Assessing discards using onboard electronic monitoring in the Northern Prawn Fishery

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NON TECHNICAL SUMMARY

2009/076	**Assessing discards using onboard electronic monitoring in the Northern Prawn Fishery**

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Objectives:

1. To deploy an electronic monitoring system on one commercial fishing vessel in the NPF and maintain its continuous operation during the Banana and Tiger seasons.
2. To evaluate the efficacy of electronic monitoring for assessing discards and a number of fishery monitoring issues.
3. To develop and evaluate an onboard discard procedure to estimate total discard weight.
4. To develop an audit-based approach to electronic monitoring data analysis for evaluating fisher logbook data quality.
5. To undertake a cost and benefit analysis of monitoring options and programs required to meet the fisheries data needs.

OUTCOMES ACHIEVED TO DATE

Implementing cost effective monitoring programs and services are critical for an economically sustainable fishing industry. This report describes trial of an electronic monitoring system for monitoring prawn discards in the Northern Prawn Fishery (NPF), and provides a valuable insight into the functionality and applications for this technology in the fishery.

The data collected was of sufficient quality and level of detail to meet AFMA's current onboard monitoring requirements. Potential cost savings for industry were identified when electronic monitoring was compared to an onboard observer program monitoring 15% of fishing effort. The break even point occurs at approximately 10% coverage; at 5% no cost savings were observed.

The report outlines how sensor and image data can be used to check the accuracy of the daily fishing logbook records.

Results of the trial indicate that electronic monitoring will assist the NPF in a number of areas including:

- Improved information on catches and catch composition to assist decision making.
- More efficient and cost-effective management arrangements such as streamlined quota monitoring and reconciliation practices, and
- Simplified regulations and improved compliance through the implementation of risk based operations by AFMA, underpinned by audit processes.

The Northern Prawn Fishery (NPF) is scheduled to introduce output based quota management arrangements during 2012. Increased observer coverage of fishing effort was recommended as a way to estimate discard rates during the fishery's transitional period to quota management. This report outlines the trial of electronic monitoring as a cost effective means of contributing to this data collection program in the fishery.

Electronic monitoring was trialled on one boat in the NPF during the 2010 and 2011 fishing seasons. The electronic monitoring system delivered very good temporal and spatial information on fishing gear setting and hauling activities, and also allowed AFMA to quantify the discarding of target prawn species, estimate the retained catch and detect interactions with protected species.

Observers and electronic monitoring saw approximately 75% of the same target prawn discards, and of those target prawn discards that were recorded by both observers and electronic monitoring, species identification was the same on approximately 93% of occasions.

Improvements may be achieved by working with the crew to develop and implement a standardised approach to handling and processing catch, enabling catch and other events to be viewed more easily using electronic monitoring.

An ongoing electronic monitoring program with audit and scoring methodologies that compare fishers' logbook data with electronic monitoring data can provide a measure of the reliability of fishing logbook records. When coupled with appropriate checks and feedback loops this can then be used to modify behaviours, improve logbook reporting and demonstrate the integrity of the data.

Introducing electronic monitoring for a fleet of 52 NPF boats and 15% monitoring coverage has the potential to deliver a cost savings of $73,207 per year and $433,446 over a 10 year period (net present value).

Additional benefits associated with electronic monitoring may also be possible if other management practices are changed. For example, restrictive management arrangements such as transiting closure rules could be modified to afford greater efficiencies for industry while meeting AFMA's necessary compliance and risk management needs.

Keywords: Northern Prawn Fishery, Electronic Monitoring, cameras, discards.

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1 BACKGROUND

1.1 THE NORTHERN PRAWN FISHERY

The Northern Prawn Fishery (NPF) is Australia's most valuable Commonwealth fishery occupying an area of 771,000 square kilometres off Australia's northern coast. The Fishery extends from the low water mark to the outer edge of the Australian fishing zone along approximately 6,000 kilometres of coastline between Cape York in Queensland and Cape Londonderry in Western Australia (Figure 1).

The fishery targets nine prawn species and catches are categorised into four general groups of banana, tiger, endeavour and king prawns. Individual species are not distinguished within those groups. Three species (common banana prawns, brown tiger prawns and grooved tiger prawns) account for between 80% and 90% of the total annual catch from the fishery.

The NPF has two distinct fishing seasons. These generally fall between March and June (banana prawn season) and between August and November (tiger prawn season).
Most operators remain at sea for the entire season, unless trawlers experience mechanical problems requiring in-port repairs. Trawlers unload onto barges, or motherships, which usually rendezvous with the trawlers every two/three weeks. Trawling is banned during daylight hours during the tiger prawn season to reduce bycatch and the catch of gravid females.

The Australian Fisheries Management Authority (AFMA) currently manages the NPF through a combination of input controls including limited entry to the fishery, gear restrictions, bycatch limits and a system of seasonal, spatial and temporal closures. Management arrangements are implemented under the Northern Prawn Fishery Management Plan 1995 (the Management Plan). The NPF has gone through extensive restructuring since the mid-1980s at which time there were approximately 280 boats, currently 52 boats are active in the fishery.

In December 2005, AFMA received a Ministerial Direction highlighting that the longstanding Australian government position is to manage all Commonwealth fisheries through output controls unless there is a strong case that can be made on a fishery by fishery basis, that this would not be cost effective or would be otherwise detrimental.

In 2008, the Northern Prawn Fishery Management Advisory Committee (NORMAC) initiated a Cost-Benefit Analysis (CBA) on management options for the NPF to determine the most cost effective and sustainable management regime. The CBA made the recommendation to move to output controls (see Kompas and Grafton 2009), and subsequently in August 2009 the AFMA Commission agreed to implement output based management in the form of quota for the NPF.

One individual transferable quota (ITQ) statutory fishing right will be allocated under an amended management plan for each of the 3 quota species includes tiger prawns (brown *Penaeus esculentus* and grooved *Penaeus semisulcatus*), red-legged banana prawns (*Fenneropenaeus indicus*) and common banana prawns (*Fenneropenaeus merguiensis*). The output based ITQ management arrangements are scheduled to be implemented in January 2012, in time for the 2012 fishing seasons.

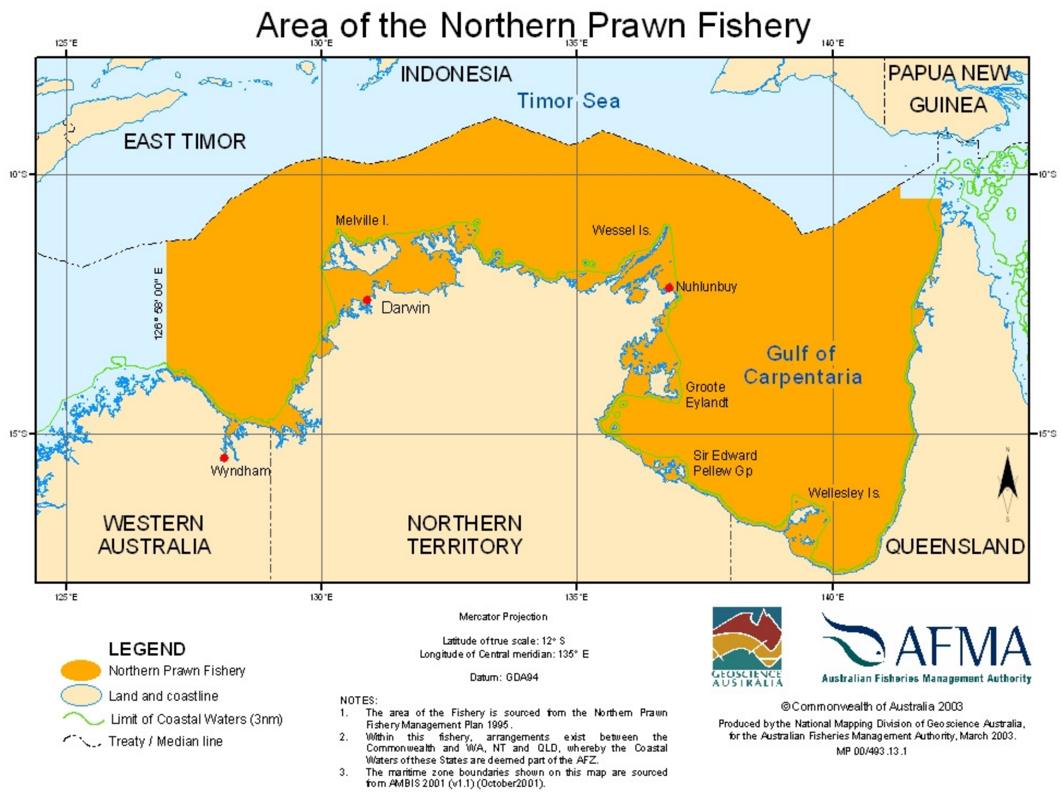

Figure 1: Area and spatial extent of the NPF.

1.2 MONITORING IN THE NORTHERN PRAWN FISHERY

1.2.1 Data Collection Programs

To collect all data needs in the NPF, several methods and practices of data collection are employed by AFMA includes Logbook , e-log program, Season Landing Reports, observer data, crew member observer program and fishing independent surveys. Programs have been implemented and modified in line with developments in the fishery, changes to management arrangements and needs for environmental assessments. An overview of the major data collection methods are summarised below.

Logbooks

NPF operators are required to complete the ‘Northern and Torres Strait Prawn Fisheries Daily Fishing Log’ (NP16), a paper logbook on a daily basis. This records a range of catch and effort information in the fishery. Alternatively, NPF operators can use an electronic version (e-log). About 80% of the fleet use electronic logbooks. Following the completion of each fishing season Concession holders are also required to complete a Season Landing Report, which is seen by AFMA and industry as an accurate record of the catch landed.

Observers

The scientific ‘at-sea’ observer program provides a data collection and verification service to management, researchers and industry. The program includes developing experimental design and project plans, training and deploying observers, collecting fishery independent data and samples, data management and production of reports and data summaries.

Observers in the NPF collect a range of data on vessel fishing activity including positional information, fishing gear, shot details, catch composition (commercial catch and bycatch), biological sampling (commercial species, protected species and species of interest), wildlife interaction observations of protected species, wildlife abundance counts, marine pollution breaches and the collection of data for specific research programs (bycatch reduction devices, species of interest for ecological risk assessments, sawfish stomach sample, sea snake data etc). Since 2005, the AFMA observer program has undertaken an average of 146 sea days each financial year resulting in <2% coverage of fishing effort.

Crew Member Observer program
A Crew Member Observer (CMO) program was developed during 2003 to create a cost effective method of assessing bycatch in the NPF by involving voluntary crew members in the collection of scientific data. The CMO program enables additional bycatch data to be obtained in a cost effective manner, especially interactions with protected species and such as turtles, sea snakes and sawfish. This data is crucial in assessing improvements in bycatch reduction and impacts of fishing.

1.2.2 Compliance risks and monitoring

In the fisheries compliance context, risk equates to the failure of fishing operators to comply with fisheries management arrangements and/or fishing permit/concession conditions. AFMA's compliance program targets high risk activities and operators and implements several monitoring programs including but not limited to vessel inspections, as sea patrols including aerial surveillance and Integrated Computer Vessel Monitoring System (VMS). The VMS technology is used to monitor fishing operations and the movement of vessels during each season including movement through restricted zones. VMS units allow AFMA to contact the skipper of vessels where reports are overdue. Compliance officers ensure that each vessel has an operating VMS and is functioning in accordance with conditions imposed on the fishing permit.

1.3 PREVIOUS ONBOARD ELECTRONIC MONITORING PROJECTS

Over the past decade, Archipelago Marine Research Ltd. has pioneered the development of onboard video based electronic monitoring technology. McElderry (2008) provides a listing of over 25 studies (including 4 in Australia) spanning diverse geographies, fisheries, fishing vessels and gears, and fishery monitoring issues.

In 2005, a series of 'proof of concept' studies over a number of Australian Commonwealth fisheries. This included an electronic monitoring trial was undertaken in the NPF on the *FV Austral* during the 2005 Banana prawn season. The scope of the project was to understand if the technology could accurately record fishing operations, to detect large bycatch species in the prawn catch and have image quality sufficient to allow identification of species that may be key indicators in the ecological risk assessment process. The trial showed electronic monitoring data can be used to differentiate between fishing and non-fishing (maintenance at sea) events, including shooting, hauling and net cleaning events. However, the trial highlighted issues with the quality video images to identify small bycatch species in the catch (see Stanley 2006).

In 2009, AFMA commenced a comprehensive trial of electronic monitoring in the Eastern Tuna and Billfish Fishery (ETBF). To support a trial in the NPF, AFMA was in a position to capitalise on the resources, software and equipment available from the ETBF pilot project (see Piasente *etc al*. 2012 in press). As part of the ETBF electronic monitoring project, evaluations and assessments were undertaken to assess the costs and benefits of electronic monitoring. These assessments assisted the necessary data inputs and comparisons to aid and support cost-benefit analyses and service delivery for integrating an ongoing electronic monitoring program in the NPF.

2 NEED

Like the majority of the world's fisheries, the 'at-sea' observer program in the NPF is implemented to record and verify catch information. Kompas and Grafton 2009, recommendation to move to output controls identified that observer coverage may need to be far larger to protect the value of the fishery, therefore understating the costs of management. During 2009, NORMAC considered the NPF ITQ Cost Benefit Analysis report and ITQ options for the NPF. Observer coverage levels were discussed to provide adequate base level information to estimates discard rates of quota species. NORMAC agreed to implement 15% observer coverage during the transitional period to quota management and requested AFMA to investigate the potential use of cameras to offset observer coverage and costs.

A 2007 AFMA commissioned cost benefit study and business case showed reduced costs if electronic monitoring technologies were adopted in preference to observers in several Commonwealth fisheries (see Gislason 2007). The challenge exists to trial electronic monitoring in the NPF and assess the uses of image data obtained onboard a prawn trawler. As such, the project was designed to understanding the utilities of electronic monitoring technologies for 'at-sea' monitoring in the NPF. The project will also assess the cost effectiveness of a program that provides economic and operational incentives for AFMA Concession or Permit Holders.

3 OBJECTIVES

The project had five major objectives as outlined below:

1. To deploy an electronic monitoring system on one commercial fishing vessel in the NPF and maintain its continuous operation during the Banana and Tiger seasons.
2. To evaluate the efficacy of electronic monitoring for assessing discards and a number of fishery monitoring issues.
3. To develop and evaluate an onboard discard procedure to estimate total discard weight.
4. To develop an audit-based approach to electronic monitoring data analysis for evaluating fisher logbook data quality.
5. To undertake a cost and benefit analysis of monitoring options and programs required to meet the fisheries data needs.

4 MATERIALS AND METHODS

4.1 PROJECT PLANNING AND VESSEL SELECTION

During 2009, industry members from the NPF indicated a willingness to undertake a trial of electronic monitoring equipment to clarify the applications of these technologies to monitor fishing activities. The NPF Industry Company, representing around 90 per cent of fishing operators in the fishery considered a project proposal during February 2010 and endorsed a one vessel trial to be undertaken during the 2010 fishing seasons.

Expressions of interest to participate in the electronic monitoring trial were sought from the NPF Industry Company. Representatives from Raptis And Sons Pty Ltd agreed to participate and nominated the *FV Australian Pearl* to take part in the trial (Figure 2). AFMA and industry representatives commenced planning for the project early 2010 defining project tasks, roles, coordination, timelines, system installation and vessel requirements.

Figure 2: Trial vessel *Australian Pearl* in port at Karumba.

Before commencement of the trial, agreement to obligations prepared to help participants understand the responsibilities and requirements during the trial such as assistance and cooperation during system installation and resolving operation problems.

4.2 ELECTRONIC MONITORING SYSTEM SPECIFICATIONS

The electronic monitoring system used for this project was custom manufactured by Archipelago. A schematic diagram of the system is provided in Figure 3. The system consists consist of four closed circuit television cameras, a GPS receiver, a hydraulic pressure sensor, a rotation (winch) sensor, and control centre.

The rotation sensor and the pressure transducer are used as indicators of fishing equipment activity and trigger video recording. The pressure transducer fitted to the conveyor system provides a distinguishing signal for catch processing for the video analysts. While the GPS is necessary for the hot stamping on the imagery of the position and time, as well as resetting the bios clock of the systems box.

All systems were fitted with satellite transceiver modems for real time reporting of system status. The system Health Statement is an hourly message sent via satellite communication while electronic monitoring systems are powered. This one line message is a synopsis of the previous hour's sensor data including vessel location, activity and system operational status. This was used throughout the project to monitor the systems hard drive status remotely, to troubleshoot technical problems and prioritise service events.

Sensors and cameras were connected to a control centre located in the wheelhouse. The control centre consists of a computer that monitors sensor status and activates image recording when the fishing gear is operational. The system was also programmed to record imagery run-on periods of 30 minutes following the use of the winch and conveyor systems. Sensor and image data were recorded onto 500GB hard drives which were estimated to last up to 3 months of normal fishing operations. The system specifications are described in Appendix 3.

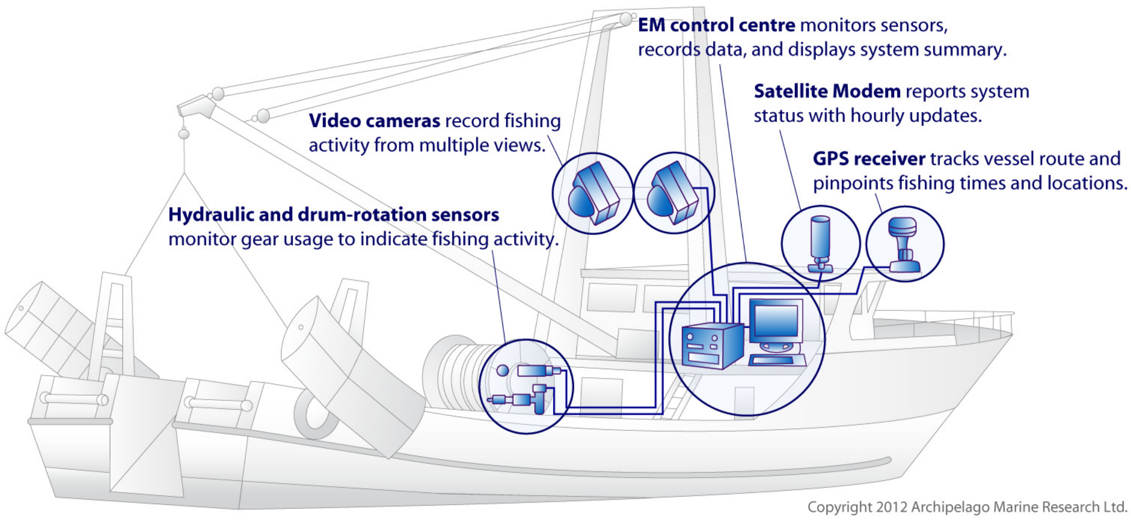

Figure 3: Schematic of a standard electronic monitoring system used in the trial.

4.3 SYSTEM INSTALLATIONS AND SERVICING

4.3.1 Banana Prawn Season 2010

One of the main challenges of this trial was to assess the ability of cameras to record the discards of target prawn species (banana & tiger prawns) and provide an estimate of discard weight by species from viewing the recorded imagery. There were very few avenues for variations to the vessels onboard catch processing methods, limiting any new or substantial modifications to processing equipment or methods during the trial. This being the case, a discard procedure was agreed to be tested during the banana prawn season as a first approach. This procedure is outlined below.

Onboard procedure to view and monitor discards
To record the discarded component of the catch the following procedure was considered and agreed to be trialled during the banana prawn season. Baskets were to be positioned to collect all discards from the chute in camera view. It was requested that the crew

undertake this extra task during processing. The intention of this procedure was to enable the viewer analysing the imagery to record the number of baskets discarded to provide an estimate of total discards. To monitor the discard procedure and fishing operations, cameras were installed to view the following areas:

1. above the discard chute to record prawns and other discards, with the aim to provide:
   - a total count of prawns (by species) discarded,
   - a count of prawns discarded by basket, and
   - a ratio of prawns to other discards by basket.
2. the area where discards are collected in baskets to record the number of baskets discarded, and
3. the spill of nets to the hopper (looking for large animals and protected species).

An AFMA observer trip was planned during periods of the trial to record catch information for comparisons with the outcomes from the image analysis. The observer trip was scheduled to record the species composition of each basket. In particular, target prawn species and ratio of prawns to other discards (by weight). The number of baskets (sub-sample) sorted will be dependent on the size of the catch.

During 19-22 March 2010, AFMA project staff and Raptis and Sons personnel commenced installation of the system on the *FV Australian Pearl* in Karumba. Before the installation commenced the technicians scoped and agreed on the preferred system component placement, cable runs, fishing operations and onboard practices.

The electronic monitoring system's GPS receiver and satellite modem was predominately mounted in the vessel rigging. The hydraulic pressure transducer was installed in the line of the conveyor system and the rotation sensor was mounted on the winch starboard (Figures 4). Following installation, the receipt of the systems' Health Statement was confirmed.

The control centre and monitor were located inside the wheel house and sensor and camera cables runs were drawn to the wheel house through ports already in place for hydraulic and electrical lines. Upon completion of the system installation, the system was powered to test all sensor and cameras. The skipper was also briefed on basic system operation, maintenance and the user interface. It was noted that the onboard discard procedure required during the trial will be unlikely carried out during the first week or two of the banana prawn season due to large catch amounts.

Two cameras were installed and fully operational, one viewing the hopper showing the catch being spilt and the second positioned at the end of the discard chute to observe discards collected into baskets. A third camera positioned to show sorting and processing on the conveyor belt was not operation due to a suspected problem with the camera's power board.

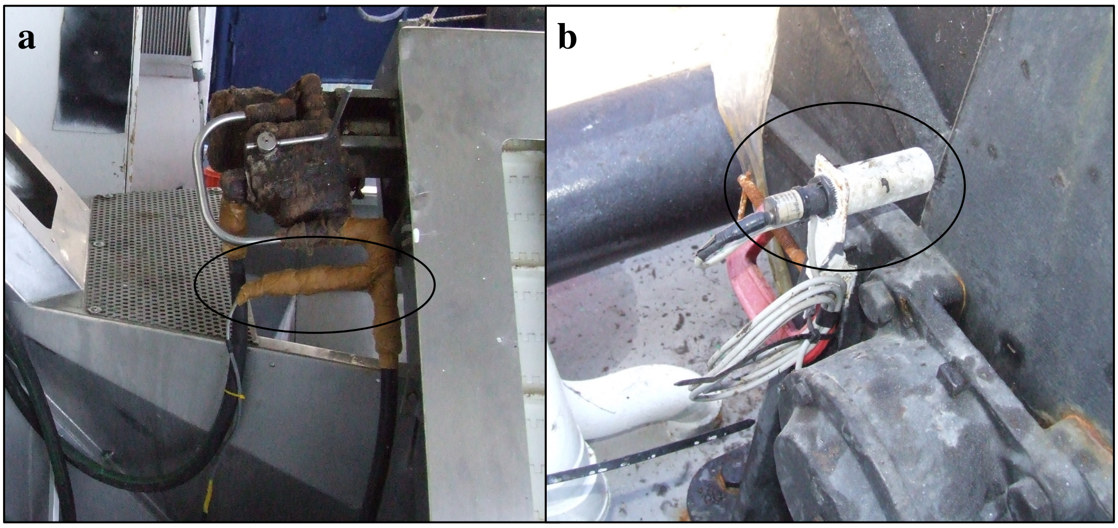

Figure 4: System sensors (circled) installed to record operational activities and activate cameras; (a) hydraulic pressure transducer installed on the high pressure at the end of the conveyor system and (b) the rotation sensor installed on the starboard winch.

4.3.2 Tiger Prawn Season 2010

During the mid-season break a review of the project was undertaken. In consultation with the NPF Industry Company, it was agreed to discontinue the trial of the discard procedure (collecting discards in baskets) as a method to estimate prawn discards. This was largely due to the logistical requirements including concerns regarding Occupational, Health and Safety (OH&S). It was agreed to trial a visual count method through installing a second camera viewing the conveyor. This camera focused on the area at the end of the conveyor after sorting has taken placed to test if target prawns species can be detected being directed to the discard chute.

It was also agreed to install of a fourth camera in the processing room to view sorting and packaging of catch. This view tested if image data can provide images of sufficient resolution and clarity to allow the image viewer to record the retained catch further assessing the applications of the uses of onboard cameras. Figure 5 and 6 show the positions of cameras installed and corresponding views during the tiger prawn season.

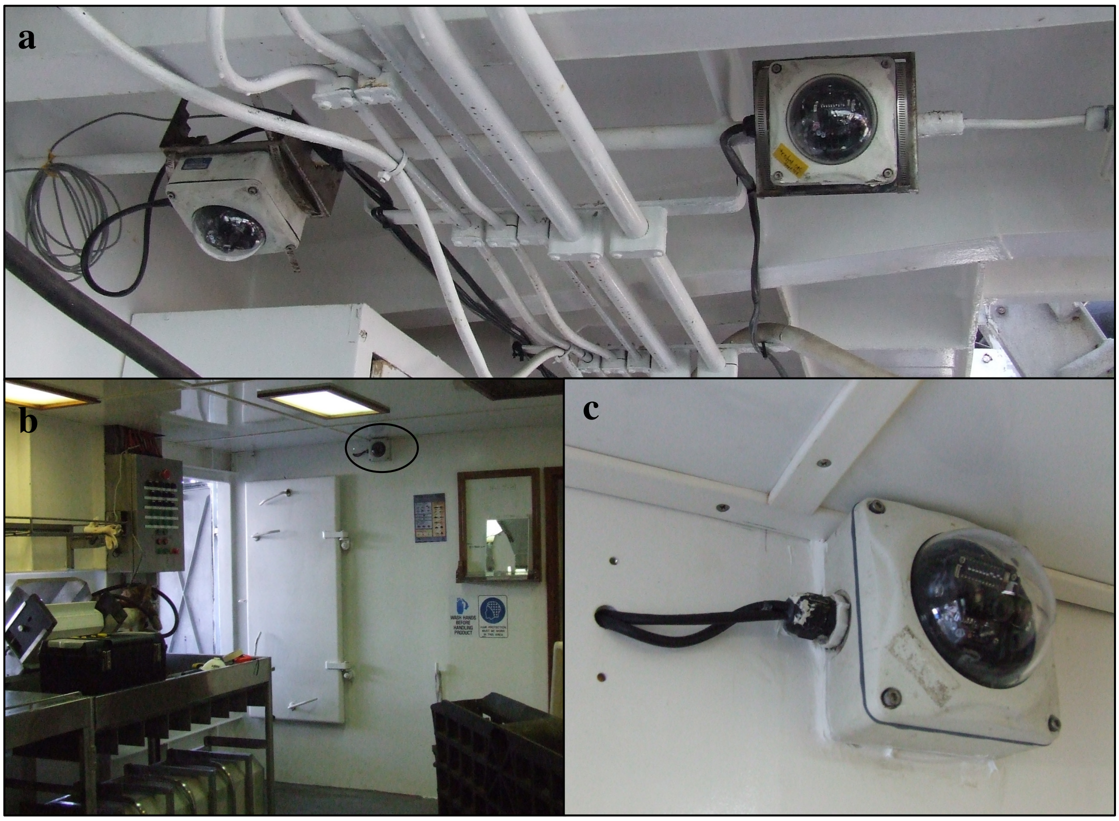

Figure 5: Cameras placed to capture views of sorting and processing catch during the tiger prawn season includes (a) the two views of the conveyor system, (b and c) camera circled in the processing room to record the retained catch.

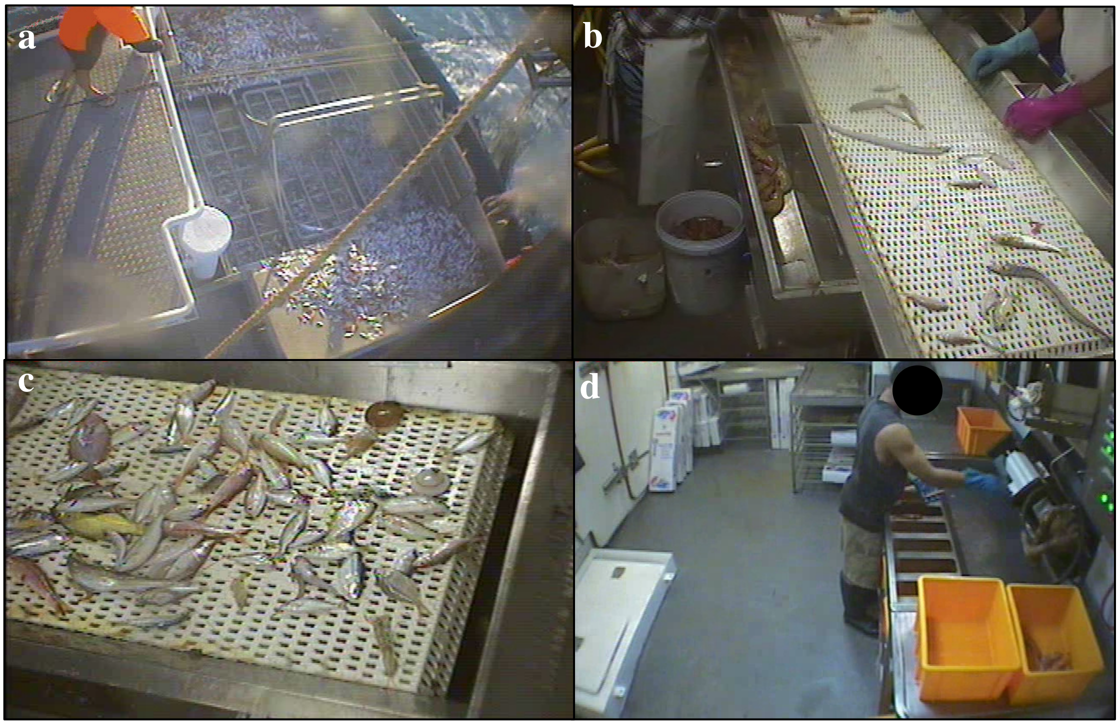

Figure 6: Capture views obtained during the tiger prawn season includes (a) catch spilt into the hopper, (b) sorting catch on the conveyor, (c) catch directed to the discard chute and (d) storing and grading retained catch in the processing room.

4.3.3 Banana Prawn Season 2011

In March 2011, the NPF Industry Company and NORMAC agreed to extend the trial to undertake onboard methods to verify the accuracy of discards recorded by image analysts to further assess the feasibility of cameras as a monitoring tool for prawn discards. Methods to verify target prawn discards indentified by the image analyst with the onboard observer were developed. These included:

1. The observer was positioned at the end of the conveyor (on the opposite side of the camera to avoid blocking cameras view) during catch processing replicating the same view of camera one (C1) and recorded prawn discards (species and time for each individual) directed to the discard chute. Observer records were compared to image analysts' records.
2. The observer inconspicuously (i.e. not noticeable from imagery camera 3, wide view of conveyor) placed a minimum of 20 commercial (banana / tiger) prawns at the beginning of the conveyor as discards. These prawns were deliberately left as discards by the crew sorting the catch, and were subsequently directed to the discard chute. Prawns were placed on the conveyor at random times to simulate a prawn discarded during the catch processing period. The time each prawn is placed on the conveyor was recorded (to match results from image analyst). These known prawns placed on the conveyor by the observer were matched against the image analysts' results to validate the ability to identify and record prawns from image data.

To assist with additional data collection for the extension of the NPF trial an *in situ* review of the electronic monitoring installation from the previous Tiger Prawn season was conducted in the last week of March. Several adjustments were made at this time to allow for the extension of the trial for the 2011 Banana Prawn season. These included the:

- The welding of the camera mounting brackets to the frame work or bulkhead as there was corrosion of the stainless steal tensioning straps;

- The installation of a new beta version of Archipelagos' system software. The object of the software change was to allow for a simpler (non technician) swap of hard drives while the vessel is at sea or in remote ports.

- Cameras were adjusted in accordance with the revised monitoring design and the pressure transducer sensor was replaced as the cabling had been damaged in past Tiger Prawn season's fishing

4.4 DATA CAPTURE AND PROCESSING

During the project the system Health Statement was regularly monitored to assess the status and available space on the systems hard drive. Using the custom-made electronic monitoring data analysis software *EM Interpret*, hard drives were processed to asses the completeness of each data set and interpret time and location information of fishing activity.

The first step in data interpretation began with an overall inventory of the data set and an assessment of its quality. Through this process a determination was made of missing data and whether the system and sensors performed properly. As the sensor data are recorded on a 10-second frequency, time breaks in the data record are easily identified as time intervals of greater than 10 seconds between adjacent records. As well, the system logs reports all instances of power interruption or system reboot. Time breaks were recorded in terms of the number of breaks and the total time missing. An evaluation of the performance of each of the systems sensors and cameras was also undertaken. The signals from the GPS, electronic pressure transducer and rotation sensor were evaluated for completeness while the signal from each camera was evaluated for each haul.

The raw image data was viewed and sampled for analysis against the logbook data and comparisons with the observer data. Image data was assessed for a number of monitoring issues with the following prioritisation:

- Assess image quality and usable data,
- Analyse shots where there is observer data,
- Prioritise those shots where protected species are known to occur,
- Assess discard component of catch and record target prawn species to the highest taxonomical level possible, and
- Determine the retained component of the catch for selected shots.

4.4.1 Prawn discard validation methods

To verify observer data with the results from the image analysis, comparisons of total prawn discards by species for each shot between onboard observer and image analysts' results were undertaken. Scoring of the success of observer and electronic monitoring system comparisons was performed in two stages:

1. A comparison was made between the records of the observer, and the records of the electronic monitoring image analyst to calculate how often the same prawn was recorded using both methods; and

2. When a prawn was recognised by both methods, a comparison was made to calculate how often the same species was recorded.

A scoring mechanism was also applied to further compare the image analysts' results to the benchmark (observers' results). The correct identification of both the event and the species was awarded 2 points, incorrect identification of the prawn species but correct identification of the discard event was awarded 1 point and failing to identify either the prawn or the event was awarded 0 points.

4.5 COST BENEFIT ANALYSIS

A key component of the project was a cost and benefit analysis (CBA) of electronic monitoring to determine the short and long term costs. In 2010, an extensive electronic monitoring pilot project was undertaken by AFMA in the Eastern Tuna and Billfish Fishery (ETBF). Information obtained during the ETBF pilot was used to provide cost estimates for the key activities and capital purchase for an electronic monitoring program (see Piasente *et al*. 2012 in press).

The cost inputs in the ETBF's CBA of electronic monitoring were used to determine the implications of electronic monitoring in the NPF and weighed against the potential benefits. Not all costs and benefits are easily quantifiable, as such items that are not quantifiable were assessed in a qualitative way as best as practicable.

An AFMA coordinated service delivery model was considered with 100% uptake of the current fleet size (52 vessels). For the proposed electronic monitoring program it was assumed that a level of observer coverage will still be required, therefore an 80% saving in the observer program was anticipated (to allow for 2-3% observer coverage to be continued) following the implementation of an electronic monitoring program.

5 RESULTS AND DISCUSSION

5.1 BANANA PRAWN SEASON 2010

The banana prawn season commenced on 31 March 2010. Four days into the season the system Health Statement stopped polling indicating a problem with the systems power or satellite modem connection. Investigations indicated an issue with system boxes power supply following water damage incident in the wheelhouse. A project technician was able to board the vessel mid May and undertake a 5 day trip to address system performance issues. A number of observations were made during this trip including:

- Identified faulty camera cable connector on cable inlet #1 inside system box rectifying the problem associated with the camera positioned to view sorting on the conveyor.
- Motion sensor on main winch working effectively. It was noted that activation of cameras to record from the rotation sensor could create a lot of unwanted files due to winching gear to the surface when vessel turns to trawl over patches of prawn multiple times without bringing codends onboard.
- In order to collect and weigh discards, the chute had to be removed. The length of the discard chute is one piece making the removal of the chute to collect discard a logistical challenge. The practicalities of carrying and emptying full baskets of discards were also identified to be an Occupational, Health and Safety (OH&S) issue.
- The hydraulic sensor stopped working during the trip and was observed working intermittently. Variations in camera activations resulted in a limited number of shots recorded where discards were weighed by basket at the chute for electronic monitoring trial comparisons were recorded. Manual activation of cameras was undertaken when the run-on period from the rotation sensor lapsed.
- Camera on Hopper was noted to have water inside the housing impacting image quality, this camera was resealed as a short term fix.
- The skipper noted that the system did not present any issues during the fishing operation. The skipper expressed support for the use of cameras, particularly to monitor catch quality and work practices of the crew.

Following this trip an AFMA observer commenced a trip for the remainder of the season. It was identified that the satellite modem stoped polling just before the technicians' departure. The observer was able to confirm that the system was operating; however the cause of not being able to receive Health Statement polls remained unclear during the season.

It was decided not to persist with undertaking the discard procedure due to practical difficulties and OH&S concerns especially in rough conditions. Due to the intermittent activation of the cameras to record by the hydraulic pressure sensor, the observer would regularly undertake regular checks to confirm cameras were recording during processing and activate the system to record manually if recording had stopped.

Limited complete sets of image data during the banana season restricted a detailed analysis of catch information to enable direct comparisons with logbook or observer data. As such, a qualitative assessment of the imagery and views enabled recommendations to modify the system and approach to monitor discards during the tiger prawn season.

Camera views
The following images show stills of the camera views trialled during the banana prawn season, include:

- Figure 7: View of catch being spilt into the hopper, to monitor catch.
- Figure 8: View of sorting on conveyor to detect and record prawns being directed to the discard chute. Shows two methods/conveyor arrangements for processing; 2a shows prawns being removed non-retained catch directed to the discard chute, and 2b shows discards being removed and re-directed the chute, while prawns remain on conveyor directed to the sorting/processing room.
- Figure 9: View of the discard chute to show discards collected in baskets to record the number of baskets discarded per shot.

Due to the decision to cease the trial of the onboard discard procedure, the camera view of the discard chute was modified to provide an increased focussed view of the chute. Removal of the cover provided the ability to assess the quality of the image and capacity to record the composition of discards. It was determined that image quality is dependent on the rate of water flow the amount of discards limits to detection of prawns from the imagery (see Figure 10).

Figure 7: View of Hopper showing (a) a clean catch of prawns and (b) shark species circled.

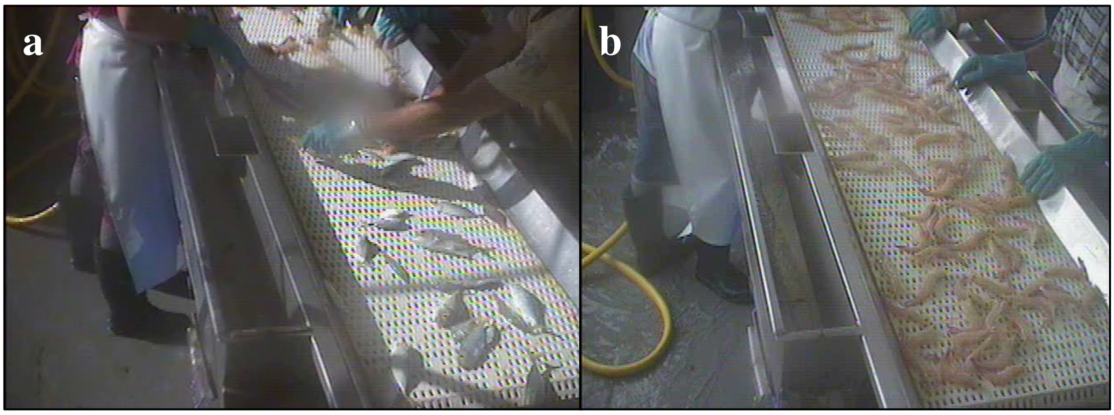

Figure 8. View of sorting on conveyor to detect and record prawns being directed to the discard chute. Shows two methods / conveyor arrangements for processing; (a) shows prawns being removed non-retained catch directed to the discard chute, and (b) shows discards being removed and re-directed the chute, while prawns remain on conveyor directed to the sorting/packaging room.

Figure 9: Original view of the discard chute to show discards collected in baskets to record the number of baskets discarded per shot.

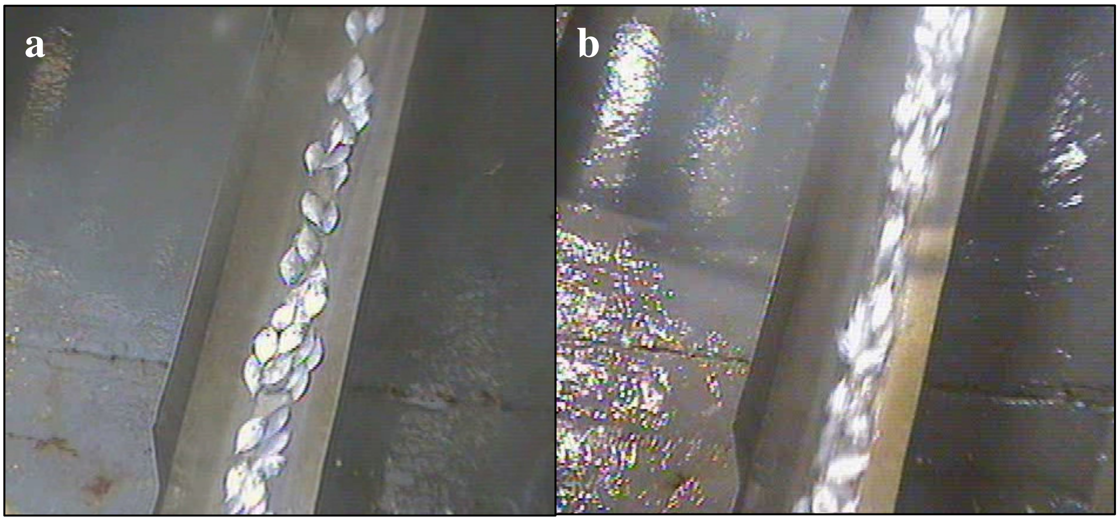

Figure 10: Modified view of the discard chute (without cover) to assess the ability to record discards passing along the discard chute showing differences in image quality in relation to water flow (a) slow and (b) fast rate.

5.2 TIGER PRAWN SEASON 2010

During the first month of the tiger prawn season the system performed well and data completeness was high in terms of capturing image data showing all of the catch processing and packaging. Following the first month the pressure sensor again worked intermittently resulting in gaps in the image data. As such, ten shots were selected for analysis over 3 nights during mid August. An assessment of system performance is provided in section 5.4.1. Results of the image analysis catch comparisons and general observations are provided below.

5.2.1 Monitoring Discards

Monitoring the camera views of the conveyor to determine prawn discards required focused concentration over extended periods of time. In general large commercial prawns were easily detected amongst other bycatch and discards (Figure 11b). On occasions large numbers of small non-commercial prawns were observed as discards (Figure 11a).
The analyst noted that after viewing 5 hauls, the ability to differentiate between commercial and non-commercial prawn species improved with each haul viewed leading to greater confidence in prawn species identification. It is recognised that a mix of small commercial and non-commercial prawn species will create challenges for image analysts to distinguish commercial species.

Table 1 provides a summary of the number of commercial prawns detected as discards from the image analysis. It was often the case that, after a prawn being seen as discarded, the analyst would take up to 6 replays to ensure confidence in recorded analysis. Figure 12 provides examples of images of commercial prawns being directed to the discard chute. For an ongoing program, it is recognised that a level of competency for species identifications will be required for image analysts.

Table 1: Number of commercial prawns observed to be discarded during image analysis

Fishing night	13-Aug			14-Aug			15-Aug			
Shot no.	1	2	3	1	2	3	1	2	3	4
Banana Prawn	0	5	3	13	0	0	0	0	0	0
Tiger Prawn	1	4	3	0	5	0	5	2	1	1
Penaeidae target spp.	14	6	4	9	16	0	7	1	2	0
Total	15	15	10	22	21	0	12	3	3	1

Figure 11: Camera view at the end of the conveyor showing (a) small non-commercial prawns being directed to the discard chute and (b) clearly observed tiger prawns amongst fish bycatch.

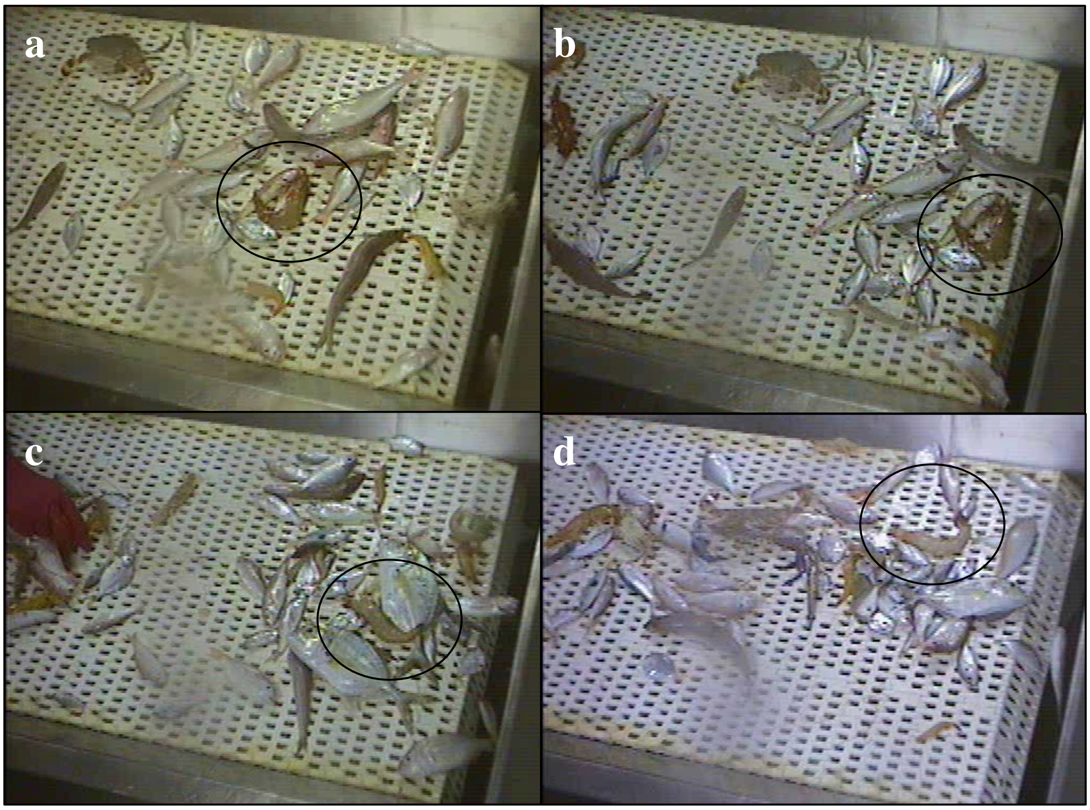

Figure 12: Camera view at the end of the conveyor shows target prawn species identified as discards by image analyst. Shows sequence of a tiger prawn directed to discard chute (a & b), possible endeavor prawn (c) and banana prawn (d).

5.2.2 Monitoring Retained Catch

Reviewing the imagery in the packing room and counting the number of cartons and boxes was trialed as a method to estimate retained catch (Figure 13). As the NPF fishing log are daily (or fishing night) entries. The recorded catch by shot was combined to provide a catch estimate for each fishing night. Comparing logbook, observer and image analysis results was used to assess the quality of image data to provide insight into the ability to record retained catch. This comparison revealed a close match of total retained weight between data sources (Table 2).

The image analyst commented that the ability to record cartons of product being packed and stored in blast freezer below decks was high however, half filled cartons placed in the small blast in packing room and retrieved and filled during next pack made it difficult to assess each hauls individual tally. Combining the recorded weights for each shot undertaken during the fishing night did provide a comparative match with the logbook data.

Distinguishing different species in the packing room and tracking the number of boxes/cartons by species did present a challenge for the image analyst. Further understanding the standard approach to processing and packing different prawn species will help image analysts determine different species and estimate retained weights.

Table 2: Comparison between total retained catch (kg) for 3 fishing nights.

Fishing night	Observer	Logbook	Electronic Monitoring
13-Aug	664	664	637
14-Aug	738	746	745
15-Aug	1076	1076	1080

Figure 13: Camera view of the packing room, counting the number of boxes and cartons each shot provides an estimate of retained catch.

5.2.3 Protected Species Interactions

Imagery obtained during the project showed a number of captured and released protected species. The protected species observed are included in the summary of all the catch and utilization recorded by electronic monitoring (Table 3). Cameras have shown to be a useful tool for detecting and monitoring handling of sea snakes (Figure 14 & 15).

Table 3: Comparison between the numbers of sea snakes recorded for 3 fishing nights.

Fishing night	Shot no.	Observer	Logbook	Electronic monitoring
13-Aug	1	1		0
	2	1		1
	3	1		0
Total		3	0	1
14-Aug	1	2		0
	2	4		3
	3	2		1
Total		8	4	4
15-Aug	1	2		1
	2	3		2
	3	0		0
	4	2		2
Total	10	7	5	5

Figure 14: Images showing the handling of sea snakes on the conveyor system.

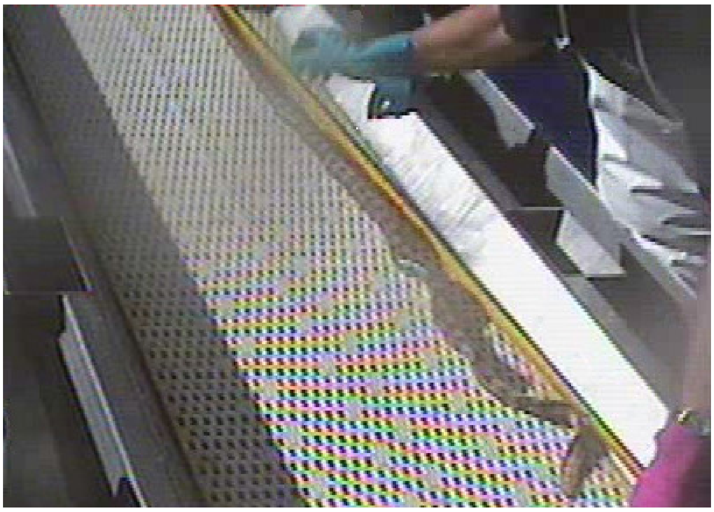
Figure 15: Image showing the observer measuring a captured sea snake.

5.2.4 Other monitoring applications

Camera views provided a means to monitor other onboard activities and bycatch during fishing operations. For example, the aft camera view of the vessels hopper was shown to be reliable for monitoring the use of turtle excluder devices (Figure 16). The detection of turtle excluder devices (TEDs) were largely observed when the trawl nets are positioned in the hopper allowing for a clear view of the nets. In comparison to TEDs, the bycatch reduction devices (BRDs) used in the NPF are significantly smaller in size making it more difficult to detect presence and type of BRD being used.

The camera views of the conveyor system were also shown to be useful detecting other bycatch such as sharks and rays (Figure 17). Benthos material was also detected on the conveyor. While, experienced observers advised that the majority of bycatch observed on the conveyor can be identified to genus level from the captured imagery. Analysis of this camera view has the potential to provide catch composition information of discards.

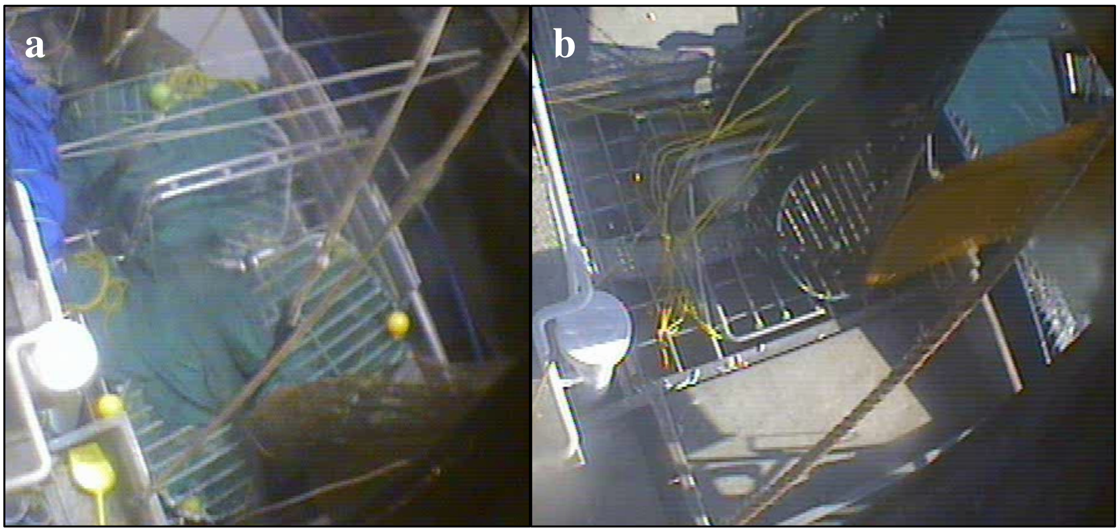

Figure 16: Camera view of the hopper shows clear view of TEDs during (a) banana prawn season and (b) tiger prawn season.

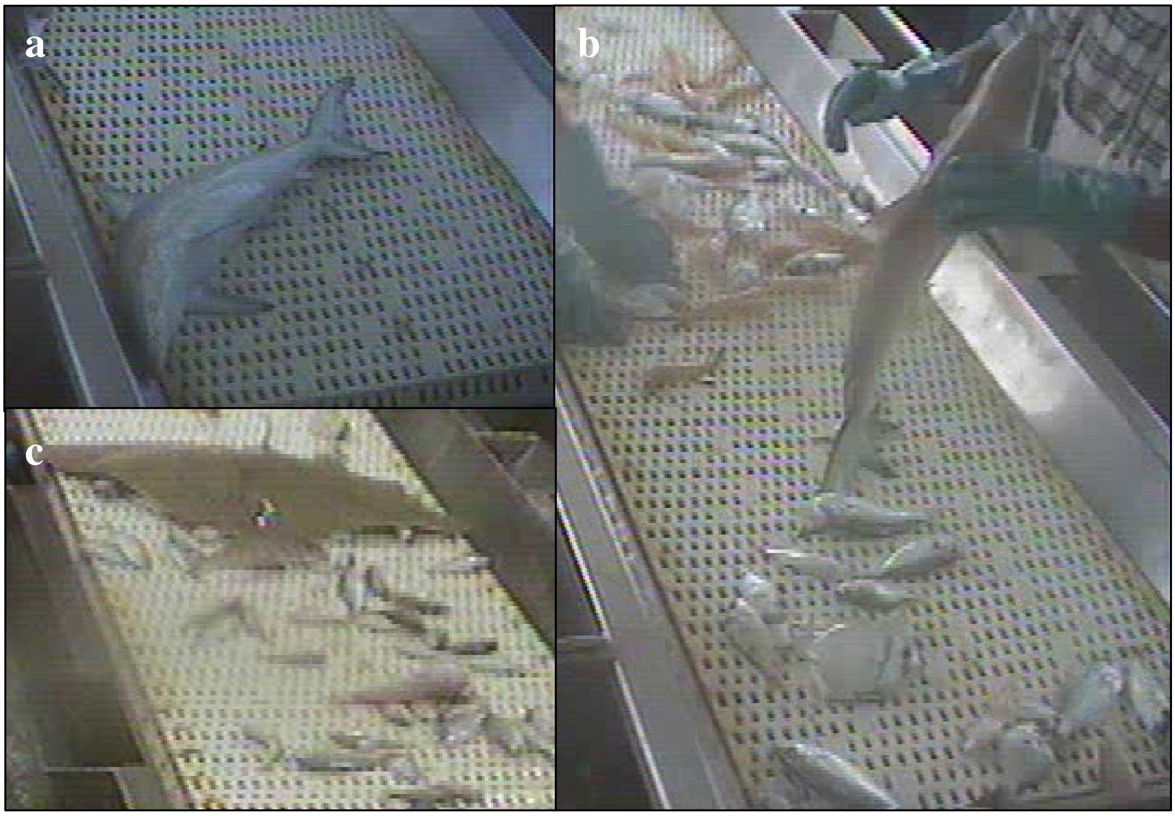

Figure 17: Images of the conveyor system showing (a & b) shark species and (c) a ray species.

5.3 BANANA PRAWN SEASON 2011

An onboard observer trip was undertaken at commencement of the 2011 banana prawns season to undertaken the discard validation methods. The methods tested during the observer trip included:

- Method 1; Accidental and deliberate (broken and/or damaged) prawn discard times were recorded as prawns reached the end of the sorting conveyor. Data was collected over 8 shots during the trip;

- Method 2; Poor quality prawns (between 30 and 80 individuals) were placed on the sorting conveyor and allowed to be discarded during a further 8 shots. Times were recorded as prawns were placed on the conveyor.

These verification methods could only be employed when the catch comprised of more bycatch than commercial product (prawns). During these shots, the crew configured the sorting conveyor so the product to be retained was removed from the conveyor. Bycatch and poor quality or non-target prawn species were left on the conveyor and directed to the discard chute. This is referred to as configuration ‘A’.

During shots where the majority of the catch was prawns (to be retained), the conveyor configuration was altered so the prawns remained on the conveyor and continued on to the dipping hopper. In this orientation the bycatch and poor quality prawns were removed by the crew and directed to the discard chute. This is referred to as configuration ‘B’.

Prawn discards were negligible when configuration ‘A’ was employed. However, a number of large shots conducted early in the season (employing sorting configuration ‘B’) were recorded where relatively large quantities of prawns (estimated weights of between 500 and 1800kg) were discarded. This was due to 3 main factors:

- The product remained in the hopper for a long period of time and the quality was compromised. This usually occurred when small prawn boxes (5kg) were used instead of large boxes (10kg) as this more than doubled the time required to process the catch;

- The water level and product in the hopper was poorly managed and the quality was compromised (large numbers of broken and damaged prawns);

- The snap freezers could not cope with the volume of product caught (prawns in hopper could not be processed until boxed product reached required temperature).

Results from the image analysis were tallied and compared by species to detect key identification issues for each shot to assess improvement overtime and determine a potential learning curve. The time taken for the analysis of each shot was recorded. These times were used to estimate a cost per shot and incorporated into the cost-benefit analysis.

The results showed that, on average, electronic monitoring image analysis recorded the presence of the same number of discarded prawns as recorded by an observer 75.2% of the time, and the same species 92.6% of the time (Table 4). Graphs showing the “learning curve” for the electronic monitoring image analysis suggested that there was no clear improvement in species or prawn recognition over the small number of samples analyzed (Fig. 18).

Table 4: Comparison of recording of the presence and species of prawns by observers and electronic monitoring analysis.

A	B	C	D	E		F		G	H
Shot #	Method	Observer discards	Analysis discards	Prawn recognition	% successful prawn recognition	Species recognition	% successful species recognition	Overall score	Comparison percentage
25	1	68	64	41	60.3%	40	97.6%	81/136	60%
28	2	50	437	44	88.0%	43	97.7%	87/100	87%
29	1	83	111	72	86.7%	68	94.4%	140/166	84%
30	2	40	122	28	70.0%	28	100.0%	56/80	70%
34	1	254	311	208	81.9%	196	94.2%	402/508	79%
35	2	50	165	32	64.0%	31	96.9%	63/100	63%
46	1	95	134	87	91.6%	69	79.3%	156/190	82%
47	2	75	714	64	85.3%	62	96.9%	126/150	84%
51	1	124	105	64	51.6%	57	89.1%	121/248	49%
54	2	50	140	35	70.0%	28	80.0%	62/100	62%
61	1	83	99	62	74.7%	53	85.5%	115/166	69%
62	2	50	206	39	78.0%	39	100.0%	78/100	78%
Totals		1022	2608	776	***75.2%***	714	***92.6%***		72.3%

NB: 1 point for prawn recognition comparison and 1 point for species recognition comparison
Column A indicates the shot Analysed.
Column B indicates which trial method was used.
Column C indicates discarded prawns recorded by onboard observer
Column D indicates discarded prawns recorded by analysis
Column E shows number of prawns recorded by both observer and analysis
Column F shows number of prawns recorded by observer at species level and recognised as same species by analysis
Column G represents the actual comparison score over the highest possible score per shot
Column H represents consistency in comparisons between observer and analysis expressed as a percentage

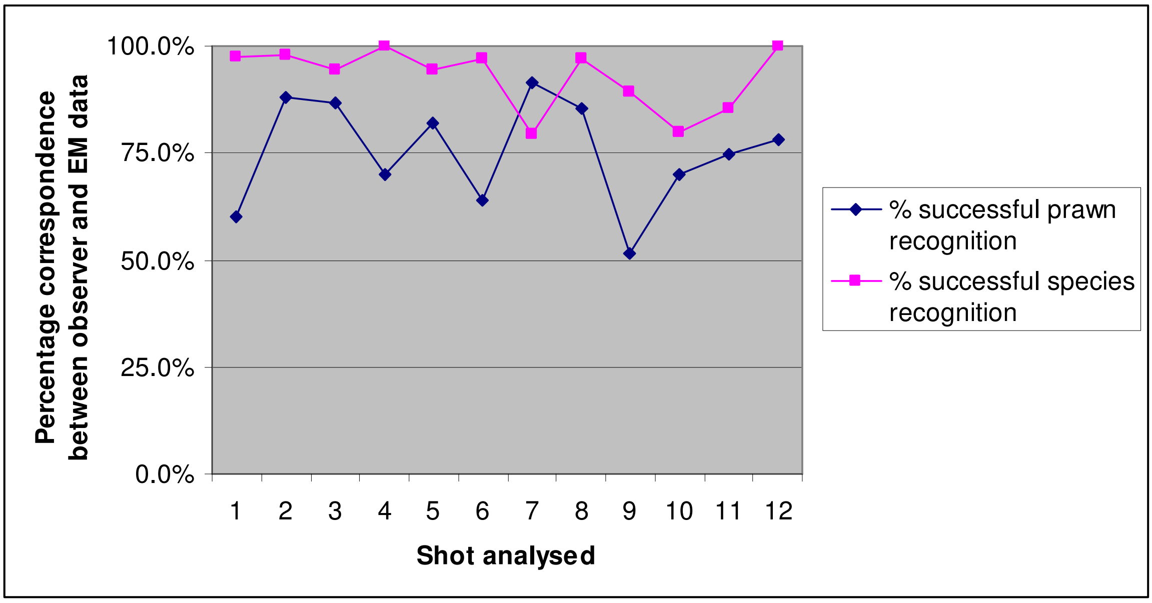

Figure 18: Percentage correspondence between the recognition of individual prawns and species during the consecutive analysis of a number of shots.

5.3.1 Summary

To assess the utility of cameras for 'at-sea' monitoring, cameras were positioned to answer the following questions:

- Can electronic monitoring image data provide images of sufficient resolution and clarity to allow an image viewer to accurately record discarded target prawn species?

- Can electronic monitoring image data provide images of sufficient resolution and clarity to allow an electronic monitoring viewer to identify interactions with protected species?
- Can electronic monitoring image data provide images of sufficient resolution and clarity to allow an electronic monitoring viewer to record and estimate the retained catch?

This project was able to demonstrate that target prawn species can be detected from images of the conveyor system. Additional work was undertaken in 2011 to verify target prawn discards indentified by the image analyst. This analysis suggested that the electronic monitoring analysis detected prawns with about a 75% success rate, and the species with a success rate of above 90%. Some issues were flagged during this analysis that could be resolved by improving or modifying the electronic monitoring technology. Sun glare was identified as a problem with shot 51 prior to the observer and electronic monitoring image data being directly compared. This sun glare reduced the ability of the analyst to clearly see prawns, and is reflected in the 50% identification rate of that shot. Glare was also identified as a problem in some other shots but was not a protracted issue. It is possible that issues of glare could be reduced by the use of polarizing filters.

Identification of prawns and some smaller TEP species could be improved by the positioning of cameras. The analyst suggested that species identification would be assisted by moving the camera closer to the hopper, perhaps on the taffail above the deck work. It should be remembered that the results reported here are specific to the boat the data was collected on, and the specific installation architecture of the equipment. It is possible that additional work could improve the results of prawn discard measurement.

It is understood that the requirement to obtain baseline measures of prawn discards exist for the transitional period as the fishery adjusts to the new quota management arrangements. Further considerations and agreement on how cameras can capture this information and acceptance of the method to estimate discards is required by stakeholders before adopting cameras as a feasible alternative to 'at-sea' observers.

It is recognised that logbook records will be used as the source of catch to be decremented from the fishing concession's quota holdings. The completion of season landing returns will still be used as a means to audit logbook catch records. It is also understood that log book misreporting (quota avoidance) is an increased compliance risk for quota managed fisheries. The capacity to monitor the packaging room and estimate retained catch enables a comparison with the logbook will provide increased level of confidence in the accuracy and reliability of logbook data records and use for quota management.

There were ten interactions with seasnakes recorded by the electronic monitoring image reviewer during this study. These interactions were all incidentally captured species during fishing. Bringing the captured seasnakes in clear view of the camera and showing the crew handling the species on the conveyor made these recognisable events in the electronic monitoring imagery. However, compared to the observers catch data, eight seasnakes were not reported from the electronic monitoring images. The missed interactions could have taken place outside the camera view. To help detect interactions and assess life status, clear onboard handling practices need to be defined (i.e. handled in clear view of the camera) and complied with by crew for onboard cameras to be a feasible replacement for the monitoring of protected species interactions.

5.4 LOGBOOK AUDIT METHODOLOGY AND FRAMEWORK

5.4.1 Background

In the ongoing electronic monitoring programs integrated in Northern Hemisphere fisheries, electronic monitoring data is used as an audit mechanism for self-reported data in fishing logbooks to be validated by comparing randomly selected portions of electronic monitoring interpreted data. This process allows industry to take ownership and responsibility for the quality of data and imagery collected. The fact that electronic monitoring technology allows for 100% data collection 'at-sea' permits the option of reviewing a subset of data collected with the option of doing a full review to obtain a complete reconstruction of catch and other activities 'at-sea' if warranted.

An audit program is an assessment and feedback loop for improving fisher logbook data that is used as inputs to management decisions. Archipelago has developed and implemented this type of audit methodology in the British Columbia (BC), Canada hook-and-line fishery. This has proved very successful in improving data quality of fishing logbooks. An output of this project was the creation of an Audit Framework that can serve as a starting point for developing an audit program in the event an electronic monitoring program is supported in the NPF.

5.4.2 Monitoring Objectives

The design of an audit depends largely on the information requirements for management. The general objectives proposed for an ongoing NPF electronic monitoring audit program would be to:

- account for catch (both retained and released including protected species) in the fishery,
- account for fishing effort, and
- monitor compliance to fishing restrictions and regulations.

These objectives would need to be further refined based on management and industry data needs and priorities in order to offer direction for the overall monitoring program design and audit.

5.4.3 Data Sources

At the core of any audit program is the baseline data against which comparisons are made. In Archipelago's BC ground fish audit-based monitoring program the data sources used are fishing logbooks, electronic monitoring, and Dockside Monitoring data. This model has electronic monitoring data as a baseline to compare the fishing logbook data.

In order to compare the data and effectively audit the logbooks, there must be a data overlap between sources. Data alignments identified between electronic monitoring and fishing logbooks to enable comparisons from both data sources include:

- total retained catch, and
- protected species interactions.

Currently the logbook requires daily entries of catch and effort information. This impacts the alignment and verification of electronic monitoring catch and effort data which is collected on a shot by shot basis. A change in data collection methods by fishers may be required to better align data for an ongoing logbook audit program.

There is some overlap between data collected by 'at-sea' observers and data available from electronic monitoring sources. The current observer program in the NPF collects data at about 2% of the effort in the fishery. If there is an interest in maintaining some observer coverage on the fishery, the observer program data could be used as validation of electronic monitoring data on an on-going basis. This comparison would allow for the continued improvement of the electronic monitoring data collection set-up and processing methods.

5.4.4 Evaluation

The evaluation approach needs to be based on the prioritised monitoring objectives and take into account the data sources. There are two cost drivers to consider when determining how to evaluate fisher provided data in an audit-based approach: how much should be tested to pass scientific scrutiny and enable stakeholder confidence, and how to determine if the data has integrity and reliability.

An acceptable level of electronic monitoring data review needs to be established based on assessment of risk and consultation with stakeholders. It is recommended that all sensor data be interpreted to determine data completeness and to determine electronic monitoring system performance. In the case of the NPF a percentage of events or fishing days would be selected either based on season or data collection period, depending of data reporting requirements. The CBA has assumed a 15% sample and audit of fishing shots per year.

Logbook data is put through several tests to measure the quality of the logbook data when compared to electronic monitoring data. Evaluation methods can be defined as scoring accuracy, standards met, and vessel history.

Vessel history can also be used in the evaluation methodology and must be based on either scores or standards and its meaning and use evolves as vessels gather history and the program matures. It can be used in different ways but the main concept is to highlight individual accountability by taking into account past performance when considering the data quality assessment scores of a current analysis. This approach is very powerful once consequences with agreed responses are applied into the program. The premise is that consistently poor performance in electronic monitoring evaluation will have consequences escalated much faster than for operators who have consistently provided good data but perhaps failed to do so on a single occasion. In industry funded programs, vessel history has proven to be an effective incentive by affecting the level of scrutiny required when sampling video and hence cost to the operator.

As the NPF moves towards the implementation of output controls, catch evaluation will be a primary focus the monitoring in the NPF and likely the most complex aspect of the audit system. This is because there are different species that may be present in any given haul, and each of them would likely need to be separated by utilisation. Not all species represent the same level of concern and an audit program can be sensitive to that. To start with, not all species need to be tested (even if catch information is still recorded for all) or at least not tested to the same level of detail. A nested approach to testing catch would be appropriate, i.e. some species may be tested separately while other may be tested as part of species groupings. For example, the recommended quota species (tiger and banana prawns) have been identified by AFMA as the primary species of concern for management purposes.

5.4.5 Electronic Monitoring Program Structure for NPF

The proposed structure of an electronic monitoring program would begin with the skipper completing fishing logbook records during the season, electronic monitoring equipment would be used to collect corresponding data. Both the electronic monitoring and fishing logbook data sets would be processed, audited and scored for each fishing season once received at AFMA. AFMA would then decide actions to be taken including the need to modify records for stock assessment work. Audit scores not meeting a predetermined threshold will be passed for further analysis. That could include 100% viewing of the electronic monitoring imagery or referral to Compliance.

Audit results would be provided to Concession Holders. Actions taken for poor audit scores would be in accordance with a "Response matrix" to be developed. If necessary, information would also be provided to the service technician to make adjustments to the electronic monitoring equipment onboard before commencement of the next season or earlier depending on the nature of the problem.

The feedback loop provided in this process gives feedback on a regular basis to Concession Holders, Skippers and Fishery Managers. The outcome sought is continuous improvement in data quality, accuracy and timeliness. The proposed audit framework is a starting point for developing a program that allows for full catch documentation and continued improvement to monitoring methods. Based on previous electronic monitoring program experiences, the feedback loop is recognised to be integral in ensuring success of the program demonstrating that fisher logbooks can become a reliable source of data with appropriate checks and feedback loops.

The audit-based monitoring program should be implemented in stages, where the emphasis in the first one or two years is to provide feedback to industry, polishing the process, and analysing the information gathered to understand where most of the data quality issues or risks are. For the first year there may only be scores and the standards are more like guidelines for each vessel to understand where they sit within the preliminary expectations. Not until the program is generally understood by industry and participants including reporting and system operational data standards would it be advisable to begin considering consequences for poor data quality.

5.5 ASSESSMENT OF SYSTEM PERFORMANCE

5.5.1 System reliability during trial

In this trial the system was powered by the boats 240 volt power system. Several factors contributed to the loss or gaps in electronic monitoring fishing events data over the course of the trial. In the banana prawn season the main problem included loss of power through water damage to the power adaptor to the control centre. Delays replacing the power adaptor resulted in the system being powered for half of the fishing season. Short power losses or time gaps to the electronic monitoring system were also observed during the trial. It is expected that these time gaps are associated with power switching or the necessity to turn off generators for oil and or filter changes. These were expected over the term of the trial. The system has an internal watchdog that re-starts the system when such events occur.

There were issues recorded with peripheral equipment during both fishing seasons. Issues included failure of the satellite modem during the banana prawn season. This did not necessarily compromise the functional collection of imagery and or sensor data for fishing operations. However, it did limit the ability of AFMA staff to remotely monitor system functionality status. The control centre was replaced during the mid season break and no issues with the satellite modem and problems receiving Health Statements were observed during the tiger prawn season.

The failure and/or intermittent reading from the pressure sensor during the trial compromised the functional collection of imagery during catch processing and packaging. Sensor reliability was assessed using the tiger prawn season once the power supply was fully operational. This assessment was based on sensor functional status on per shot (set/haul) and processing basis rather than an hourly or trip duration. For each fishing shot functional status of each sensor was categorised as either complete (normal sensor reading), partial malfunction (intermittent or abnormal sensor reading), or total malfunction (no sensor reading). An example of normal sensor readings are provided in Figure 18, in comparison an example of intermittent pressure sensor readings are provided in Figure 19.

Sensor performance during the tiger prawn season is summarized in Table 4. Complete GPS and rotation sensor data was obtained for 100% of the shots monitored, while only 23% of the trips had complete hydraulic sensor data. Recommendations to improve system performance are provided in Appendix 4 (Table 14). Recommendations described have also been aided by the experiences and observations undertaken during the 2009/10 ETBF electronic monitoring pilot project.

Table 4. Summary of performance by system component during the tiger prawn season.

	Pressure Sensor	Rotation Sensor	GPS
Complete	85	373	373
Partial Malfunction	130	0	0
Total Malfunction	158	0	0
Total shots	373	373	373
Percent complete	23%	100%	100%

Figure 18: Screen capture from electronic monitoring Interpret shows line graph of normal fishing pressure sensor data (red - pressure sensor, green - vessel speed, blue - rotation sensor). This results in a consistent capture of image data during processing which is shown in green for the 4 camera below the line graph.

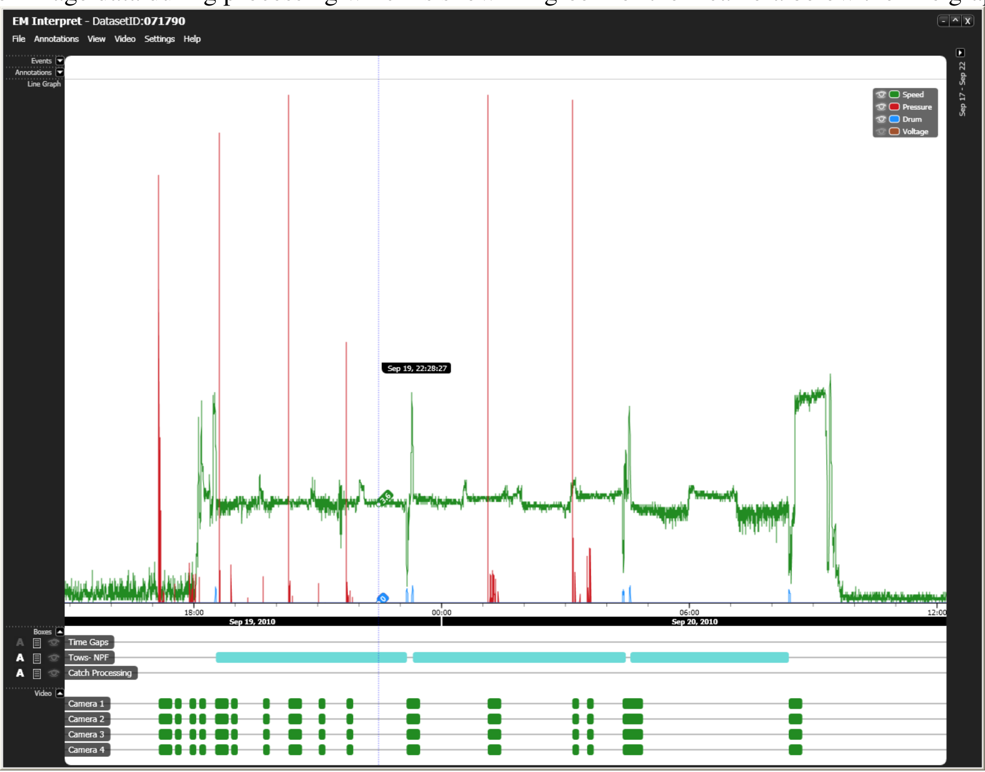

Figure 19: Screen capture from electronic monitoring Interpret shows inconsistent spikes in the pressure sensor data resulting in variable triggers and time gaps in the image data.

5.5.2 Camera related issues impacting image quality

Cameras were noted to function reliably during the trial. The project did however identify a number of camera related issues impacting image quality and usability, these problems are detailed below.

Humidity and moisture build up
During installation the cameras had desiccant gel packs inserted inside the camera housings. However there were several cases of moisture ingress into the camera housing that affected image quality, particularly the camera view of the hopper (Figure 21b). A regular function test regime should identify the development of these problems and issues. In most cases the camera housing should be resealed with a silicon pack and gel to deal with moisture problems. In a worst case scenario the camera's power board and lens would need to be replaced.

Glare
Glare on the water will often occur with low sun angles and in some case specific lighting incident angles. Those occurrence due to sun angle are largely unavoidable but might be reduced with wider angle views and the use of sun shades within the camera housing. In those instance where the glare is due to lighting incident angles the only possible remedy is a change in the camera location if it possible. Glare problems were observed on outboard camera views during hauling (Figure 20).

Figure 20: Glare impacting image quality during early morning on the conveyor.

Maintenance
During the trial salt build up was noted mainly on the exposed camera view of the Hopper (Figure 21a). External salt build up on the camera domes compromised imagery in some cases and this build up would have been noted with regular skipper initiated function tests and remedial cleaning could have been undertaken.

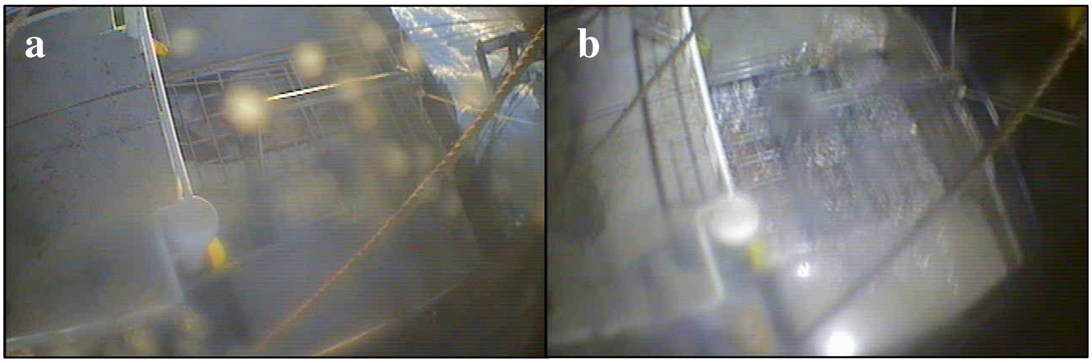

Figure 21: Examples of salt build up (a) and humidity (b) impacting image quality on camera view of the hopper.

Monitoring and uses of the System Health Statement

During the course of the trial the Health Statement was used to check vessel location and the equipment status. It proved a useful tool for monitoring vessel activities and identifying possible issues with the system and components (e.g. sensors). Data from the hourly statements was graphed over time to determine fishing events and activities. Incomplete and inconsistent data was interpreted and in some instances validated with the vessels owner or skipper.

This tool also enabled project technicians to prioritise service events (e.g. hard drive exchange) and identify issues requiring further attention. Further experiences with Health Statement data and documenting interpretations of this data would assist the reductions in response time to problems and guide necessary actions if the use of this tool were to be ongoing.

In an operational electronic monitoring program the Health Statement will be used by:

- AFMA to monitor the operational status of systems and compliance with function testing requirements and protocols. It may also be used as a proxy for VMS.
- Field service providers to schedule servicing.
- The fishing operators for the remote management of fishing operations.

5.5.3 Summary and Recommendations

Apart from the power issue during the banana prawn season the electronic monitoring system was able to operate consistently during the trial. The data collection problems associated with the hydraulic pressure sensor were either due to a faulty sensor and/or inadequate position in the hydraulic line. Irregular and abnormally high pressure sensor readings were noted over several periods and these might well have indicated an issue with the hydraulic system dump valve. It is expected that replacing the pressure sensor and/or repositioning will improve data completeness and reliability of the system. The use of a proximity sensor (triggered by movement of the conveyor) or link to the conveyor power (on/off) switch are possible alternatives to activate the system to record imagery during catch processing. Either option would require further testing and possible software development and configurations (in the case of the power switch), to be a viable option.

In an ongoing program, vessel personnel will need to learn more about the operation of the equipment to detect and report equipment failures. The priority toward resolving issues needs to be at the forefront of Concession Holder and Skippers' minds such that problems are resolved in a timely fashion and fishing vessels are not at sea with inoperable electronic monitoring systems.

AFMA will need assurance at the start of each trip that the electronic monitoring system is fully functional and that the imagery will be fully suitable for monitoring needs. This can be achieved with the use of regular Heath Statement monitoring and the requirement to have the owners and skippers to undertake a system function test before a trip start and routinely over the course of the trip. The in-port function test should be conducted well before scheduled sailing such that service technicians can address any issues that are noted during the test. A strong engineering support framework will be necessary from the manufacturers, installers and service technicians.

5.6 COSTS AND BENEFITS OF ELECTRONIC MONITORING IN THE NPF

5.6.1 Service delivery model

An effective electronic monitoring program requires strong links between the key activities and elements to enable efficient capture, storage and use of the data. The service delivery model specifies how the program will be delivered. In the Northern Hemisphere, the development and integration of electronic monitoring programs has supported a fully-stand alone service delivery model or 'Canadian model' based on a single third party contractor offering full service monitoring programs.

In regard to electronic monitoring programs, alternatives to the 'Canadian model' were limited due to the very little electronic monitoring expertise, infrastructure and experience that exist within Australia. This being the case, the costs associated with an AFMA conceptualised co-ordinated program model are considered with a focus on electronic monitoring capacity development and collaborations with stakeholders for effective service delivery. Figure 22 outlines a high-level process map of key operational activities, data movement and management framework for the considered service delivery of an electronic monitoring program.

The implementation of electronic monitoring in the NPF involves considerable costs. Consequently, the potential benefits must be weighed against the costs to determine if electronic monitoring is appropriate. Not all costs and benefits are easily quantifiable. Items that are not quantifiable are assessed in a qualitative way as best as practicable. This CBA applied a 15% image analysis and logbook audit which is comparative to the recommended 15% observer coverage. In this case the implementation of electronic monitoring and costs are assessed with the following characteristics:

a. 100% participation
b. Industry responsible for:
    - Installation of equipment
    - Hard drive exchange
    - Maintenance of equipment
c. AFMA responsible for:
    - Reviewing footage and other data
    - Managing process (analysing data, comparisons, database management, reporting, certification, distribution of hard drives, use of data etc.)

The CBA represents current management arrangements and recommended coverage levels during the transitional phase to quota management. It is assumed that coverage levels will be reduced following the completion of the transitional phase. However, it is possible that community expectations regarding discarding practices may increase the minimum acceptable level of monitoring in the future. To compare the options, net present values (NPV) are calculated over a 10 year planning horizon at an annual real discount rate of 5%.

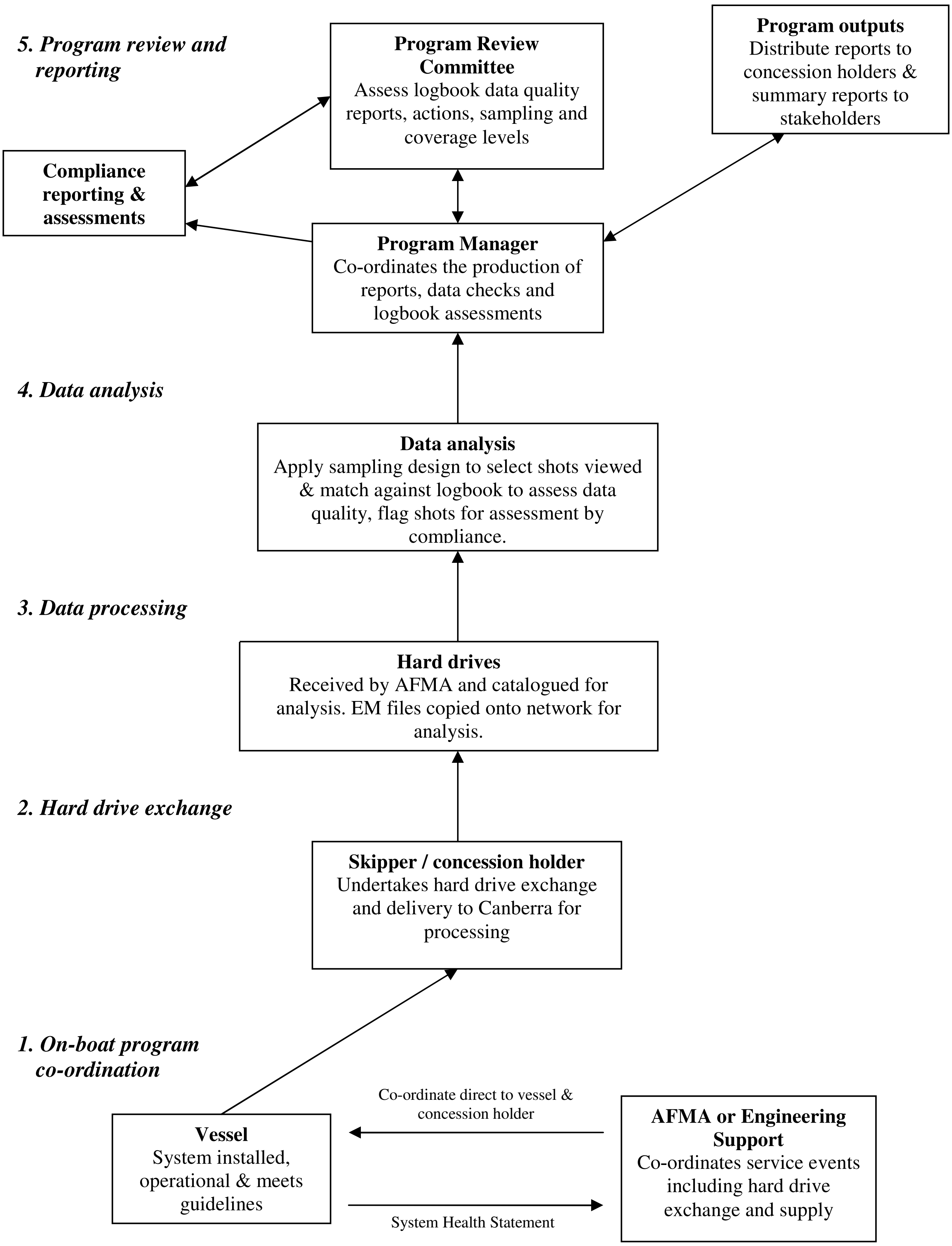

Figure 22: High level process map of an AFMA co-ordinated electronic monitoring program.

5.6.2 Program costs

The following provides cost descriptions and estimates of the program set-up and ongoing elements for the electronic monitoring program options. A description of each cost item is provided in Table 5. The details of each cost item and any assumptions are outlined below.

Table 5: Summary of items and cost inputs for an electronic monitoring (EM) program in the NPF.

Item #	Cost item	Year 1 (set-up cost)	Ongoing annual cost	Responsibility	Who pays
1	EM system purchase	$669,240		Concession holders	Concession holders
2	Installation	$99,840		Concession holders	Concession holders
3	Maintenance of equipment	$67,600	$67,600	Concession holders	Concession holders
4	Archipelago training	$10,000		Concession holders	Concession holders
5	Hard drive purchase	$33,800	$13,520	AFMA	Recoverable cost
6	Hard drive exchange	$3,245	$3,245	Concession holders	Recoverable Cost
7	Database development	$16,625	$0	AFMA	Overhead
8	Program Coordinator	$166,249	$83,125	AFMA	Recoverable Cost
9	IT data storage hardware	$22,000		AFMA	Recoverable Cost
10	IT data storage software	$1,600	$250	AFMA	Recoverable Cost
11	Resourcing - AFMA IT support	$28,099	$12,049	AFMA	Recoverable Cost
12	Analysis of imagery and reporting - AFMA data entry	$606,004	$606,004	AFMA	Recoverable Cost
13	Control centre software lease	$25,740	$25,740	Concession holders	Concession holders
14	Analysis software lease	$10,395	$10,395	AFMA	Recoverable Cost
15	Health Statement	$30,888	$30,888	AFMA	Recoverable Cost
16	Ongoing independent audit (5% of analysis)		$30,300	AFMA	Recoverable Cost
Total		$1,791,325	$883,116		

1. System Purchase Costs

Includes electronic monitoring system cost with the current ETBF configuration (4 cameras, satellite modem), shipping and currency exchange. Equipment life is estimated at five years, (McElderry 2010 per comm.). Therefore when Net Present Values (NPVs) are calculated, this cost is included in the initial year and year 5.

2. Installation of equipment

In this model, local technicians arranged by the concession holder will under take installation and maintenance of the system. The time for the system installation is dependant on a number of factors including the vessel design and feasibility to undertake adequate cable runs and fit cameras to the defined standard. In this case it is estimated that installation should take 18 hours. This figure is considerably less than other fisheries such as the Eastern Tuna and Billfish Fishery (28 hours). This is because the NPF has a discrete fishing season, after which time all NPF boats return to three distinct ports. Having access to multiple boats in one location and at the one time enables installation and maintenance costs to be undertaken with less travel and other incidental costs. Other factors which contribute to increased installation efficiency are that fact that the majority of NPF boats are of a similar design and layout, and that few if any require construction of booms for cameras or additional lighting.

Based on the average time per install and at a rate of $800 per day (TMQ International estimate July 2010), 52 vessels total install costs are estimated at $99,840. In this instance, travel time for the technician is not included in costs.

Requirements for this cost item include:

- Local marine technicians required for installation and maintenance.
- Development of system function and non-function specifications and software requirements (user-friendly hard drive swap).
- Vessels demonstrating issues with power supply to support the system will require an additional purchase of a stand alone battery bank at a cost of $2,500 for the system. These costs are not included in Table 5. The requirement of this purchase will be determined by AFMA, in consultation with the concession holder.
- Systems install verification checks will be undertaken following collection of the vessels first hard drive. Checks will be undertaken against an agreed standard of hard drive file content (files types) and camera views.

3. Maintenance of equipment

Maintenance costs are the responsibility of the concession holder and would depend to a large extent on the care and upkeep provided. As a general rule, Archipelago Marine Research suggests using 10% of the equipment purchase price for annual maintenance.

4. Training from Archipelago

As local marine technicians will be responsible for installation and maintenance, and AMR will be required to provide specialised training. Training costs are estimated at $10,000 per year although this cost may vary depending on the range of technicians adopting service roles, the turn over of technicians and need for ongoing support. Also complex equipment repairs may still require shipping the control centre to Canada further exacerbating the maintenance of equipment costs.

5. Hard drive purchase

AFMA would purchase the hard drives and we estimate a requirement of 5 hard drives per vessel. It is assumed that due to some hard drive failures and requirements for some original hard drives to be stored for compliance, two extra hard drives will need to be purchased per vessel per year.

6. Hard drive exchange

In the longer term, AFMA expects that this would be an industry responsibility where the concession holder would be responsible for exchange of the hard drive and posting to AFMA. It is assumed that with current fishing efforts the average hard drive exchange will occur every 3 months. Registered postage costs to Canberra, including shipping material are estimated at $3,245 per year in total.

7. Database development

Electronic monitoring data modelling, integration with AFMA's databases and database development is estimated to take one month to complete at the EL1 level. The majority of the data modelling is complete and there is potential for these remaining costs to be covered in-kind through existing AFMA budgets.

8. Program co-ordinator

The program co-ordinator will be required to undertake a number of tasks before commencement of the program. One FTE EL1 is budgeted for this role for the first 12 months of the program (includes the 6mth implementation phase). Following this period, 0.5 FTE EL1 is budgeted to co-ordinate the program. The data management protocols that need to be described for an electronic monitoring program during the implementation phased are listed below. Experiences and recommendations from ETBF pilot project will assist the development of these operating procedures.

1. System installation guidelines and assessment process to check system install complies with guidelines by field service staff.
2. Process to monitor Health Statements and reporting.
3. Hard drive catalogue and tracking system.
4. Copying, storing and recycling hard drives.
5. Sampling design of electronic monitoring data and storage of electronic monitoring analysis outputs in AFMA's electronic monitoring database.
6. Training requirements and testing of data analysts.
7. Data captured during image analysis, compliance checks and audit scoring methodology against logbook.
8. New permit conditions relating to the program relating to data handling and operational matters.
9. Penalties described and legislated for data discrepancies between logbook and electronic monitoring data including communication and appeal process.
10. Notifying and handing protocols of compliance flagged files.
11. Education and communication program.

Ongoing program co-ordination tasks include:

1. Manage Health Statement monitoring and reporting,
2. Co-ordinate service events, hard drive exchange and supply, and
3. Manage data analysis and reporting services.

9. IT data storage hardware

In order to provide enough capacity to support the electronic monitoring data received by AFMA for analysis, a small disk array is recommended. This proposed device will initially have 20 terabytes (TBs) of disk space with the capacity to expand up to 196TBs. It connects directly into a switch and can be accessed from anywhere on the network. A small server would also be required to support a dedicated network. Set-up costs include the iSCSI disk array - $14,000 and server - $8,000. A 4 year warranty is included in costs, however the hardware would need to be replaced post this (i.e. every 4 years).

10. IT data storage software

Data storage software required includes Windows server 2008, Antivirus; set-up costs $1,600 and ongoing costs $250.

11. AFMA IT support resourcing

In the initial stages of the project, the requirement of IT support anticipated is 0.2 of an APS4 FTE. While, on-going support would be approximately 0.1 of an APS4 FTE. Services to install and configure the server by an external contractor would be required at a cost of $4000 in the first year.

12. Data analysis and reporting
To determine data analysis costs, estimates of annual fishing effort were undertaken. In this case, the 2009 and 2010 logbook records showed that 28,143 and 28,314 shots were undertaken, respectively. Analysis costs were therefore based on a 15% (logbook audit) of 28,000 shots at an average analysis time of 2.2 hours per shot. The analysis time (2.2 hours) is based on analyses undertaken during the trial.

The ETBF CBA showed that AFMA data entry contractors can provide equivalent electronic monitoring image analysis results compared to an AFMA observer (see Piasente *et al*. 2012 in press). Analysis costs are therefore calculated using AFMA data entry contractors' hourly rate. An additional 20% of time is added to account for other administrative duties including Health Statement monitoring, database management, data comparisons and reporting (Table 6).

Data analysis will require a training curriculum and testing to a minimum standard for each new analyst. Training and links with the observer program for data quality assurance and testing can also be built in to ensure analysis and reporting standards are achieved.

Table 6: Summary of analysis costs for option 2.

Position	Hourly rate on 10/11 salaries with oncosts & overheads	52 Vessels, 28,000 shots per year, 15% audit @ 2.2 hrs per shots plus 20% for other reporting duties = 11,088hrs
AFMA Data entry contractor	$54.65*	$606,004

*Includes oncosts, AFMA overhead A and half of AFMA overheads B and C.

13. Electronic monitoring control centre software (EM Record™)
This includes annual license fees for control centre software.

14. Electronic monitoring analysis software
This includes annual license fees for data analysis software. It is anticipated that three licenses will be required for an ongoing electronic monitoring program. The analysis workload and subsequently the number of licenses will also be dependent on the analysis turn around requirements and participating vessels.

15. Health Statement communication costs
This includes monthly communication costs for satellite health statement communications.

16. Ongoing program audit
An independent audit program is budgeted at 5% of the analysis costs to check the outcomes and competency of the programs video analysers. This program will demonstrate data quality assurance to industry and stakeholders.

5.6.3 Program Benefits

Not all other benefits of adopting this option are quantifiable. Nevertheless it is possible to quantify some major cost savings and describe some of the non-quantifiable benefits. A summary of quantifiable benefits is provided in Table 7.

Table 7. Summary of quantifiable benefits of option 2.

	Annual saving
Observer cost savings (80% of total costs)	$1,110,973
VMS savings (polling costs for 52 vessels)	$23,213
Total quantifiable benefits	$1,134,186

Savings in observer costs

The easily quantifiable benefits of electronic monitoring are in the form of potential saved costs from reduced 'at-sea' observer coverage. With 15% coverage level proposed in a 52 boat fleet the total NPF observer budget is calculated at $1,388,716. It is also assumed that increasing the observer coverage to 15% and additional observer coordinator would be required to manage the program. In this case the costs associated with this position haven't been incorporated into the program costs.

It is understood that a level of observer coverage would still be required in an ongoing electronic monitoring program. Therefore in this case, savings from the observer program are estimated to be reduced by 80% or $1,110,973 per year. This will allow for the 'at-sea' observer coverage to be maintained at 2-3% of fishing effort in combination with the electronic monitoring program.

Compliance savings

An assessment of the application of electronic monitoring for detecting non-compliance was undertaken. It showed that under an electronic monitoring program the majority of risk ratings (e.g. compliant with spatial and temporal closures) will be reduced as electronic monitoring provides a greater capacity for assessing the compliance performance of each vessel. AFMA has determined the impacts of electronic monitoring, from a compliance perspective, are as follows;

1. There will be no reduction in the need for, or costs associated with port based inspections.
2. The need for at sea patrols in the fishery will be reduced. However, the need for, and costs associated with, at sea patrols in other related fisheries would remain and hence there will be no real reduction in costs.
3. There is likely to be an increase in compliance costs in the fishery in the short to medium term as a result in a "spike" in detection rates. It is impossible to quantify this likely increase.

Vessel Monitoring System (VMS)

VMS is used to monitor fishing operations and the movement of boats in and out of ports. AFMA monitors the activity of the fleet through VMS to ensure that the vessels and VMS's are working in accordance with conditions imposed on fishing permits.

The electronic monitoring system Health Statement is an hourly message via satellite communication while electronic monitoring systems are powered. The one line message is a synopsis of the previous hour reports on vessel location, activity and system health status. The system Health Statement may remove the need for VMS requirements in an ongoing program. Although the video footage will not provide real time information, this may not be necessary where sufficient penalties are applied for breaches in retrospect. Differential costs between the electronic monitoring systems Health Statement and VMS

polling are provided in Table 8. For 52 vessels participating in the removal of VMS polling costs amounts to an annual saving of $23,213.
It is assumed that VMS will be required during the introductory period of an electronic monitoring program.

The NPF fleet operates for extended periods in remote areas of the fishery without returning to port. The use of systems such as electronic monitoring and VMS that report positional information is important to ensure fishers comply with spatial closures protecting sensitive environments. It is expected that fishers will be required to continue to use VMS for at least the first three years following electronic monitoring implementation in the NPF. This will provide a safeguard for compliance monitoring and avoid fishers having to return to port if the electronic monitoring system requires maintenance during a fishing trip. Savings in the cost of VMS are expected to occur from year 4 onwards.

Table 8: Summary of VMS and electronic monitoring (EM) unit and polling costs.

	VMS	**EM**
Unit Cost (per boat)	$3-4000	Complete EM system ~$14,000
Polling Costs (Boat/Month at 1 hour polling)	$37.20 ($0.05x24 Hoursx31 days)	$50.00
Message Costs (per character)	$0.24	N/A

The current electronic monitoring system Health Statement has restricted functions and utilities in comparison to VMS. For example, electronic monitoring Health Statements are currently limited to hourly polls, and not set-up for real time polling, no capacity for shore to ship messages, and no emergency beacon. In time, further development and needs may increase the systems functionalities in terms of Health Statement polling. The current variations in utilities of VMS and the systems Health Statement are provided in Table 9.

Table 9: Utility and functionality status of VMS and electronic monitoring (EM) systems.

Function / Condition	**VMS**	**EM**
Variable polling rate	Yes (remote)	Health Statement restricted to hourly polling
Real time - on demand Poll	Yes (remote)	No
Shore to ship message Capability	Yes	No
Emergency Beacon	Yes	No

Reduced Occupational, Health and Safety (OH&S) risks
There are considerable OH&S concerns for at sea observers. An integrated program of electronic monitoring and 'at-sea' observers reduces the level of observer coverage with the additional benefit of reducing AFMA's OH&S exposure in the NPF.

Behaviour change
The presence of an observer is determined in advance and is known to all onboard. Consequently, fishers are aware that the chance of being observed is either zero or close to

100%. This means fishers may behave differently when no observer is onboard, particularly regarding the reporting of discards and interactions with protected species.

Conversely, electronic monitoring would involve recording 100% of fishing activity. This means all behaviour would be observable but not necessarily observed. If a random sample of video was audited then fishers could never be certain whether or not any action would be monitored. All fishing activity would have a chance of being observed between zero and 100% (dependent on the proportion of video to be audited). Behavioural changes are expected to be greatest when the logbook audit methodology and scoring has clear consequences and there is a strong feedback loop to operators.

Although there is a risk that fishers will develop new methods of avoiding detection or tamper with the cameras, penalties should minimise this risk. For example, there should not be a problem with tampering with the onus on the operator to ensure the cameras are working (and there are enforceable penalties associated with a failure to do so). There would be additional costs to concession holders where the audit score indicated concerns over inconsistencies in reporting therefore requiring full analysis of the imagery.

Increased accuracy of scientific information

The accuracy of logbooks should improve dramatically given the above described behaviour change. Logbook and observer data are key inputs to stock assessments and understanding the impacts of fishing on the environment. Electronic monitoring could improve the reliability of this information by providing an independent, verifiable record of fishing activity which would strengthen environmental stewardship.

Improved scientific information has many flow-on benefits. Fisheries managers rely on the accuracy of stock assessments to set total allowable catch and effort levels, improved information may therefore lead to better management outcomes. Stakeholders and the wider community can also be more confident that economic returns are being maximised and sustainability goals are being met. Reducing uncertainty through improved data quality may make environmental auditing procedures simpler. This may have positive implications for market access and product certification.

More cost effective rules

With a greater capacity for onboard monitoring, electronic monitoring also has the potential to enable a far greater range of management options. Tailored management arrangements aligned to an electronic monitoring program have the potential to provide a range of fishing operational benefits to industry such as modifications to navigation rules when transiting closures. Industry members have expressed interest in the systems being able to show the vessels fishing operational status and a potential cost saving tool that enables vessels to transit closures at slow speeds to save fuel and by the most direct means given the direction of tides. New rules may require a trial period before acceptance and adoptions by all stakeholders.

5.6.4 Net benefits compared an observer program

In nominal terms, this option is expected to cost an average of $1,054,015 each year. Net benefits are reduced by $22,000 every fourth year assuming IT hardware replacement costs. An electronic monitoring program results in an overall cost decrease of $732,067 over a 10 year period (Table 10). This equates to a net present value of $433,446 over a 10 year period with a 5% annual discount rate (Table 11). The benefits are calculated on the assumption that the 15% observer coverage is implemented over the 10 year period.

When considering a significant reduction in observer coverage levels, this scenario would not result in any net benefits from a comparative electronic monitoring program. For example, in comparison with an observer program completing 5% coverage of fishing effort, based on a fleet of 52 boats and 100% uptake rate of electronic monitoring this results in an overall cost increase of $2,563,523 over a 10 year period for nominal costs (Table 12) or $2,251,365 over a 10 year period (net present value, Table 13). Based on total nominal costs over a ten year period, the breakeven point between electronic monitoring and equivalent observer coverage occurs at 9.8% coverage and a cost of approximately $8.1 million.

Table 10: Nominal costs and benefits in 2011 for a 10 year period (15% observer coverage scenario).

	Marginal costs	**Marginal benefits**		**Total benefits**	**Net benefits**
Year		Observer savings	VMS savings		
0	$1,791,325	$1,110,973	$0	$1,110,973	-$680,352
1	$883,116	$1,110,973	$0	$1,110,973	$227,857
2	$883,116	$1,110,973	$0	$1,110,973	$227,857
3	$905,116	$1,110,973	$23,213	$1,134,186	$229,070
4	$883,116	$1,110,973	$23,213	$1,134,186	$251,070
5	$1,639,897	$1,110,973	$23,213	$1,134,186	-$505,711
6	$883,116	$1,110,973	$23,213	$1,134,186	$251,070
7	$905,116	$1,110,973	$23,213	$1,134,186	$229,070
8	$883,116	$1,110,973	$23,213	$1,134,186	$251,070
9	$883,116	$1,110,973	$23,213	$1,134,186	$251,070
Total	$10,540,151	$11,109,729	$162,490	$11,272,219	$732,067

Table 11: Net present value assessment of costs and benefits for a 10 year period (discount rate 5% and 15% observer coverage scenario).

	Marginal costs	**Marginal benefits**		**Total benefits**	**Net benefits**
Year		Observer savings	VMS savings		
0	$1,791,325	$1,110,973	$0	$1,110,973	-$680,352
1	$841,063	$1,058,069	$0	$1,058,069	$217,006
2	$801,012	$1,007,685	$0	$1,007,685	$206,673
3	$781,873	$959,700	$20,052	$979,752	$197,879
4	$726,542	$914,000	$19,097	$933,097	$206,556
5	$1,284,902	$870,476	$18,188	$888,664	-$396,238
6	$658,995	$829,025	$17,322	$846,347	$187,352
7	$643,249	$789,548	$16,497	$806,045	$162,795
8	$597,728	$751,950	$15,711	$767,662	$169,934
9	$569,265	$716,143	$14,963	$731,106	$161,842
Total	$8,695,954	$9,007,570	$121,830	$9,129,401	$433,446

Table 12: Nominal costs and benefits in 2011 for a 10 year period (5% observer coverage scenario).

	Marginal costs	**Marginal benefits**		**Total benefits**	**Net benefits**
Year		Observer savings	VMS savings		
0	$1,387,322	$370,324	$0	$370,324	-$1,016,998
1	$458,913	$370,324	$0	$370,324	-$88,589
2	$458,913	$370,324	$0	$370,324	-$88,589
3	$480,913	$370,324	$23,213	$393,537	-$87,376
4	$458,913	$370,324	$23,213	$393,537	-$65,376
5	$1,215,694	$370,324	$23,213	$393,537	-$822,157
6	$458,913	$370,324	$23,213	$393,537	-$65,376
7	$480,913	$370,324	$23,213	$393,537	-$87,376
8	$458,913	$370,324	$23,213	$393,537	-$65,376
9	$458,913	$370,324	$23,213	$393,537	-$65,376
Total	$6,318,322	$3,703,243	$162,490	$3,865,733	-$2,452,589

Table 13: Net present value assessment of costs and benefits for a 10 year period (discount rate 5% and 5% observer coverage scenario).

	Marginal costs	**Marginal benefits**		**Total benefits**	**Net benefits**
Year		Observer savings	VMS savings		
0	$1,387,322	$370,324	$0	$370,324	-$1,016,998
1	$437,060	$352,690	$0	$352,690	-$84,370
2	$416,248	$335,895	$0	$335,895	-$80,353
3	$415,431	$319,900	$20,052	$339,952	-$75,479
4	$377,549	$304,667	$19,097	$323,764	-$53,785
5	$952,528	$290,159	$18,188	$308,347	-$644,181
6	$342,448	$276,342	$17,322	$293,663	-$48,785
7	$341,776	$263,183	$16,497	$279,679	-$62,097
8	$310,611	$250,650	$15,711	$266,361	-$44,249
9	$295,820	$238,714	$14,963	$253,678	-$42,142
Total	$5,276,792	$3,002,523	$121,830	$3,124,354	-$2,152,439

6 EXTENSION

The extension of information to stakeholders occurred throughout the course of the project. The trial was conducted on an industry vessel that willingly nominated to participate in the project. The extension commenced with a project proposal considered by the NPF Industry Company and NORMAC providing support and endorsement for funding. Following the funding approval a request for expression of interest for project participation was sought from NPF concession holders.

Following the selection of project participant, project obligations and responsibilities were agreed which largely related to a number of data management and system operational matters. Parties associated with the project acknowledge that the direct involvement and participation by industry members has assisted the success of the project regardless of the operational issues encountered during the trial. It is essential for an ongoing program that the vessel's personnel learn as much as possible about the equipment to maintain system operational standards and to monitor, report and address equipment failures in a timely manner.

Imagery obtained during the project was presented to various stakeholder groups. Overall, the responses to the uses of the imagery were positive. Other support has been from representatives from environmental groups (both government and non-government) involved in fisheries and marine resource management. The concept and logbook audit design of an ongoing program was supported largely due to the increased abilities to 'hold operators to account' for reporting protected species interactions and monitoring the compliance performance of vessels.

It is recognised that the success of an electronic monitoring audit-based monitoring program is dependent on industry buy-in from an early stage and the process and end result need to be transparent so that all stakeholders will trust the resulting data. The first step in any monitoring program must be communication with, and involvement of, industry members. The collection of data for monitoring use depends on fishers completing forms, running equipment, adjusting certain catch handling behaviour, and reporting data. The development of an industry engagement plan and options to further develop and trial electronic monitoring equipment will be developed in consultation with the NPF Industry Company and NORMAC.

7 BENEFITS AND ADOPTION

The response from industry members and stakeholder groups has been positive in their support for using electronic monitoring technologies for onboard monitoring. This support is a result of the potential benefits associated with these systems in a clearly defined and structured program. The benefits include:

- cost effective onboard monitoring to NPF fishing concession holders,
- a feedback loop to operators detailing the output of logbook audit reports (and consequences / penalties) will prompt onboard behavioural changes such as improved reporting of protected species interactions and uses of mitigation measures,
- increased capacity to evaluate the accuracy of fisher logbook records providing confidence to stakeholders,
- reducing the level of observer coverage has the additional benefit to AFMA of lowering the OH&S risks,
- compliance risks in the fishery will be significantly reduced,
- tailored management arrangements aligned to an electronic monitoring program are recognised to provide a range of fishing operational benefits to industry, and
- a sense amongst concession holders that electronic monitoring offers a more equitable solution of monitoring as some operators feel they have higher level of observer coverage than others.

The benefits and beneficiaries are similar to those in the original application.
Industry and AFMA will directly benefit from this project and the further development and adoption of electronic monitoring through reduced management and business costs,

improved relationships and greater stewardship of fisheries resources. Furthermore, the commercial fishing industry continues to face increased scrutiny into onboard fishing practices and impacts on the environment. Ongoing extensions of the results of this project will help build support for the integration and adoptions of these technologies for fisheries monitoring purposes.

8 FURTHER DEVELOPMENT

To implement electronic monitoring in the NPF a number of areas will require further developments in the near future, these include:

1. A continuation of the trial to investigate and measure improvements to system reliability and performance.
2. Undertake onboard methods to verify the accuracy of discards recorded by image analysts to further assess the feasibility of cameras as a monitoring tool for prawn discards.
3. Undertake a review of data needs in the NPF to determine the level of onboard observer coverage required in conjunction with an electronic monitoring program.
4. Agreement with stakeholders regarding the method to estimate discards from electronic monitoring image data.
5. A review of data alignments between electronic monitoring data and logbook data for auditing purposes.
6. Develop data handling / storage protocols and policies to address privacy concerns.
7. Development of the legislative framework including conditional requirement for the program including:
    a. System operational matters and specifications,
    b. Handling and the delivery of hard drives,
    c. Data processing, storage, access and released of information.
8. Development of a communication strategy and outreach program to support the information flow relating to the electronic monitoring program structure and operational requirements.

The implementation of an AFMA co-ordinated electronic monitoring program will required a review and re-design of systems and business processes to administer the receipt and assessment of all ‘at-sea’ data collected (electronic monitoring, logbook, observer and VMS data). The system will be required to align all data collected to meet the information requirements of fishery managers, scientists and compliance officers for the management of the fishery. As an electronic monitoring program evolves and more Commonwealth fisheries adopt these technologies further uses and access of electronic monitoring data are expected. For example, the development of presentation layers to provide data back to authorised stakeholders, such as concession holder access to electronic monitoring data via online secure portal will help streamline the reporting and program review process.

9 CONCLUSION

This study produced valuable insights into the functionality and applications of electronic monitoring systems in the NPF. A number of system problems were observed and it is likely that better performance could be expected using lessons learnt from this trial.

Results have show electronic monitoring systems can be used for a number of monitoring functions and the benefits of adopting a logbook auditing program are described.

The original intent was to trial a specific onboard procedure to provide estimates of discards. The procedure was modified mid-season due to practical and safety concerns and expanded to collect information on a broader range of objectives, including estimating discards.

The trial has shown that electronic monitoring can perform a number of functions including (but not limited to):

- Identify fishing events (e.g. net deployment and retrieval) and the location where those events took place
- Determine the presence and number of target prawn discards
- Estimate the total retained catch, and
- Detect and identify protected interactions including the life status of captures.

Electronic monitoring image analysts recorded a number of interactions with sea snakes during this study. Bringing the captured seasnakes in clear view of the camera and showing the crew handling the species made these recognisable events in the electronic monitoring imagery. Working with the crew to develop and apply a standardised approach to handling catch, will help ensure catch and events from the image data.

Audit and scoring methodologies are considered to enable fishers' logbook data to be validated by comparing random portions with electronic monitoring interpreted data. The structure of the proposed audit program is a series of steps that include collecting data, evaluating data, and providing feedback. Each stage of the program involves both fishers and managers, so that communication is ongoing.

The process begins with the operator completing a fishing trip, recording catch in the fishing logbook, and using electronic monitoring equipment to collect data. Both the analysed electronic monitoring data and the fishing logbook data sets would then be used for processing, auditing and scoring the trip/s. Based on previous electronic monitoring program experiences, the feedback loop is integral in ensuring success of the program demonstrating that fisher logbooks can become a reliable source of data with appropriate checks and feedback loops.

Electronic monitoring systems functioned and operated successfully during the trial. However, problems with the hydraulic pressure sensor resulted in only 24% of shots having imagery data completeness for catch processing during the tiger prawn season. A number of recommendations are made to improve performance including image quality and usability.

In an ongoing program, vessel personnel will need to learn more about the operation of the equipment to detect and report equipment failures. The priority toward resolving issues needs to be elevated such that problems are resolved in a timely fashion and fishing vessels are not at sea with inoperable electronic monitoring systems. The installation program must be set up with adequately trained and resourced technicians using pre-defined quality assurance procedures.

An electronic monitoring program with 100% uptake was examined in terms of costs and benefits. The most easily quantifiable expected benefit from electronic monitoring is in the form of cost savings through reduced observer coverage. In comparison with a comparative observer program based on a fleet of 52 boats and 100% uptake rate results in an overall cost decrease of about $73,207 each year and a decrease of $433,446 over a 10 year period (net present value). This assumes that the recommended 15% observer coverage levels are maintained over the ten year period post the transitional phase to quota management.

Other benefits from electronic monitoring include improved scientific information and the potential for behaviour change (e.g. improved logbook reporting). There are further benefits available from electronic monitoring if other management practices are changed. For example, fisher behaviour change would be greater if electronic monitoring were also used for compliance purposes. Also, more restrictive management tools could be removed in favour of more outcome focused methods. As electronic monitoring provides a greater capacity for assessing the compliance performance of each vessel, it is expected that a number of compliance risks in the fishery will be reduced.

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10 APPENDIX 1: INTELLECTUAL PROPERTY

The intellectual property associated with this project includes the software leased from Archipelago Marine Research Ltd. including control centre (EM Record™) and data analysis / interpretation software.

11 APPENDIX 2: STAFF

Name	Organisation	Project Involvement
Matthew Piasente	AFMA	Principle Investigator
Bob Stanley	AFMA	Co-investigator
Steve Hall	AFMA	Field technician and image analyst

12 APPENDIX 3: SYSTEM SPECIFICATIONS

Control Centre

Dimensions	8” x 8” x 13” (20 x 20 x 31 cm)
Weight	11 lbs, 5.2 kg
Chassis/Container	Welded Aluminium (splash-proof)
Video Storage	Removable hard disk up to 500 Gigabytes
Recording Time	Configuration dependent, up to 1000 hrs
Recording Channels	4
Video Resolution	VGA (640-480 pixels)
Video Compression	Windows or DivX
Frame Rate (fps)	Up to 30 total
Operating System	Microsoft Windows XP Embedded on Solid State Disk
Operating Software	Autonomous at-sea execution, user configurable recording operations according to sensor input events

Power Specifications

DC Power	12 to 16 VDC
AC Power (adaptor)	90 to 240 VAC
Operating Current	6 Amps
Protection	20 Amp fuse, Battery deep discharge prevention
Protection	Low current (20 mA) Sleep Mode

Available Sensors and Options

GPS, Radio Frequency ID Tag, pressure, rotation, acoustic receiver, contact closure, power supply monitor, and Iridium satellite modem (ship to shore).

Standard Camera

Housing	Powder coated cast aluminium, sealed to IP66
Power	12 VDC
Resolution	480 TV lines, analogue NTSC signal
Lenses	2.9 (fisheye) to 16 mm (telephoto)
Light rating	1 – Lux
Aiming	Fixed aim, internally adjustable for Pan, Tilt, and Rotation.

13 APPENDIX 4: RECOMMENDATIONS REGARDING ELECTRONIC MONITORING SYSTEM INSTALLATION AND MAINTENANCE

Table 14: Summary of key electronic monitoring system performance issues and recommendations.

Component	**Key issues**	**Installation recommendations**	**Maintenance / Testing recommendations**
Hydraulic Pressure Sensor	Installation	Installed by a hydraulic specialist. Permanent install recommended in the engine room if possible reducing risks of damage and operational problems being exposed on the working deck. Using a ¼ inch NPT female socket.	Check for visible signs of oil leak at the pressure transducer.
		The use of a proximity sensor (triggered by movement of the conveyor) or link to the conveyor power (on/off) switch are possible alternatives to activate the system to record imagery during catch processing.	Either option would require further testing and possible software development and configurations (in the case of the power switch), to be a viable option.
Rotation sensor	False signals	Where possible lock the drum to restrict movement.	
	Reflector problems	Where the drum design allows install a proximity sensor to reduce issue with the reflector (e.g. alignment) and ongoing maintenance requirements.	Regular Function Test by owner or skipper would highlight any reflector issues.
	Mounting brackets	Use heavy gauge welded mounting bracket with mechanical protection.	
GPS	Functioning 'lock-up'		Regular Function Test by owner or skipper
Systems box	Cooling ventilation and access	Install in the wheelhouse in a position that allows for the ready removal and replacement of the hard drive. The location of the systems	Do not restrict airflow near the systems box with books, charts or rags.

Component	Key issues	Installation recommendations	Maintenance / Testing recommendations
		box should allow for unimpeded ventilation of the systems box.	
Cables	Protection	Where possible have cables run through aluminium or steel conduit/pipe to offer the best possible mechanical protection. PVC is an alternative but has limited life due to ultra violet light degradation. Use the 4 wire heavy wall piezo (Geotech) cable due to its heavier outer case and added protection.	Where there are splices and joins in exposed wires at the work deck level they might be examined on a monthly basis for any oil or seawater ingress and nicks or chaffing.
Camera	Initial set-up & focus		Onboard monitoring and maintenance required by vessel personnel.
	Orientation	For exposed cameras (hopper view) don't install cameras facing directly down; install cameras with a viewing angle at a minimum 30 degrees off the vertical to reduce water accumulation on the dome impacting image quality.	
	Humidity and moisture build up.	The use of silica gel packs during camera installs will reduce moisture issues.	Regular system function tests and monitoring by vessel personnel will highlight image quality deterioration.
	Glare	Glare will be inevitable at particular times of the day. Install sun shield in housing will help limit the impact of glare.	
	Lighting		Implement and monitor operational standards in terms of lighting requirements for the program.

Component	Key issues	Installation recommendations	Maintenance / Testing recommendations
	Salt build-up		Onboard monitoring and maintenance required by vessel personnel.
	Mounting brackets		When the optimum camera locations are agreed the stainless steel straps might be replaced by permanent welding of the brackets to the supporting structure.
Power supply	Problematic power supply	Where necessary use a UPS or run directly from a dedicated battery bank if significant power issues become apparent.	Regular Function Test by owner or skipper would identify if there is a low voltage issue.
Installation	Who arranges?	This should be an industry responsibility. AFMA should set minimal specifications that are outcome focussed. AFMA may have a QA role.	
Maintenance arrangements	As above	Again, an industry responsibility. Going to sea with equipment not working would incur penalties.	
AFMA Role	To be defined	Current thinking is that AFMA would have a role in ensuring a robust implementation and maintenance framework is in place and an ongoing QA role.	