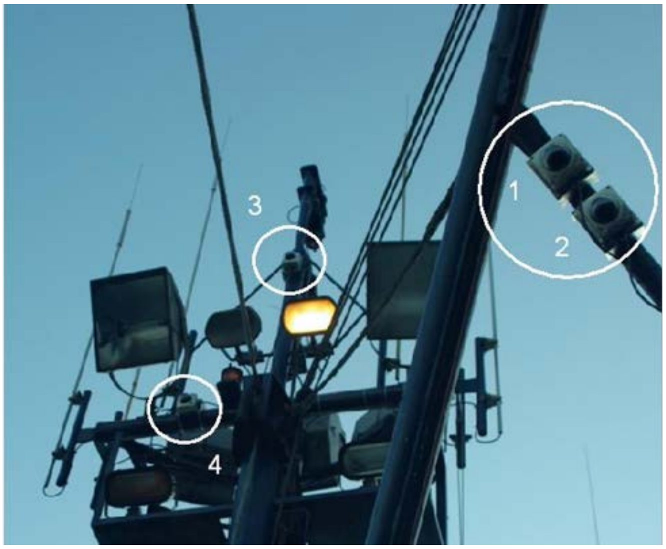
Control Box

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 (Fig. A1). 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 (Fig. A1). 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 three camera set up in this study (combined total of 13fps) and a 500-gigabyte hard drive would provide continuous recording for about 63 days.

Figure A1. EM control box (V4) and user interface installation

Figure A2. The four CCTV camera installations aboard the F/V *Sea Mac*. Each camera has a mounting bracket and stainless steel mounting straps.



CCTV Cameras

Waterproof armored 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.

Three color cameras with 480 TV lines of resolution and low light capability (1.0 lux @ F2.0) were used in this application (Fig. A2). 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

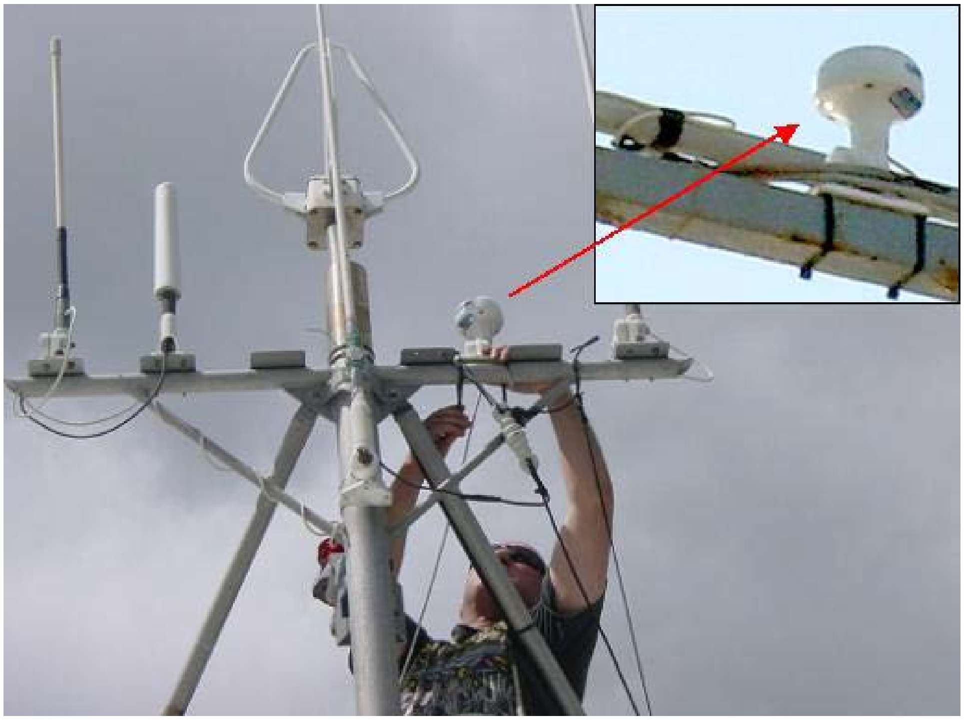
An independent Garmin 17N GPS receiver is installed with the EM system. The GPS receiver and antenna are integrated into a single plastic dome that is wired directly to the control box, there is no attached display interface. The GPS receiver is fixed to mount on top of the wheelhouse away from other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

APPENDIX 2 – Regulatory Approaches