Evaluating the use of onboard cameras in the Shark Gillnet Fishery in South Australia

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NON TECHNICAL SUMMARY:

2010/049	**Evaluating the use of onboard cameras in the Shark Gillnet Fishery in South Australia**

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OBJECTIVES:

1. To assess the capacity of electronic monitoring systems to provide high quality, in-season data on interactions with Australian sea lions (ASLs) and other protected species in the shark gillnet fishery off South Australia.
2. To improve the level of certainty on the impact of fishing operations on ASLs.
3. To investigate the use of electronic monitoring systems for collecting data currently collected by at-sea observers with a focus on opportunities to improve the data integrity and data quality of the Independent Scientific Monitoring Program (ISMP).
4. To assess the cost and benefits of utilising electronic monitoring system in the shark gillnet fishery.

OUTCOMES ACHIEVED TO DATE

Implementing cost effective management arrangements and services are critical for an economically sustainable fishing industry. This report describes the trial of electronic monitoring systems in a Commonwealth managed shark gillnet fishery in waters off the coast of South Australia.

The trial demonstrated that electronic monitoring is able to provide high quality, in-season data on interactions with Australian sea lions and other protected species. The data collected during the trial has helped improve AFMA's understanding of the extent of these interactions and has led to significant changes in the way these interactions are monitored and managed by AFMA.

AFMA has gained a greater understanding of the capabilities of electronic monitoring for collecting different types of information, how these capabilities can be influenced by equipment setup and monitoring approach, and how these factors affect the costs of monitoring.

A cost benefit analysis has indicated that electronic monitoring is capable of delivering significant cost-efficiencies where monitoring requirements exceed approximately 10% coverage.

The Australian Sea Lion (ASL) is listed as a threatened (vulnerable) species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Some scientists have suggested that interactions with the gillnet fishery could present an obstacle for the recovery of ASL populations; however information on the extent of these interactions is limited.

To address concerns about the potential threat gillnet fishing poses to ASL populations, the Australian Fisheries Management Authority (AFMA) established area closures in the shark gillnet fishery off the coast of South Australia where the majority of ASL interactions had been observed. The level of monitoring of fishing activities was also increased to 100% in the area of the Australian Sea Lion Management Zone (ASL Management Zone). The use of at-sea observers for this monitoring is costly. Finding a cost-effective and reliable monitoring alternative is therefore highly desirable.

Information on ASL and other protected species interactions, as well as catch composition was collected from five commercial gillnet fishing boats operating in the Gillnet Hook and Trap fishery (GHAT) off the coast of South Australia using electronic monitoring systems and at-sea observers. Data collected by electronic monitoring was then compared to that collected by at-sea observers and a cost benefit analysis undertaken to determine its cost efficiency.

The most prominent problems noted during electronic monitoring footage analysis were obstructions of camera views by people, fishing equipment or slipping sunshields in the camera housings. Other issues included poor deck lighting and an occasional failure of the systems to record footage. These issues only affected a small proportion of the footage however, and overall the electronic monitoring systems functioned well.

Although there appeared to be good agreement between the data collected by electronic monitoring and at-sea observers, the low interaction rate with marine mammals made it difficult to determine this agreement statistically. More than 5000 shots would need to be compared in order to statistically validate any difference between the electronic monitoring and at-sea observer methods.

The catch composition data provided by at-sea observers and electronic monitoring analysts differed significantly on a shot-by-shot basis; however these discrepancies may be due to data collection and handling issues, inappropriate electronic monitoring configuration, and similarities between species that may have led to misidentification. It is likely that improved training processes, increased documentation and careful consideration of electronic monitoring system setup requirements on fishing boats would improve data consistency substantially. AFMA has progressed many of these improvements significantly since data was collected for this study.

A cost benefit analysis (CBA) was performed based on a fleet of 12 active fishing boats and sought to compare the cost of collecting data using at-sea observers and electronic monitoring systems under two scenarios: collecting data for TEP interactions, and collecting data for catch composition (which includes TEP interactions). The CBA assumed an ongoing level (3%) of at-sea observer coverage in addition to electronic monitoring to allow for the collection of biological samples and other information not possible with electronic monitoring.

The CBA suggests that electronic monitoring systems provide substantial cost savings when monitoring protected species interactions across 100% of fishing activity (the current requirement for gillnet fishing in some areas of the GHAT). If fishing activity in those zones over a 10 year period (our net present value planning horizon) continued to be similar to that used in our model, each boat fishing in those zones would realise an approximately $100,000 per year economic benefit by having an electronic monitoring system fitted.

As was seen in trials of electronic monitoring technology in the Northern Prawn Fishery (Piasente *et al*. in review-a) and the Eastern Tuna and Billfish Fishery (Piasente *et al*. in review-b), the capital cost of electronic monitoring equipment tends to make at-sea observers more cost effective when monitoring coverage is low. The "break even" point for electronic monitoring was approximately 7.6% monitoring coverage when analysing for TEP interactions, and 12.5% when analysing catch composition.

Our analysis leaves little doubt that the electronic monitoring systems currently deployed in the shark gillnet fishery are providing substantial economic benefits to concession holders in the fishery. Our analysis also shows that, if input costs are carefully controlled and minimised, electronic monitoring is likely to be a cost effective alternative at approximately 10% monitoring coverage.

Our cost benefit analysis did not include some unquantifiable benefits of electronic monitoring that may be substantial. In particular, the use of electronic monitoring systems is likely to change the reporting behaviour of fishers and lead to more accurate data reporting in fisher's logbooks. The increased data quality obtained from logbook records (which cover 100% of fishing activity) is a substantial benefit of electronic monitoring that is not costed in our CBA.

If electronic monitoring is used to largely replace at-sea observers for monitoring protected species interactions in the gillnet fishery, where meeting the 100% monitoring required, substantial cost savings may be realised. Likewise, with careful implementation electronic monitoring technology can be used to monitor catch composition, although at a higher cost than for protected species interactions. The challenges encountered during this research when trying to achieve both objectives simultaneously (recording catch composition and protected species interactions), suggests that a critical feature of a successful electronic monitoring program, just like an at-sea observer program, is to prioritize monitoring objectives clearly before implementation, and regularly review these priorities. Proper personnel training, clearly established methods and processes, and the cooperation and acceptance from industry and other stakeholders are also necessary for the successful use of electronic monitoring technology.

KEYWORDS: Electronic monitoring, fisheries management, cameras, threatened species interactions, Australian Sea Lions.

ACKNOWLEDGEMENTS

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The authors would like to thank members of the Gillnet Hook and Trap Fishery for allowing electronic monitoring systems to be installed on their boats. The skippers and owners of the *FV Baroness*, *FV Ester J*, *FV Lidia C*, *FV Fig Tree Bay* and *FV Cutting Edge* are thanked for providing footage, data and useful insights into their operations. The cooperation and support was doubly appreciated as it occurred during a difficult transition period for the fishery.

Dr Marcus Finn is thanked for adopting the project mid-stride and managing it through to completion, as are other AFMA staff for their input and advice on various sections of the report; particularly Narelle Williams, Gary (Basil) Adams, Laurence Martin, Steve Hall and Craig Geier for reviewing the footage and providing valuable feedback on camera placement and capacity for species identification. The help of Archipelago Marine Research staff for their assistance in answering technical questions was appreciated.

Statistical analyses were performed by Dr. Bernd Gruber from University of Canberra.

1 BACKGROUND

1.1 GENERAL

Interactions between fisheries and marine protected species such as marine mammals, seabirds and marine turtles is a worldwide issue that poses a serious threat to some populations, particularly those with slow life histories and small population sizes (Read 2008). These interactions include: direct interactions where there is physical contact between the animal and fishing gear with adverse consequences to the animal (Beverton 1985); depredation where the animal removes or damages the catch (Read 2005, Read 2008) and indirect interactions where fishery removals modify the trophic structure of an ecosystem causing an adverse impact on marine populations (DeMaster *et al*. 2001).

The threat of direct interactions where physical contact between protected species and fishing gear leads to the death of the animal (bycatch mortality) has been highlighted as significant, particularly in the case of marine mammals (Read *et al*. 2005). It has been estimated that hundreds of thousands marine mammals (cetaceans and pinnipeds) are killed globally by these interactions, with gillnet fisheries accounting for over 90% of them (Read *et al*. 2005). However, the nature, extent and impact that commercial fishing has on marine mammal populations are still not well understood, mostly because of lack of information (Read *et al*. 2005).

Accurate bycatch estimates are crucial when dealing with small populations due to their high vulnerability as is the case of dugongs, false killer whales, Australian and New Zealand Sea Lions and Mediterranean Monk seals, among others (Babcock & Pikitch 2003, Read 2008). While participants in the fishing industry are required to report these interactions in many places around the world, there is a tendency for under reporting (Northridge 1996). As a consequence, estimates of marine mammal bycatch rely on data collected by at-sea observer programs (Harwood & Hembree 1987, Julian & Beeson 1998, Orphanides 2009, Orphanides 2010).

Observer programs rarely cover 100% of a fishery (NMFS 2002, Chilvers 2008) therefore bycatch rates are usually calculated from observer data and then applied to some measure of total fishing effort in a particular fishery (Read *et al*. 2005). Cost, logistical difficulties, and availability of suitably trained observers can sometimes constrain the amount of data collected and lead to inaccuracy when data is extrapolated (Babcock & Pikitch 2003, McElderry *et al*. 2007). Other bias may also be introduced through non-random sampling and behavioural changes in the fishing crew due to observer presence (Babcock & Pikitch 2003, McElderry 2008).. Alternatives must be sought in order to obtain the needed information, and video based electronic monitoring technology could prove to be one alternative with the capacity to monitor all fishing activity (McElderry 2008).

The use of electronic monitoring technology has been explored in a diverse range of fisheries, with several pilot studies carried out to address different fisheries monitoring objectives such as catch, discard and protected species interactions (Ames *et al*. 2005, McElderry *et al*. 2005a, McElderry *et al*. 2005b, McElderry *et al*. 2005c, Ames *et al*. 2007, Bonney & McGauley 2008, McElderry 2008, McElderry *et al*. 2010b, Piasente *et al*. in review-a, Piasente *et al*. in review-b). These pilot studies have concluded that electronic monitoring is a useful tool for monitoring in fisheries that bring their catch back to the boat in a serial manner, such as gillnet and longline, and has been proven to be useful for monitoring catch interactions with protected species and assessing the efficacy of mitigation measures (McElderry *et al*. 2004, McElderry *et al*. 2005a, McElderry *et al*. 2010a). The preliminary success of trials has led to the implementation of electronic monitoring technology in some fisheries, and it is thought that electronic monitoring will be an integral part of fisheries monitoring in the near future (McElderry 2008, Kindt-Larsen *et al*. 2011).

1.2 SOUTH AUSTRALIAN GILLNET FISHERIES

1.2.1 Australian Sea Lions

Australian Sea Lions (ASL) are listed as a threatened (vulnerable) species under the EPBC Act and the majority (86%) of the estimated remaining 14,730 ASLs are thought to occur off the coast of South Australia (Goldsworthy *et al*. 2009). They have a breeding cycle of 17-18 months which is temporally asynchronous across their range (Gales *et al*. 1994). Their breeding, gestation, and lactation periods are also unusually long compared to other pinniped species, with some ASLs not pupping consecutively each breeding season, but suckling their young for up to 40 months (Higgins & Gass 1993). Female ASLs also exhibit strong fidelity to specific natal sites which results in little genetic transfer between colonies (Campbell *et al*. 2008).

Because of these unusual reproductive traits and their limited population size, ASLs are considered particularly vulnerable to the effects of fishing (Walker *et al*. 2007, Campbell *et al*. 2008). Their habit of foraging on, or close to the sea bed at depths and distances where gillnets are commonly set also increases their risk of entanglement, injury and death. Further studies have indicated that ASL colonies may be genetically distinct, and a colony could be at significant risk of disappearing, even if only one adult female from the colony is removed (Goldsworthy & Lowther 2010, Goldsworthy *et al*. 2010).

The extent of interactions between ASLs and fisheries, particularly the shark gillnet fishery is poorly known and has contributed to the classification of ASLs as being at high risk from the impacts of gillnet fishing (Walker *et al*. 2007). Under the EPBC Act, operators in Australian fisheries are required to record interactions with protected species in their logbooks and other forms. Additional independent data on these interactions are also collected by at-sea observers. However, small levels of historical observer coverage (<2% before 2010) and potential under-reporting by industry have contributed to the uncertainty in the level of interactions between ASLs and the gillnet component of the shark gillnet fishery off the coast of South Australia. Given this uncertainty, the small ASL population size and low reproduction rates, AFMA has classified ASLs as being at high risk from the impacts of fishing operations in its ecological risk assessment for the shark gillnet fishery (Walker *et al*. 2007).

To reduce this uncertainty, a study was carried out to assess the extent and impacts of ASL bycatch mortality in the shark gillnet fishery (Goldsworthy *et al*. 2010). Available data on population abundance, foraging behaviour, bycatch rates and fishing effort distributions were used for the assessment. Independent at-sea observer data from 10 trips (234 shots) carried out between 2006 and 2008 were used to estimate bycatch mortality. Bycatch estimates were calculated in three different ways and estimated an ASL bycatch mortality of 374 (272-506 ±95%CL) per breeding cycle (Goldsworthy *et al*. 2010). Based on these results, the authors recommended that:

- female ASL bycatch be reduced to 0 to prevent the further decline of some subpopulations
- consideration be given to the reduction of ASL male bycatch
- the area of the gillnet fishery off South Australia be reduced; particularly in shallow, inshore waters
- the level of fishing effort be managed in areas that overlap ASL foraging grounds
- comprehensive ASL subpopulation monitoring programs be developed.

In considering these findings, AFMA sought advice from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). This advice suggested that:

- The data (sample size) underpinning the Goldsworthy *et al*. (2010) report was geographically limited and consequently the findings may not be representative of the fishery as a whole.
- Key assumptions behind the model-based projections were highly uncertain and the projections may be better suited to provide an assessment of relative risk to ASL populations rather than actual risk, as presented in the report.
- Modelled risks to studied ASL populations did not fit the actual data (e.g. the largest colony at Dangerous Reef is growing at 5% per breeding cycle but the model-based projections assume the population is static (no growth).
- Fishing mortality estimates are not consistent with population monitoring data for ASLs. If mortality estimates were correct then the historical population would have needed to be much larger than the data shows.
- The mortality rates observed during the study were 3-4 times higher than those from AFMA at-sea observer data that was collected over a broader geographical area of the fishery, and over a longer period of time.

AFMA considered that urgent, short term, action was required to minimise the risk to ASLs posed by shark gillnet fishing. On 30 June 2010 AFMA finalised and implemented its *Australian Sea Lion Management Strategy 2010 (SESSF Closure Direction 3 2010)*. This initial strategy included area closures, an increase in monitoring requirements, and triggers for regional closures should a predetermined number of ASL interactions occur. On 1 May 2011, AFMA increased the area of spatial closures under the Australian Sea Lion Management Strategy to 18,500 km^2, an area encompassing two thirds of all locations where ASL interactions had been observed. The level of monitoring cover required was also increased to cover 100% of gillnet fishing activity in the area of the ASL Management Zone (Figure 1), and 10% of both gillnet and hook fishing activity in all other areas (Figure 2). Other measures such as prohibition of offal discharge and provision for certain fishers to change from using gillnets to hooks were also included.

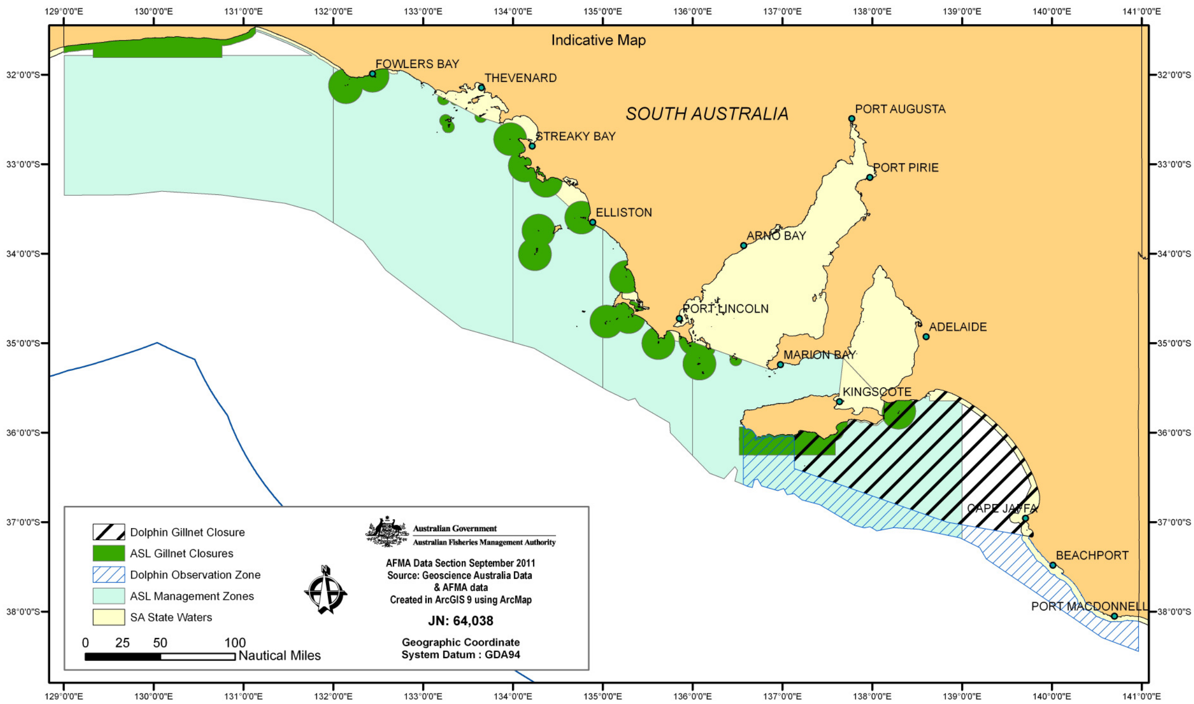

Figure 1: Area of study: South Australian waters open to gillnet fishing

1.2.2 Dolphins

There was an increase in reported and observed dolphin interactions (~50) between September 2010 and September 2011. This prompted AFMA to respond by:

- closing a large area to gillnet fishing where the majority of the dolphin interactions occurred (Figure 1)
- increasing the required monitoring coverage to 100% in the area adjacent to the dolphin closure
- allowing some operators to fish with hooks instead of gillnets within and adjacent to the dolphin closure.

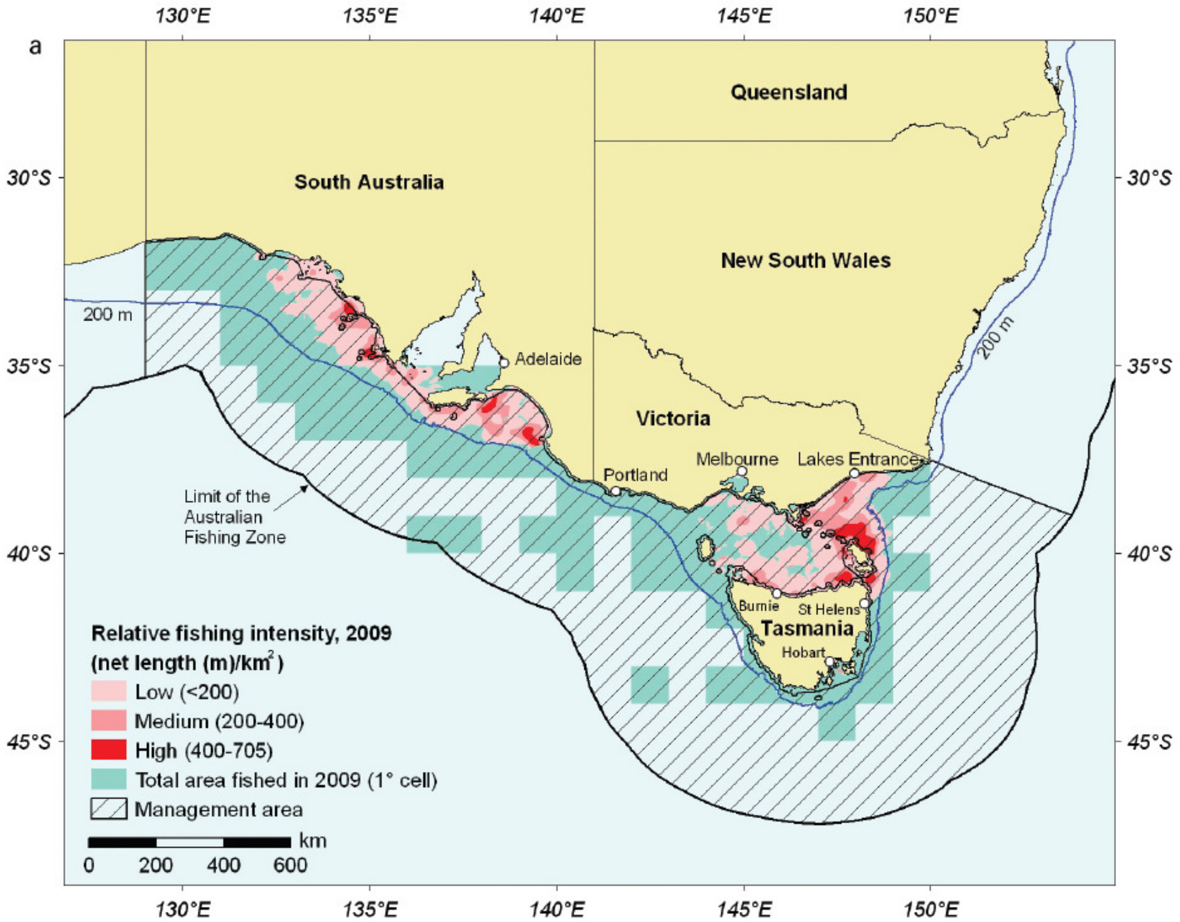

Figure 2: Area of the Gillnet, Hook and Trap fishery (cross-hatched area) showing areas where gillnet fishing activity occurred during 2009 (Wilson *et al*. 2010).

1.2 NEED

In addition to the issues of dolphin interactions highlighted by the additional electronic monitoring coverage, gillnet fishing has been suggested to pose one of the most serious risks in the recovery of ASL populations, mostly because of the large spatial overlap between the ASL's foraging effort and gillnet fishing effort (Goldsworthy *et al*. 2010). In order to manage this risk, it is essential to have an accurate and timely account of bycatch mortality. AFMA made the decision to increase monitoring to 100% of gillnet fishing activity in the ASL Management Zone and in the area adjacent to the dolphin closure to ensure that adequate data was available.

The use of at-sea observers for data collection can pose a significant financial burden on the fishery, potentially making it financially unviable. Thus, there is a strong need for an efficient and cost effective monitoring alternative. Electronic monitoring technology could provide a cost effective alternative, but it will only be helpful if the quality of data obtained is capable of supporting management decision-making.

This report explores the effectiveness and economic benefits of using electronic monitoring technology for collecting information on interactions between gillnets, ASLs and other marine mammals when compared to at-sea observers. It also assesses the ability of electronic monitoring system to accurately record a broader range of data such as catch composition.

1.3 OBJECTIVES

1. To assess the capacity of electronic monitoring systems to provide high quality, in-season data on interactions with ASLs and other protected species in the shark gillnet fishery off South Australia.

2. To improve the level of certainty on the impact of fishing operations on ASLs.

3. To investigate the use of electronic monitoring system for collecting data currently collected by at-sea observers with a focus on opportunities to improve the data integrity and data quality of the Independent Scientific Monitoring Program (ISMP).

4. To assess the cost and benefits of utilising electronic monitoring system in the shark gillnet fishery.

2 ELECTRONIC MONITORING SYTEM TRIAL

2.1 METHODS

2.1.1 ELECTRONIC MONITORING SYSTEM

2.1.1.1 Description

The electronic monitoring system consists of closed circuit television (CCTV) cameras, hydraulic and rotation sensors to record video footage of fishing activity and a removable hard drive to store the data. The sensors activate the cameras to start recording when fishing activity commences, with the footage electronically stamped with the time, date and location of the boat using a GPS receiver. Data on vessel location and sensor activity is sent off the boat via satellite every hour while the electronic monitoring system is in operation. High resolution data on boat location and sensor activity (recorded at 10 second intervals), as well as video footage, are stored in a hard drive and were retrieved by exchanging the boat's hard drive.

The electronic monitoring systems used for this project were manufactured by Archipelago Marine Research Ltd (AMR). Each system consisted of up to three CCTV cameras, a GPS receiver, a satellite transceiver modem, a hydraulic pressure sensor, a rotation sensor and a control centre (Figure 3). The rotation and hydraulic pressure sensors detect when fishing equipment is being used and trigger video recording, while the GPS receiver allows the location, date and time to be recorded on the imagery and ensures that the control system clock remains accurate.

The sensors and cameras are connected to the electronic monitoring system control centre which is usually located in the boat's wheelhouse. The control centre is composed of a computer to monitor the sensors, activate image recording, trigger system status reporting, and to allow operators to perform function tests and ensure the system remains operational. Sensor and image data are recorded by the system's control centre onto removable hard drives, which can be exchanged when they approach capacity (approximately every three months during normal fishing operations) or as required.

Electronic monitoring systems could be fitted with uninterruptible power supply units to ensure that it remains operational during times when the boat's generated power supply is unavailable. Data on any power outages as well as other data could be recorded by the electronic monitoring system and transmitted to land to ensure system functionality.

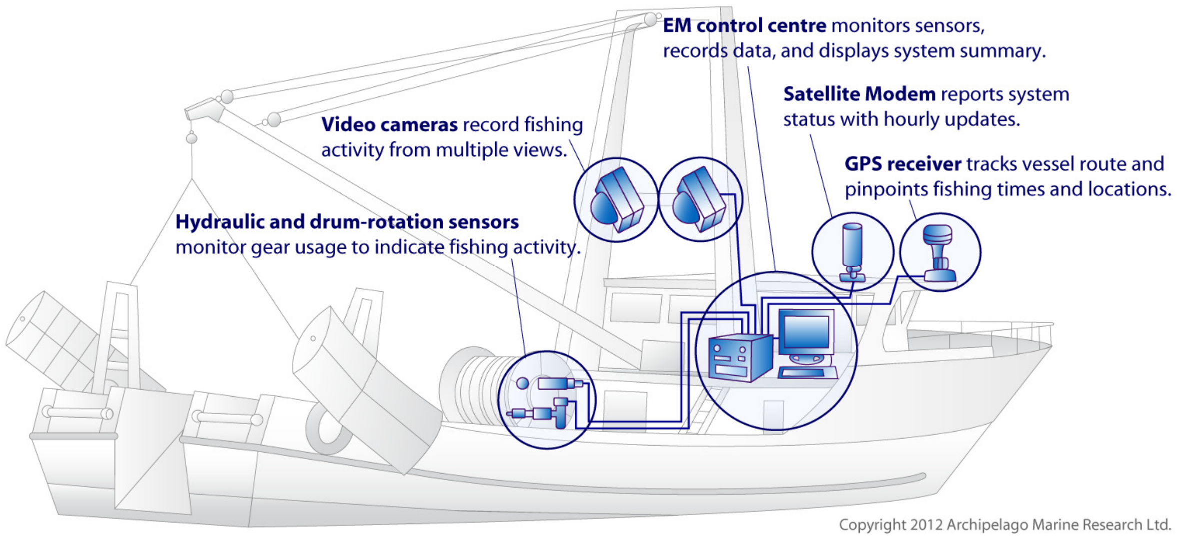

Figure 3: Schematic of a standard electronic monitoring system used in the trial

2.1.1.2 Data collection

The trials were conducted between September 2010 and September 2011 on five gillnet fishing boats that were selected to participate based on their history of fishing activity in the ASL Management Zone. The CCTV cameras (Figure 4) were mounted in elevated positions with camera angles that allow coverage of the net as it left the water and came over the net roller, a wide view covering the deck of the boat, and a narrow view of the deck or sorting station to allow for species identification (Figure 5). Care was taken to ensure the cameras did not constrain normal fishing operations, did not catch the fishing gear, did not pose a health and safety risk to crew, and would not be obstructed by fishing equipment or other parts of the boat. The cameras were also mounted in a way that avoids water remaining in front of the lens. Desiccants helped limit any condensation inside the camera housings, and sunshades were also fixed in place inside the housings to limit glare from the sun. Video recording was set to 5 frames per second with 640x480 pixels images and a dynamic image compression ratio.

The satellite transceiver modem was set to send status reports to AFMA on an hourly basis during times the electronic monitoring system was in operation. These reports were a synopsis of the previous hour's sensor data and included boat location, activity and system operational status. This information was also used to monitor remaining hard drive storage, to troubleshoot technical problems and to prioritise service events.

Health Statement Viewer software developed by AMR was used to determine place and time of fishing activity on a near real-time basis. This software displays hourly packets of information sent to AFMA via satellite modem by the electronic monitoring system. These hourly data are also recorded to the hard drive in the boat together with the high resolution 10 second interval data. Time, date and boat information are hot-stamped on the video footage to allow AFMA determine the exact time and location of any interactions occurring with protected species when footage is reviewed.

Figure 4: Closed circuit television cameras mounted on Commonwealth fishing boats as part of electronic monitoring systems

2.1.1.3 Footage analyses

Quality

Footage quality was analysed for the 640 net hauls recorded during this trial (corresponding to 274 fishing days). Records were made of any issues that affected an analyst's ability to review the video footage, including visibility level, presence of camera obstruction, recording failure during a fishing event and lighting problems. The frequency of issues experienced by an analyst was later used to assess how well electronic monitoring systems recorded information on fishing activities.

Marine mammals

A total of 640 individual net hauls were recorded and analysed to obtain the number of direct interactions between marine mammals and gillnets. This included instances where animals fell out or were otherwise removed from the net between the water surface and the boat. Electronic monitoring system footage was analysed by a number of analysts that included an independent data analyst (D&S Data Fix), and an experienced AFMA observer. The independent data analyst with low-level species identification skills took screen shots and captured short clips of relevant video when interactions were detected. These short clips were subsequently reviewed by the experienced AFMA observer to identify individuals to the finest taxonomical level possible. As analysts gain further experience and expertise in species identification it is possible that identification could be done during the analysis phase.

Analysis of electronic monitoring footage was undertaken using VLC Media Player and electronic monitoring Interpret Pro™, which is a dedicated video analysis software package produced by AMR. Both pieces of software allowed electronic monitoring system footage to be reviewed at different speeds. Due to the large size of marine mammals, which allows easy detection in the video footage, speeds up to 6 times that of real-time were used for video analyses to minimise costs. Speed was slowed down when interactions were detected and analysed on a frame-by-frame basis to identify individuals to the finest taxonomical level possible. Time and position information was recorded for each interaction as well as the nature of the interactions.

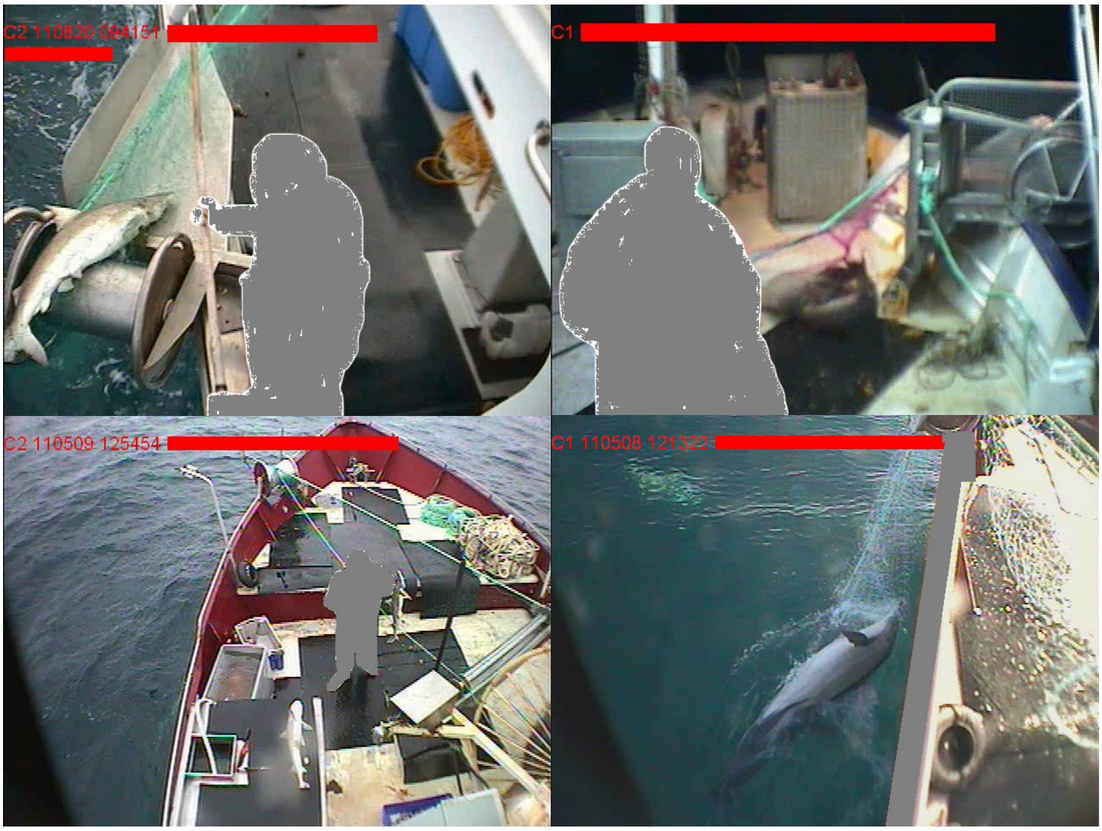

Figure 5: Images taken from electronic monitoring systems on gillnet fishing boats. Boat names and GPS locations have been masked in these images

Catch composition

Video footage of 14 electronic monitoring system shots was reviewed to obtain catch composition data. Electronic monitoring system footage was reviewed by an AFMA observer with extensive experience in the gillnet fishery and thus was familiar with the species being caught. An independent data analyst (D&S Data Fix) with little experience in species identification was also asked to review the footage. Data from the inexperienced reviewer was not used for statistical analyses, but was used to compare results between video analysts. No pre-defined list of species was utilised.

The electronic monitoring system video footage was analysed using VLC Media Player at up to 4 times the speed of real-time and was subsequently reviewed on a frame by frame basis when a catch item was detected.

To best enable comparisons with catch recorded in logbooks and by observers, the electronic monitoring system analyst was instructed to focus only on species brought aboard in the net. This method was chosen to be consistent with that undertaken by at-sea observers. Of the three cameras fitted on board, the two cameras with view of the net as it passed between the net roller and the deck provided the clearest picture for species identification (Figure 6). Catch recorded as dropping out of the net before it reached the net roller (24 fish, 1 sponge) were not included in the dataset used for comparing catch composition analysis between at-sea observers and electronic monitoring system.

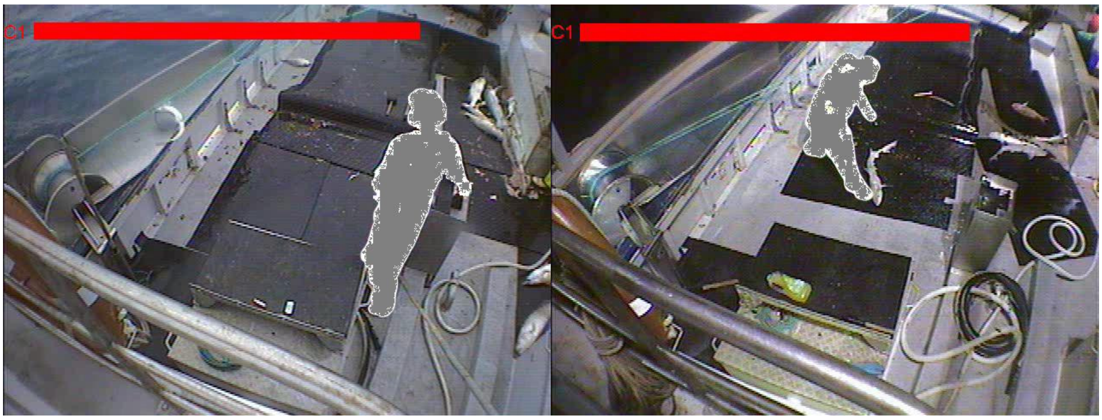

Figure 6: Example footage used by electronic monitoring data analysts to determine catch composition

2.1.2 AT-SEA OBSERVERS

2.1.2.1 Data collection

Marine mammals

AFMA observers were placed on fishing boats fitted with an electronic monitoring system to provide an independent dataset against which to compare electronic monitoring system data. They observed 127 of the 640 shots recorded by an electronic monitoring system to collect data on interactions with protected species such as ASLs. Interactions in this case are any physical contact an individual (person, boat or gear) has with a marine mammal that causes death, injury or stress to the individual directly resulting from fishing activities.

While collecting data for the trial, observers followed the standard AFMA protocol designed to maximise their ability to detect any ASL interactions. The protocol consisted of observers standing in a position where they have full view of the gillnet as it is emerging from the water in order to detect protected species caught in the nets, including individuals that fall out prior to the net coming onto the deck of the boat (Figure 7). Data such as date, shot number, time of start and end of observation, species code, life status of the individual, fate, sex, estimated weight, abundance of seal or sea lions in the area and fishing gear details are recorded in special data sheets designed to report ASL interactions. No attempt was made by the observers to record information on catch composition during most of these trips as their objective was to detect protected species interactions, particularly with ASLs.

Catch composition

To test the ability of the electronic monitoring system to accurately record catch composition, at-sea AFMA observers were asked to record catch composition from the 12 – 16 of September 2010 for a subset of 14 shots. To ensure the two data sets were independent from one another, the observer who collected data on the fishing boat was not involved in the video analysis. Both the at-sea observer and the video analyst had extensive experience; 8-9 years as at-sea observers with 2 years experience in the gillnet fishery and were familiar with the species being caught. No pre-defined list of species was utilised.

The at-sea observer stood near the net roller to collect data. AFMA's standard vessel information was recorded while catch composition data included:

- shot number
- species
- place of removal (deck, water, roller)
- method of removal (crew, self)
- life status
- retained or discarded.

Figure 7: AFMA on board observer collecting data

2.1.3 DATA ANALYSES

2.1.3.1 Marine mammal interactions

Consistency between methods per sighting event was directly compared. The number of events where both methods detect the same number of individuals is indicated in the diagonal, shaded area, so all entries away from the diagonal indicate inconsistency between methods (Table 3).

Encounter rates with marine mammals were calculated using the 640 shots surveyed by the electronic monitoring system, where the probability of encounter is:

p.pr = total # sightings / total # shots ……(1)

The probability of the electronic monitoring system detecting interactions was calculated using the 127 shots where both an observer and an electronic monitoring system collected data:

p.ems = # electronic monitoring system sightings / # observer sightings ……(2)

Power analysis

Due to the rare nature of encounters between gillnets, ASLs and dolphins during this study, the data available to test if there was a significant difference between on board observers and electronic monitoring system was limited. Power analysis was performed to estimate the number of shots necessary to find a significant difference between the two methods. This test shows the proportion of repetitions within a given number of shots, N, where a significant difference could be detected with 95% confidence. It is dependent on the encounter probability (p.pr) with marine mammals and the electronic monitoring system sighting probability (p.ems). In the analyses, the null hypothesis of no significant difference between methods is given a value of 1.

The following combinations of parameter values were used to perform the analysis using R:

p.pr = 0.1-1 in 0.1 steps

N = 10-100 in 10 steps and 150, 200, 500, 640, 1000, 1500, 2000, 5000

p.obs = 1

p.ems = 0.1-1 in 0.1 steps

where p.pr is the interaction probability, N is number of shots, p.obs is at-sea observer detection probability and p.ems is electronic monitoring system detection probability.

Data were simulated for 1000 repetitions under each scenario, counting the number of times the 95% confidence interval included 1 (i.e. no significant difference between methods was found) (Figure 8). The objective is to delineate the range of values of parameter combinations in a given N where significant difference between methods could be found using a 95% level confidence interval (i.e. we are interested in the black area of the contour plot).

For example, in Figure 8b there is a probability of finding a significant difference between methods in 100 shots, N = 100, only if the methods are very different at a low interaction rate (i.e. p.pr<0.2, p.obs=1 and p.ems=0); or if the rate of interaction is 100%, p.pr=1, and the electronic monitoring system detection rate is 80%, p.ems=0.8. In other words, we are interested in the area where less than 10% of the data includes the null hypothesis (i.e. a significant difference is found in >90% of the shots; the black area of the graphs).

It is important to note that power analysis is a test designed to estimate the sample size needed to enable accurate statistical testing. It is not designed to test if there are significant differences between methods. For the purposes of our study we were interested in establishing, given the low interaction rates we encountered, how many samples would need to be collected to enable us to statistically validate our methods of data collection with 95% confidence.

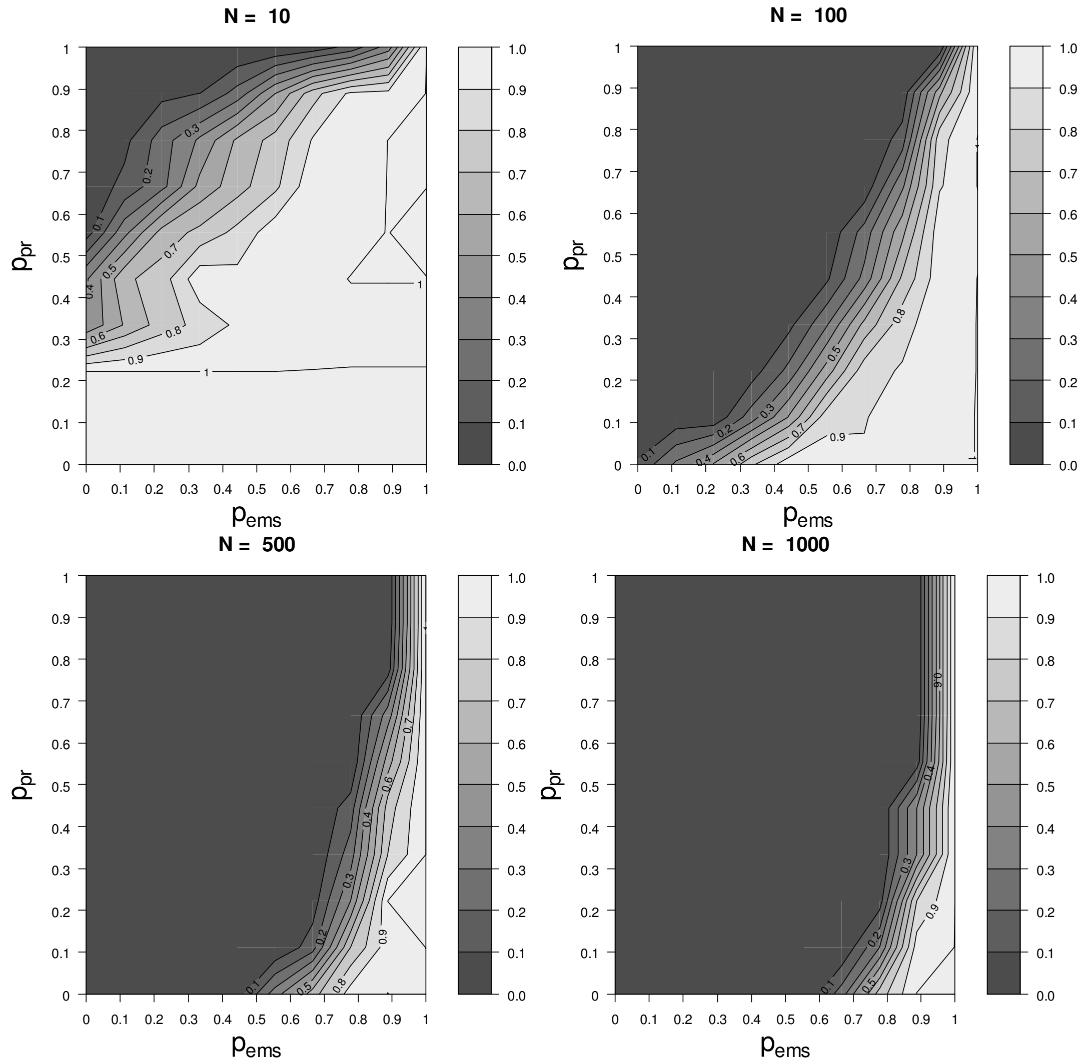

Figure 8: Contour plots showing examples of the power analyses for 10, 100, 500 and 1000 shots. p.pr is the probability of encounter, p.ems is the probability of detection by the electronic monitoring system. Levels of grey indicate the proportion of observations that contain the null hypotheses (no significant difference between methods).

2.1.3.2 Catch composition

Parameter calculation

Estimates of p.pr, p.ems and p.obs were calculated for individual taxa in most cases. However, there was no assumption of 100% detection by the at-sea observer, thus p.obs and p.ems were calculated as follow:

p.obs = # of shots where species a was detected by observer / Total # of shots ……(3)

p.ems = # of shots where species a was detected by electronic monitoring system / Total # of shots ……(4)

Maximum Likelihood Estimation (MLE) based on a Poisson distribution (Pois), which is appropriate for count data, was used to calculate the probability of encounter for each species (p.pr), the number of individuals detected by the observer (N.obs) and by the electronic monitoring system (N.ems), and their respective 95% confidence intervals, using a hierarchical approach. In this approach, the probability of detecting a certain number of individuals of a given species depends firstly on the probability that it is present in a catch (p.pr), and secondly on the probability that it is detected by either method (N.obs, N.ems).

$$p.ems = p.pr * Pois(x1 \ldots xn \mid N.ems) \;\ldots\ldots(5)$$

$$p.obs = p.pr * Pois(x1 \ldots xn \mid N.obs) \;\ldots\ldots(6)$$

where p.pr, N.obs and N.ems are the parameters to be estimated using MLE, x is the number of detected individuals and n is the total number of observations where $p.pr \neq 0$

A "0" can be recorded for two reasons:

a) no individual of species x was present in the shot; or

b) species x was present but was not detected by either the electronic monitoring system or observer.

In those instances, the equations used were:

$$p.ems = (1-p.pr)+p.pr * Pois(0 \mid N.ems) \;\ldots\ldots(7)$$

$$p.obs = (1-p.pr)+p.pr * Pois(0 \mid N.obs) \;\ldots\ldots(8)$$

Theoretically if both the observer and electronic monitoring system methods are comparable, an overlap of their confidence intervals should be found. In those instances where p.pr could not be estimated using MLE, the values of p.obs and p.ems were used in its place to estimate N.ems and N.obs.

Test for difference between methods

Two tests were performed to ascertain if there was a significant difference between methods:

1) The difference in number of individuals detected per species within each shot (paired test).

2) The overall difference in number of individuals detected per species by method (neglecting the identity of shots, unpaired test).

A generalized linear regression model (GLM) analysis was used in both tests with “method” used as the predictor. The purpose of this model is to find if a relationship exists between the observed response, Y, and a number of covariates/predictors, X. In this case, when the variability in the observed number of individuals (Y) of a given species is explained by the predictor “method” (X), there is a significant difference between methods.

In the first analysis (paired test) data were used as pairs and the difference between methods was tested on a shot by shot basis (i.e. 15 parameters were estimated, 14 for each shot and one for method). In this test, if the variability in the number of individuals observed in each shot can be explained by the method, then there is a significant difference between methods.

In the second analysis (unpaired test) the number of individuals was allowed to vary within shots and the test was performed for the total number of individuals of a given species. If the variability in the number of individuals over all 14 shots can be explained by the method, then a significant difference between methods was found.

As abundance data for many species is heterogeneous by nature due to the patchiness in the distribution of marine organisms, there is an excess of “0” counts. Thus the sample variance will exceed the sample mean. To account for this over dispersion, a negative binomial distribution of their residual variance was specified for the generalized regression model.

2.2 RESULTS

A total of 274 fishing days and 640 shots were recorded, of which 76 shots were affected by issues associated with image quality (Table 1). The most prominent problem encountered during footage analysis was the obstruction of one of the cameras, affecting all of the footage for that particular shot and camera. This problem affected one boat in particular where the boat’s stabilizer obstructed the view of the net roller while it was in its stored position. The second most common problem was deck lighting, although this affected only a small amount of the footage. There was a single day where the electronic monitoring system did not record any footage or sensor data for ~15 hours (one shot). During that fishing event a dolphin interaction was reported by the at-sea observer and biological samples were taken. Corruption or bad image quality affected 10 shots out of the 640 analysed.

Table 1: Summary of image analysis outlining the issues encountered during the trial

Problem	Number of shots affected	% of shots affected	Time affected
Camera obstruction	48	7.5%	entire shot for one camera
Poor footage quality	10	1.6%	ranged from 8 minutes to most of the shot
No footage recorded	1	0.16%	15 hours
Lights not on	14	2.2%	approx. 8 minutes per shot
Glare	3	0.47%	Entire shot

2.2.1 MARINE MAMMAL INTERACTIONS

A total of 26 marine mammal interactions were detected with the electronic monitoring system out of the 640 net hauls analysed, from which 24 sightings were dolphins and 2 were pinnipeds (Table 2). From the 127 net hauls monitored by both observers and an electronic monitoring system, a total of 10 sightings were detected by observers and 9 by the electronic monitoring system, with dolphins accounting for all the sightings (Table 3).

The dolphin interaction not seen by the electronic monitoring system data was due to the system not recording any footage during that particular day (3:14-17:57, 24/01/2011). Out of the 9 dolphins detected by both an electronic monitoring system and observer, all were identified as common dolphin, *Delphinus delphis*. However, there was a level of uncertainty in 2 of the electronic monitoring system identifications due to the dolphin dropping out before reaching the net roller, or because of subject distance from the camera. Of the other 17 marine mammal interactions recorded by an electronic monitoring system and analysed, 2 were identified as ASL, *Neophoca cinerea*, 12 were identified as common dolphin (with a level of uncertainty for 4 of those identifications), 1 was tentatively identified as bottlenose dolphin and 2 were unidentified dolphins.

The total interactions recorded by the electronic monitoring system resulted in an encounter rate per fishing shot (p.pr) with marine mammals of 0.0422 or 4.22%, with dolphins accounting for 3.91% and pinnipeds accounting for only 0.31%.

The low marine mammal interaction rate did not provide sufficient data to test whether the two methods (observer and electronic monitoring systems) were statistically different with a 95% confidence (Figure 9a). Power analysis performed to estimate the number of simultaneous observations necessary to test if there were any significant difference between the two methods at the estimated encounter rates (p.pr = 0.003 for pinnipeds and p.pr = 0.039 for dolphins) showed that over 5000 shots would be necessary in order to test if there are significant differences between methods with 95% confidence, assuming the p.ems of 90% is the same for dolphins and pinnipeds (Figure 9b). This analysis also showed that at the estimated p.pr for pinnipeds and dolphins, a p.ems of less than 50% would be necessary in order to test if there is a significant difference between methods given the total number of shots analysed in this study. Alternatively, an encounter rate (p.pr) with marine mammals of more than 70% will be necessary with the current p.ems of 90% (Figure 9b).

Table 2: Marine mammal interactions reported by electronic monitoring (EM) system and at-sea observer, date and time of interaction and species identification. T_{EMS} is time when interaction occurred as recorded by the EM system, T_{OBS} is time of the interaction as reported by the at-sea observer

	Date	T_{EMS}	EM system	Comments	T_{OBS}	Observer	Comments
1	23/09/2010	13:16	*Delphinus delphis*	Identification using EM system was uncertain	13:17	*Delphinus delphis*	
2	25/09/2010	5:30	*Delphinus delphis*		5:32	*Delphinus delphis*	
3	10/10/2010	11:12	*Delphinus delphis*			*No Observer onboard*	
4	14/10/2010	9:35	*Delphinus delphis*	Identification using EM system was uncertain		*No Observer onboard*	
5	17/10/2010	13:39	*Delphinus delphis*			*No Observer onboard*	
6	27/11/2010	6:38	*Tursiops aduncus / T. truncatus*	Identification using EM system was uncertain		*No Observer onboard*	
7	5/12/2010	8:48	*Delphinus delphis*			*No Observer onboard*	
8	5/12/2010	9:12	*Delphinus delphis*			*No Observer onboard*	
9	9/12/2010	9:57	*Delphinus delphis*			*No Observer onboard*	
10	15/01/2011	2:11	*Delphinus delphis*	Identification using EM system was uncertain		*No Observer onboard*	
11	15/01/2011	2:46	Unidentified dolphin			*No Observer onboard*	
12	21/01/2011	18:06	*Delphinus delphis*	Identification using EM system was uncertain	18:06	*Delphinus delphis*	not possible to measure
13	21/01/2011	18:31	*Delphinus delphis*		NR	*Delphinus delphis*	not possible to measure
14	22/01/2011	11:20	*Delphinus delphis*		10:15	*Delphinus delphis*	not possible to measure
15	22/01/2011	19:22	*Delphinus delphis*		19:23	*Delphinus delphis*	female, measured
16	24/01/2011			No video footage recorded from 03:14 to 17:57	11:53	*Delphinus delphis*	female, measured and dissected
17	26/01/2011	19:24	*Delphinus delphis*		19:25	*Delphinus delphis*	length estimated from photo taken
18	28/01/2011	15:33	*Delphinus delphis*		15:34	*Delphinus delphis*	male, length estimated from photo taken
19	10/02/2011	20:45	*Delphinus delphis*			*No Observer onboard*	
20	15/02/2011	22:47	*Delphinus delphis*	Identification using EM system was uncertain		*No Observer onboard*	
21	8/05/2011	15:42	*Delphinus delphis*			*No Observer onboard*	
22	8/06/2011	12:13	*Delphinus delphis*	Identification using EM system was uncertain		*No Observer onboard*	

23	8/06/2011	12:22	Unidentified dolphin			*No Observer onboard*
24	13/07/2011	14:05	*Neophoca cinerea*	Female		*No Observer onboard*
25	15/07/2011	3:38	*Neophoca cinerea*	Female		*No Observer onboard*
26	21/08/2011	21:24	*Delphinus delphis*		21:26	*Delphinus delphis*
27	15/09/2011	0:44	*Delphinus delphis*			*No Observer onboard*

Table 3: Summary of net hauls (n=127) monitored by both an electronic monitoring system and at-sea observer, showing the consistency of the methods (green shading)

Interactions detected		Electronic monitoring system		
		0	1	2
At-sea observers	0	119	0	0
	1	1	5	0
	2	0	0	2

2.2.2 CATCH COMPOSITION

A total of 3,498 individuals belonging to 18 taxonomical groups were reported by the at-sea observer during the 14 shots analysed for catch composition, while a total of 3,395 individuals belonging to 27 taxonomical groups were reported from electronic monitoring system footage analysis (Table 4). Gummy Shark (*Mustelus antarcticus*), was the most frequent species detected by both methods followed by Elephant Fish (Callorhinchidae/Rhinochimaeridae), Saw Shark (*Pristiophorus* spp.) and Snapper (*Pagrus auratus*). However, the fifth most abundant group detected by the observer was the Spurdog (*Squalus megalops*) while Port Jackson Shark (*Heterodontus portusjacksoni*) was the fifth most abundant according to electronic monitoring system analyst. In addition, 5 individual sharks were placed in the unidentified shark category and two observations were placed in a general unidentified category by the electronic monitoring system analyst, while the at-sea observer did not place any individuals in unidentified categories.

All groups reported by the at-sea observer were also reported by the electronic monitoring system analyst. However, the N.ems and N.obs confidence intervals overlapped only for 10 taxonomical groups (Figure 10). From the groups whose confidence intervals did not overlap, N.ems was higher in 11 groups and N.obs was higher in 6 groups. Out of the 11 groups where N.ems was higher than N.obs, 7 were new taxonomical groups recorded by the electronic monitoring system but not the at-sea observer and 2 were unidentified groups (Table 4).

The pairwise GLM that tested for differences in the number of individuals detected per taxonomic group on a shot by shot basis found a significant difference between methods ($p<0.01$) for all taxonomical groups. It is important to note that for some groups there was not enough data to complete a pairwise comparison.

Unlike the paired test, the unpaired GLM did not show a significant difference between methods in the detection of 16 of the 25 taxonomical groups (minus the unidentified categories). Of the groups where a significant difference between methods was found, Australian Salmon (*Arripis trutta*), Broadnosed Shark (*Notorynchus cepedianus*), Blue Morwong (*Nemadactylus douglasii*), Trevally

(Carangidae) and Whiskery Shark (*Furgaleus macki*) were detected only by the electronic monitoring system, while the number of Port Jackson Shark (*H. portusjacksoni*) detected by electronic monitoring system was more than double the number recorded by the at-sea observer. The two unidentified categories were only used by the electronic monitoring analyst.

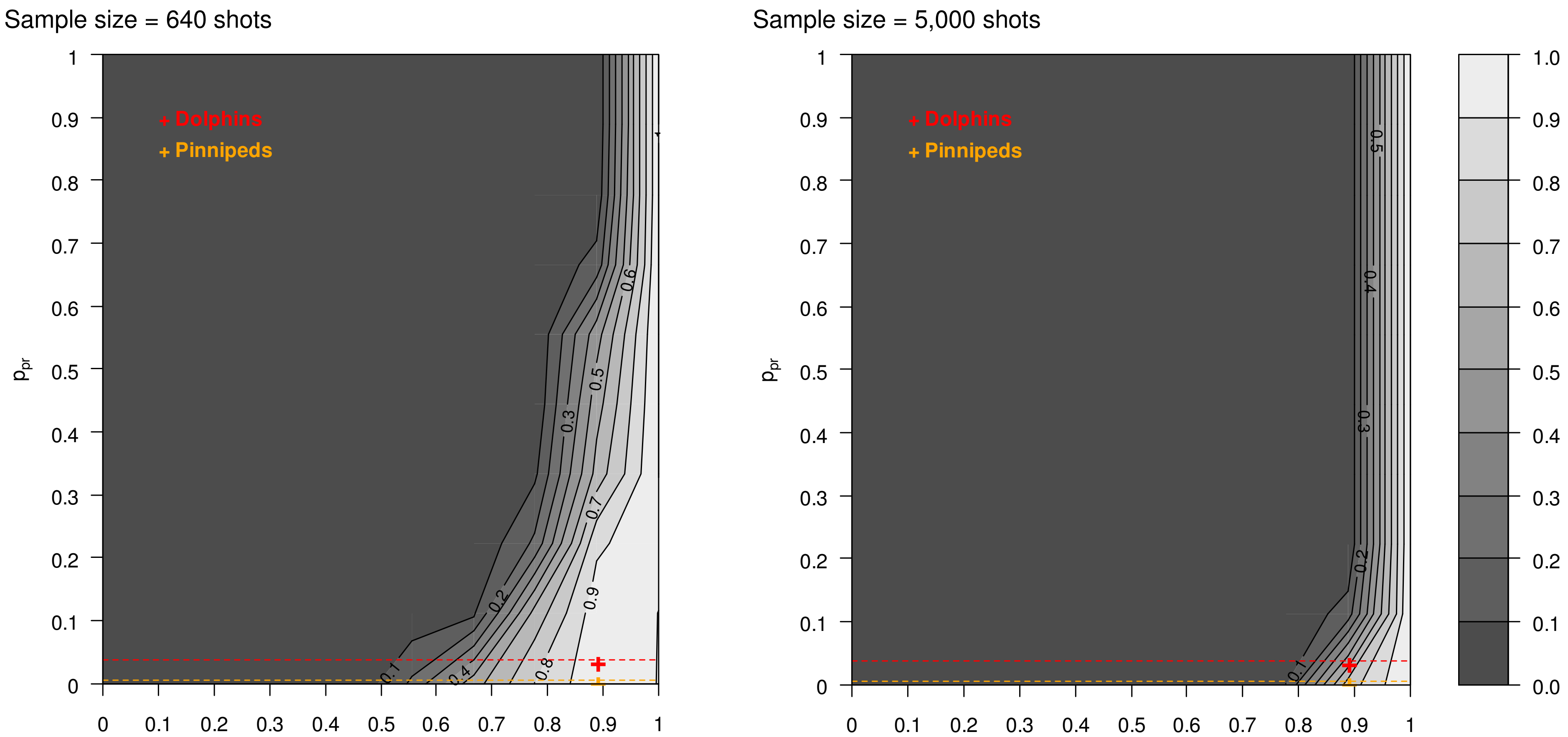

Figure 9: Contour plots showing the power analysis results for a) 640 shots analysed in this study and b) 5000 shots necessary to be able to find a significant difference between at-sea observers and electronic monitoring systems. Calculated probability of encounter with dolphins (red) and Australian sea lions (orange) are indicated. p.pr is the probability of detection by the electronic monitoring system. Levels of grey indicate the proportion of observations in the model that contain the null hypothesis (no significant difference between the methods)

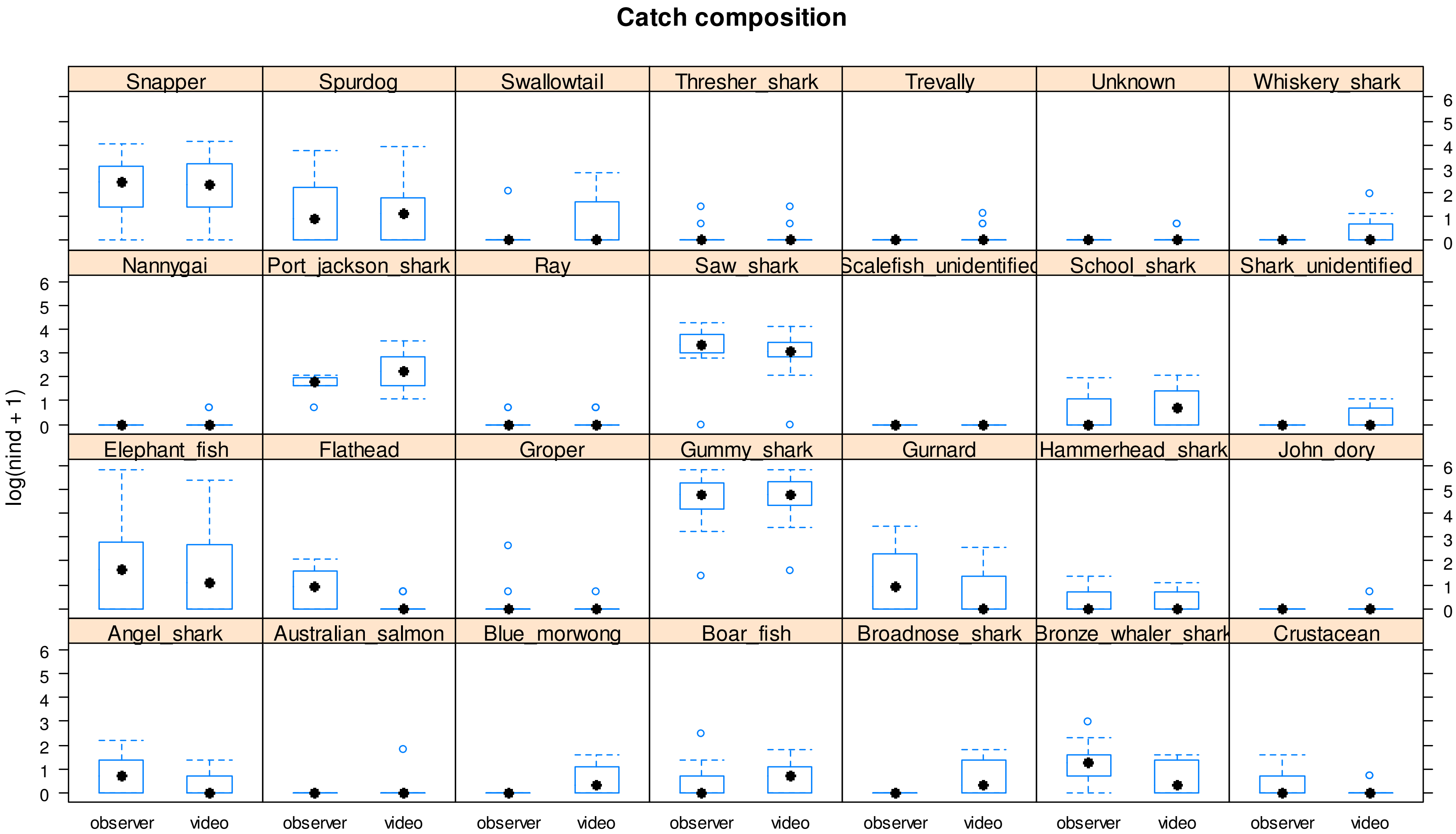

Figure 10: Boxplots showing the median (closed circle), 25% and 75% quartiles (box), with handles depicting the 1.5 interquartile distances. Values outside this range are indicated as outliers (open circles)

Table 4: Taxonomical groups detected by at-sea observers and electronic monitoring (EM) systems, their probability of detection (p.obs, p.ems), mean number of individuals detected by each method (N.obs, N.ems), their lower and upper 95% confidence intervals, and paired and unpaired GRM results. Abbreviations: p.obs = probability of detection by observers; p.ems = probability of detection by EM systems; N.ems – mean number of individuals detected by an observer; N.ems = mean number of individuals detected by an EM system; NS = not significant; * = p<0.05; ** = p<0.01; *** = p<0.001

		Encounters		Counted number ind.											
Common name	Species	Observer	EM system	Observer	EM system	p_{obs}	p_{ems}	low N_{obs}	N_{obs}	up N_{obs}	low N_{ems}	N_{ems}	up N_{ems}	paired	unpaired
Angel Shark	Squatinidae	9.00	4.00	26.00	7.00	0.64	0.29	1.64	2.73	4.42	0.32	0.84	3.18	**	*
Australian Salmon	*Arripis trutta*	0.00	1.00	0.00	5.00	0.00	0.07	0.00	0.00	0.00	4.36	4.97	4.97	***	**
Blue Morwong	*Nemadactylus douglasii*	0.00	7.00	0.00	13.00	0.00	0.50	0.00	0.00	0.00	0.64	1.59	3.38	***	***
Boar Fish	*Pentaceropsis recurvirostris*	6.00	8.00	19.00	17.00	0.43	0.57	1.41	2.90	5.41	0.90	1.89	3.66	---	NS
Broadnose Shark	*Notorynchus cepedianus*	0.00	7.00	0.00	19.00	0.00	0.50	0.00	0.00	0.00	1.16	2.53	4.67	***	***
Bronze Whaler Shark	*Carcharhinus brachyurus*	12.00	7.00	53.00	17.00	0.86	0.50	4.37	4.37	4.41	1.56	1.56	2.84	***	*
Crustaceans	Crustacea	4.00	2.00	7.00	2.00	0.29	0.14	0.26	1.44	3.60	0.01	0.45	1.90	---	NS
Elephant Fish	Callorhinchidae / Rhinochimaeridae	10.00	10.00	535.00	350.00	0.71	0.71	51.33	53.50	55.74	33.25	35.00	36.81	***	NS
Flathead	Platycephalidae	10.00	3.00	32.00	3.00	0.71	0.21	2.28	3.07	4.22	0.12	0.30	1.18	***	***
Western Blue Groper	*Achoerodus gouldii*	2.00	1.00	14.00	1.00	0.14	0.07	6.97	6.99	6.99	0.42	0.44	0.44	***	NS
Gummy Shark	*Mustelus antarcticus*	14.00	14.00	1884.00	1983.00	1.00	1.00	127.34	135.00	141.23	135.47	141.64	148.33	***	NS
Gurnard	*Lepidotrigla vanessa / Chelidonichthys kumu*	9.00	6.00	97.00	29.00	0.64	0.43	7.90	10.80	14.28	2.58	4.74	7.90	---	NS
Hammerhead Shark	*Sphyrna zygaena*	4.00	4.00	7.00	6.00	0.29	0.29	0.25	1.44	3.69	0.18	1.18	3.18	---	NS
John Dory	*Zeus faber*	0.00	1.00	0.00	1.00	0.00	0.07	0.00	0.00	0.00	0.67	0.67	1.60	***	NS
Nannygai	*Lutjanus malabaricus*	0.00	2.00	0.00	2.00	0.00	0.14	0.00	0.00	0.00	0.68	0.68	2.15	***	NS
Port Jackson Shark	*Heterodontus portusjacksoni*	14.00	14.00	69.00	153.00	1.00	1.00	3.33	4.93	5.43	8.43	10.93	12.99	***	***
Rays	**Batoidea**	2.00	3.00	2.00	3.00	0.14	0.21	0.01	0.51	2.28	0.03	0.70	2.38	***	NS
Saw Shark	*Pristiophorus spp*	13.00	13.00	422.00	348.00	0.93	0.93	30.12	32.50	35.23	24.44	26.77	28.45	***	NS
School Shark	*Galeorhinus galeus*	6.00	8.00	17.00	26.00	0.43	0.57	1.01	2.51	4.99	1.71	3.12	5.25	*	NS
Shark - unidentified	**Selachii**	0.00	4.00	0.00	5.00	0.00	0.29	0.00	0.00	0.00	0.11	0.93	2.77	***	**
Snapper	*Pagrus auratus*	12.00	12.00	200.00	205.00	0.86	0.86	14.44	16.70	18.45	15.43	17.08	20.00	***	NS
Spurdog	*Squalus megalops*	9.00	8.00	103.00	147.00	0.64	0.57	8.95	11.40	14.37	14.97	18.38	22.26	***	NS
Swallowtail	*Centroberyx lineatus*	1.00	6.00	7.00	33.00	0.07	0.43	1.54	6.93	15.37	3.46	5.48	8.11	---	NS
Thresher Shark	*Alopias vulpinus*	2.00	2.00	4.00	4.00	0.14	0.14	1.63	1.70	1.70	1.63	1.70	1.70	***	NS
Trevally	Carangidae	0.00	3.00	0.00	4.00	0.00	0.21	0.00	0.00	0.00	0.08	0.94	2.85	***	*
Whiskery Shark	*Furgaleus macki*	0.00	4.00	0.00	10.00	0.00	0.29	0.00	0.00	0.00	0.62	2.28	4.73	***	**
Unidentified		0.00	2.00	0.00	2.00	0.00	0.14	0.00	0.00	0.00	0.68	0.68	2.15	***	NS

2.3 DISCUSSION

Overall electronic monitoring systems performed well with 88.1% of shots unaffected by image quality issues. Of the 11.9% of shots that showed some issues, 1.7% resulted from technology issues and equipment failures (e.g. corrupted video files). The remainder of image quality issues were associated with camera setup on the boats, rather than equipment issues. Most of the setup problems were related to the obstruction of the field of view of one of the cameras. This problem affected one vessel in particular where the stabilizer of the boat obstructed the net roller's view; an issue that could be resolved by changing the placement of the affected camera.

Problems related to the functioning of the electronic monitoring system or image quality represented 1.7% of the shots and did not affect the complete footage of those particular shots, except for the single instance where the electronic monitoring system failed to record any footage or sensor data for a period of 15 hrs. These results suggest that the electronic monitoring systems are a reliable tool suitable for monitoring activities in the gillnet fishery; particularly if care is taken to place cameras in locations where no obstruction is likely, the systems are serviced regularly and there is cooperation from the crew to maintain good lighting conditions when a fishing event is taking place.

2.3.1 MARINE MAMMAL INTERACTIONS

Despite the fact that we could not statistically test if there were significant differences between the electronic monitoring system and at-sea observer, the consistency found in the number of detections and species identification between both methods suggests the electronic monitoring system is an effective tool for monitoring protected species interactions. This has been demonstrated in other studies conducted in Australia and around the world, where the effectiveness of the electronic monitoring system in detecting protected species interactions (including seabirds and marine mammals) was ascertained (McElderry *et al*. 2004, McElderry *et al*. 2005a, McElderry *et al*. 2010a).

The electronic monitoring systems performed well in detecting marine mammal interactions compared to the at-sea observer, probably due to the large body size of marine mammals. The single case where an interaction was not detected by the electronic monitoring system was due to the system's failure to record the fishing event, rather than an inability of a functioning electronic monitoring system to detect the interaction. Species identification of dolphins completed using electronic monitoring footage was still possible even in instances where the animal had been dead for some time. This was due to their distinctive morphological traits such as colour, beak size and body shape. The video analyst was able to identify 62% of the dolphins with a high degree of confidence, and was also able to identify the two ASLs detected by the electronic monitoring system using coloration. The most common reasons for large mammals not being identified with certainty using electronic monitoring were:

- individuals being ejected from the net before adequate footage could be captured

- individuals being removed from the net in a position that did not allow for a complete camera view
- cameras being located too far from the place of removal
- poor image resolution and unsuitable lighting and frame rate.

There are a number of ways these issues can be resolved. These include modifying the electronic monitoring system setup (including the placement of cameras), improving lighting, adding an additional (fourth) camera to provide an additional view, changing camera lenses (magnification), increasing the frame rate and working with the crew to ensure key identifiers on the animals can be seen by the cameras.

The small sample size and low interaction rates with marine mammals (in particular with ASLs), did not allow us to statistically test if the electronic monitoring system was less accurate than at-sea observers. Power analysis conducted using information from our collected data set suggested that, due to the low interaction rates between gillnets and ASL in our study, more than 5000 shots would need to be co-recorded by observers and electronic monitoring systems to statistically validate whether the methods give different results. Attempting to collect over 5000 shots of concurrent observer and electronic monitoring data to meet this objective was outside the capacity of this study, and the cost of doing this work in the future would be very high.

The low interaction rates with marine mammals found in our study are common in those fisheries where the encounter rate with protected species is moderate or rare (Wade 1998, Baird & Bradford 2000). In order to assess if the impact of the fishery is sustainable and if the existing management measures are effective, mortality rates in the fishery need to be estimated every year and an estimate of the population size need to be available (Slooten & Dawson 2010). Low encounter rates make it difficult to estimate the level of mortality and the difficulty increases with small populations, as the precision in the abundance estimates and in the prediction of the probability of encounter (i.e. incidental take) decreases (Taylor & Gerrodette 1993, Wade 1998, Dixon *et al*. 2005, Orphanides 2009), as is the case of ASLs. This will mean that the amount of data needed to estimate the probability of encounter and bycatch mortality of ASLs would be inversely proportional to the size of their population.

The level of at-sea observer coverage in the gillnet fishery increased from approximately 0.8% in 2007 to approximately 5.6% in 2011 (and was observed sporadically before 2007). At-sea observer derived data have been relied upon as fishery independent data by fisheries managers and researchers around the world to make stock assessments and estimate bycatch levels and interactions with protected species (Harwood & Hembree 1987, Julian & Beeson 1998, Orphanides 2009, Orphanides 2010). However, the low ASL encounter rate in the gillnet fishery increases the need for high levels of monitoring coverage to allow mortality rates to be estimated with an increased level of accuracy.

As demonstrated in other pilot studies, electronic monitoring systems have the ability to provide the level of monitoring needed to accurately estimate bycatch mortality of protected species at a lower cost than at-sea observers (McElderry *et al*. 2007, McElderry 2008, McElderry *et al*. 2010a). However, electronic monitoring systems may not be as suitable for monitoring interactions with individuals that are present in the vicinity of a fishing vessel or are not brought into the camera's field of view (McElderry 2008). Another disadvantage to electronic monitoring systems is the inability to prevent tampering; while electronic monitoring systems are tamper evident, cooperation and acceptance from industry is important for successful implementation. Additionally, a level of at-sea observer coverage will still be necessary in order to collect important biological samples not possible with electronic monitoring systems.

2.3.2 CATCH COMPOSITION

Although no significant difference in catch composition was found between at-sea observer and electronic monitoring system (based on multivariate approach), results showed significant difference in the abundance of species between methods on a shot by shot basis (paired test). This included 6 taxonomical groups reported by the electronic monitoring system analyst that were not recorded by the at-sea observer (excluding the unidentified categories). Several issues associated with data collection, data handling and footage analyses may have led to these discrepancies:

- A standard species list was not used by both the at-sea observer and the electronic monitoring video analyst. Providing a standard list of species likely to be encountered in the fishery may have avoided the differences in total species recorded between the two methods.

- Video footage of shots where new taxonomic groups, or very different individual counts, were reported by the video analyst was not re-analysed to identify the source of error.

- The species count reported by the at-sea observer was not done in a serial manner, with time of retrieval indicated. This would have allowed the alignment of the data reported by both methods and a detailed examination of inconsistencies in species count and identification.

- Data inclusion criteria for analyses was not standardised between methods prior to analysis (i.e. the electronic monitoring analyses did not include catch that dropped out of the net before it reached the net roller, while the same data was not excluded from the at-sea observer data).

Due to these inconsistencies in the methods and data handling, a *post hoc* comparison of catch composition data reported by industry was carried out. This comparison showed there was a closer agreement between the fishermen and at-sea observer in the number of individuals counted for Bronze Whaler Shark (*Carcharhinus brachyurus*) and the target species Gummy Shark (Appendix 3), while the remainder of the taxonomical groups differed across all data sources. Furthermore, inspection of the data reported by the video analyst with limited species identification experience showed disagreement in number of species and number of individuals per species with both at-sea observer and the video analysis made by the analyst with high-level experience in species identification (i.e. a trained Observer). This suggests a relatively high level of uncertainty and low levels of precision in identification and piece counts among at-sea observers, and trained and untrained electronic monitoring system analysts. These issues highlight the critical nature of a clear methodology, and a consistent training and quality assurance regime for any electronic monitoring program.

Besides the data handling issues identified, a number of additional issues that could have led to this uncertainty were identified:

- Camera configuration during the trial was largely focused on recording threatened species interactions. This made camera views less suitable for catch composition analysis (included viewing angles not targeting for close up video footage).
- Camera views were sometimes obstructed by crew members.
- Image resolution, lighting and the frame rate of image capture was sometimes unsuitable for identifying species.
- Individuals were sometimes ejected from the net before adequate footage could be captured.
- Bad weather could affect image quality;
- The length of time at-sea observer's had to identify and count catch as it was brought aboard in the net was constrained by the need for fishing activity to continue.
- Morphologically similar species (such as some sharks) were sometimes difficult to identify using video footage.

Despite these issues, when catch composition was analysed over all shots (unpaired test), the difference in the number of individuals reported by the observer and the electronic monitoring system analyst was not significant for 17 species. This included the six species recorded in the greatest abundance by the at-sea observer, representing over 93% of the total catch. Moreover, on a species diversity scale, both methods were found to be similar.

Previous studies in the long-line and gillnet fisheries have reported similar findings where differences between at-sea observers and electronic monitoring systems are on the fine scale, while overall, both methods were deemed to be similar (Ames *et al*. 2005, Bonney & McGauley 2008, McElderry *et al*. 2010b). Previous investigations on the use of electronic monitoring system in the gillnet fishery in 2005 that analysed 24 fishing events concluded that the system could meet the monitoring requirements of the fishery. (McElderry *et al*. 2005c). However, the 2005 trial did not compare the effectiveness of the equipment with at-sea observers as is the case of the present study.

There are several advantages electronic monitoring systems have over at-sea observers to monitor catch composition, these include:

- the ability to adjust the viewing speed for species count and identification
- the ability to review footage of the same event as many times as is necessary
- a permanent record of the fishing events is kept
- data reported can be verified independently
- the amount of footage reviewed can be scaled up and down as an audit tool against logbooks completed by fishers
- the analysis of recorded video footage can be more readily designed to meet statistical requirements than observer deployments

- video footage can be reviewed by shot, by day, by boat or by trip in a *post hoc* manner once recorded, while observer activity needs to be designed prior to deployments; an observer is restricted to recording data from a single boat for an entire fishing trip.

However, these advantages are dependent on the quality of the footage obtained. Therefore the placement of cameras, type of lenses and frame rate should be designed and fitted according to the monitoring objectives electronic monitoring systems need to fulfil. If the objective is to use the electronic monitoring system as a tool to help improve data integrity and quality of the ISMP, modifications to the current camera set up need to be undertaken, and should include:

- changes in the current camera placement that includes a view of the catch at an optimal angle that aid species identification
- lenses on some cameras that zoom the view to increase an analyst's ability to distinguish morphological traits important for species identification
- an increase in the recording speed to provide more images for video analysis.

It is important to note that there are limitations inherent to this type of monitoring, such as the difficulty of identifying rare species or those that closely resemble one another (morphologically similar species), a need for fish handling operations to take place in front of cameras to record species, a difficulty in estimating catch weight and inability to take biological samples (McElderry 2008). Therefore a level of at-sea observer coverage may still need to be maintained.

3 COST BENEFIT ANALYSIS

3.1 INTRODUCTION

The use of at-sea observers for data collection can pose a significant financial burden on the fishery. However, the capital and program management costs of electronic monitoring equipment mean the total cost of electronic monitoring implementation can also be quite high. To provide an objective assessment of whether financial savings are likely to be provided by an electronic monitoring program, we undertook a cost benefit analysis (CBA).

Cost benefit analysis involves comparing the costs and benefits of various options. These options usually include the status quo as a "base case" to provide a clear basis for any comparisons. In our study, the base case is provided by assuming that all monitoring coverage is provided by at-sea observers; the situation currently experienced in nearly all of AFMA's fisheries.

The aim of our CBA was to provide a clear, objective assessment of whether the potential benefits of electronic monitoring would outweigh its costs. It should be noted that not all costs and benefits can be readily quantified. Costs associated with electronic monitoring that could not be readily quantified include any fishing "down time" that may occur on fishing boats as a result of poor electronic monitoring system maintenance. Benefits that could not be readily quantified include increased reporting accuracy in boat logbooks, and reductions in the amount of time observers would be exposed to at-sea environments (considered high occupational health and safety risk environments). As much as possible, we have focused our CBA on comparing “like for like” in a quantified fashion, and have discussed those non-quantifiable aspects separately.

3.2 METHODS

A cost benefit analysis (CBA) was performed based on a fleet of 12 active shark gillnet fishing boats (boats that have recently caught gummy shark in the ASL management zone). Logbook and observer records were used to determine the average number of trips (15 per annum) and trip length (8 days) for boats involved in the analysis.

The cost-benefit analysis compared two scenarios against the “base case” of providing all monitoring coverage using observers:

- **Base Case:** the cost of an at-sea observer providing monitoring coverage (from 0% - 100% cover). May include collection of a range of different data including catch composition and protected species interactions.
- **Scenario A**: the first 3% of monitoring cover provided by at-sea observers. All remaining monitoring is provided by electronic monitoring with video analysis targeting interactions with threatened species.
- **Scenario B**: the first 3% of monitoring cover provided by at-sea observers. All remaining monitoring provided by electronic monitoring with video analysis targeting catch composition, including threatened species interactions.

When comparing these levels of monitoring coverage, the base case assumes that all monitoring is undertaken by onboard observers. In the alternative scenarios, it was assumed that all but 3% of monitoring coverage was being provided by electronic monitoring systems. This 3% minimum observer coverage allows for the collection of biological samples and other information not possible via electronic means.

The cost-benefit analysis includes calculations of net present values (NPV) to determine the relative costs and benefits of electronic monitoring over a ten year planning horizon. An annual discount rate of 5% was used in this calculation to account for the fact that a dollar today is worth more than a dollar in the future (because of inflation and other monetary pressures).

The CBA also considered the level of video analysis that would be performed. The cost of analysing electronic monitoring footage for catch composition (including protected species interactions) is higher than the cost of analysing footage for interactions with threatened species. This is largely related to the need to review the footage more slowly when counting catch, and the additional time taken to record and annotate data. The two scenarios shown in the CBA allow an assessment of how different data requirements in the fishery (i.e. only threatened species, or all catch) could change the point at which electronic monitoring become economically viable.

The following section outlines the assumptions made in calculating the cost of the items in the cost benefit analysis. These costs are also outlined in Table 10 (Appendix 4). Where possible, the assumptions used in the cost benefit analysis have been aligned with current AFMA policy and practice. Costs and currency conversion rates were current at the time the analysis was undertaken (August 2011); changes in these variables may result in a different outcome.

The costs associated with electronic monitoring can be broadly grouped into four categories:

1. initial purchase and installation costs
2. software licensing and data transmission costs
3. servicing and maintenance costs
4. data analysis and management costs[1].

1. Electronic monitoring system

The electronic monitoring systems used in the trial were manufactured by AMR. Each electronic monitoring system included a control centre, four colour CCTV cameras, four stainless camera mounts and straps, a GPS receiver and mount, a pressure sensor, a rotation sensor with reflector, a keyboard with trackball, a 14” 12v LCD monitor, an AC voltage power supply, and a satellite modem.

The costs outlined in this report include shipping and handling and upgrade of each system to accommodate SATA hard drives. The manufacturer of the electronic monitoring systems has suggested that five years is a realistic life span for the electronic monitoring systems, but reported that systems in some other fisheries were still being used after 10 years (McElderry per comm. 2010). The life span of the electronic monitoring system in the analysis was set at five years as per the manufacturer’s recommendation.

2. Uninterruptible power supply

Uninterrupted power supply units were used in conjunction with each electronic monitoring system to ensure the system could operate at all times, regardless of whether the boat’s power generators were operating or not. The UPS units used in the trial were Centurion model PSCE2000LA units with PSCEB12 battery banks. The cost of the UPS outlined in Appendix 3 includes $60 shipping and handling.

The lifespan of the UPS units will vary depending on the extent and frequency that the batteries are drawn down. These factors will vary considerably depending on the individual boat’s fishing practices. For simplicity, the useful life of the UPS units has been aligned to that of the electronic monitoring systems (five years).

[1] While other fisheries are likely to implement e-monitoring in the future, this cost benefit analysis attributes the entire cost of program management to the shark gillnet fishery. We do this for two reasons. Firstly, the shark gillnet fishery is currently the only AFMA fishery where e-monitoring cameras are currently installed (although the ETBF is moving to an operation phase in 2012-13). Secondly, it allows this report to be read and understood as a stand-alone document. However, readers should be aware that the program costs outlined in this document may in reality, be lower if they are spread across a number of AFMA fisheries.

3. Hard drives

A total of five 500 Gigabyte SATA hard drives have been allocated for each boat using electronic monitoring systems (a total of 60 hard drives); this provides for drive exchange every three months, the provision of a single backup drive in case of drive failure and drive re-use every 12 months. After this initial purchase, a further five drives are allocated for each subsequent year. These additional five drives will be used to cover all 12 boats and will provide for replacement of any damaged drives or drives that may need to be retained beyond the 12 month period. The serviceable life of purchased hard drives is otherwise set to five years for the cost-benefit analysis.

4. Electronic monitoring and Uninteruptable Power Supply installation

Local technicians arranged by the concession holder performed the installation of electronic monitoring systems using guidelines developed by AFMA and AMR. Installation costs are influenced by the design of the fishing boat which may require booms for lighting, additional cable, glands and other fittings. The cost of $3,500 per boat used in this analysis is based on installations performed in the shark gillnet fishery and other research trials performed during 2009-2011.

5. Certification of installed electronic monitoring system

Certification of completed electronic monitoring installations is performed by an AFMA technician, or an observer located in the region closest to the boat. The time required for certification varies depending on the travel required by the certifying agent. For the purposes of the cost benefit analysis it has been costed at one full day of labour. This figure acknowledges that there will be times when no travel occurs and multiple boats are certified in one day, and instances where travel costs will be incurred and only one boat will be certified. Certification generally involves adjustment of camera angles and focus, electronic monitoring system software set up and a short run of the system (a “function test”) to ensure the system operates as intended. The certification of an electronic monitoring system does not assess the installation, it only ensures that the electronic monitoring system operates as intended, and will return the camera angles and data that AFMA requires. The cost of certification is only included in the cost-benefit analysis once; however if an electronic monitoring system on a boat is modified, or the data collection requirements in the fishery change, more than one certification may be required.

6. Electronic monitoring system software licensing and data transmission

There is an annual software license fee associated with each electronic monitoring system. A satellite modem fee is also charged to allow electronic monitoring Health Statement data to be transmitted from the electronic monitoring system on the boat via satellite modem to AFMA. These Health Statements contain basic information on the function of the electronic monitoring system at hourly intervals. The total cost of $12,780 ($13,200 CAD) for software and satellite modem fees is based on a fleet size of 12 boats using electronic monitoring for 12 months of the year ($1,065 per boat per annum).

7. Servicing and maintenance

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.

8. Hard drive exchange

While the existing model of hard drive exchange being used in the shark gillnet fishery uses AFMA staff when they are available, the cost benefit analysis assumes that hard drives will be exchanged by boat operators and posted to AFMA for analysis. Registered postage between South Australia and AFMA's office in the Australian Capital Territory is estimated to cost $15.60 per item. The cost benefit analysis assumes that hard drives will need to be exchanged on a quarterly basis, so the total cost of hard drive exchange to the shark gillnet fishery will be $1,498 per year. This is comparable to reporting and data entry practices associated with on-board observers.

9. Program management

The staff resources required to manage and implement an electronic monitoring program of the scale seen in this trial are outlined in Table 5. These costs have been calculated at the top of the band range and include all overheads and on-costs. Additional savings will be possible if the number of boats using electronic monitoring in this and other fisheries increases.

Table 5: Staff costs for electronic monitoring program management

<table>
<tr><th>Resource</th><th>Cost</th><th>Total</th></tr>
<tr><td>0.10 FTE EL1</td><td>$17,013</td><td rowspan="2">$84,590</td></tr>
<tr><td>0.50 FTE APS6</td><td>$67,577</td></tr>
</table>

10. Electronic monitoring data analysis and data entry

Data analysis costs are based on 325 shots (fishing net hauls) being performed by each boat each year. With a fleet of 12 boats this equates to 3,900 shots per annum. Each shot averages approximately 1 hour 45 minutes. All shots contained on the hard drives collected from fishing boats are downloaded to a computer network, before being annotated and grouped by fishing trip using the *EM Interpret* analysis program. This annotation takes place prior to the video footage being reviewed, and labels the sensor data and linked video footage to allow video analysts to focus on footage of interest (e.g. a 7% random selection of net hauls). Annotation of three months of sensor data typically takes one hour (total 48 hours per annum for all 12 boats).

The time taken for video analysts to complete analysis was derived from analyses performed in this trial, and discussion with experienced analysts. Analysing the footage to detect any interactions with protected species takes approximately 13 minutes per hour of footage (23 minutes per shot). Catch composition takes much longer (approximately 75 minutes per hour of footage). The cost-benefit analysis assumes that protected species interactions are recorded while analysing the broader catch composition and that there was no need to conduct a separate video review for protected species.

The cost for the data analyst is based on the APS 3 level (approximately $68.46 per hour) and includes all overheads and oncosts.

11. Independent data audit of analysed data

An independent audit of analysed footage has been included for quality control purposes. This audit involves the analysis of a randomly selected 5% of analysed footage and comparison of results. The cost for the data audit is based on the APS 3 level (approximately $68.46 per hour).

12. Observer cost

Observer costs (Table 6) were calculated based on 12 boats completing 15 fishing trips per year with an average trip length of 8 days. The trip length used in the analysis was calculated using observer data collected during 2010-11, while the average number of trips taken per year was calculated using logbook records from 2009-2010. The current rate for an AFMA observer is $1,200 per sea day and includes all overheads and on-costs (correct as of March 2012).

Table 6: Observer costs

Observer coverage	Cost per annum
100%	$1,735,534
10%	$173,553
3%	$52,066

13. Sensitivity analysis

Sensitivity analyses were undertaken to test the effect of changing costs in the cost benefit analysis (un-modified costs are outlined in Appendix 4, Table 10). For the sensitivity analysis, input costs for the NPV calculation were manipulated to reflect:

- input costs at 75% of those estimated (Sensitivity Case 1)
- input costs at 90% of those estimated (Sensitivity Case 2)
- input costs at 110% of those estimated (Sensitivity Case 3).

The figures used in the sensitivity analyses are an example only and are intended to show how changes to the cost of different electronic monitoring components might affect the NPV associated with electronic monitoring in the shark gillnet fishery.

NPV calculations were performed with a ten year planning horizon and annual discount rate of 5%.

3.3 RESULTS AND DISCUSSION

Studies undertaken in Longline and Trawl fisheries found that e-monitoring could be implemented for between 30-40% of the cost of comparable observer programs (Ames *et al*. 2005, McElderry *et al*. 2010a). The results of our CBA suggest that the level of savings resulting from an electronic monitoring program are strongly related to the level of monitoring coverage required and the nature of the data being collected (Table 7).

Our CBA suggested that regardless of the level of analysis undertaken (entire catch composition including protected species, or analysis for protected species only), the use of electronic monitoring systems did not result in cost savings to operators when less than 9.6% of fishing activity is monitored (Table 8). When less than approximately 10% of fishing activity is being monitored, the "base case" of providing all monitoring cover using at-sea observers appears the more cost effective option.

Table 7: Summary of net present values for different electronic monitoring scenarios, assuming a ten year horizon and annual real discount rate of 5%

NPV	Scenario A (relative to Base Case)	Scenario B (relative to Base Case)
5% monitoring coverage	-$648,681	-$737,115
10% monitoring coverage	$61,806	-$247,715
20% monitoring coverage	$1,482,779	$731,086
50% monitoring coverage	$5,745,699	$3,667,489
100% monitoring coverage	$12,850,565	$10,844,063

Table 8: Summary of break-even points between observer and electronic monitoring coverage scenarios, over a ten year period. The break even point occurs at the percentage of monitoring coverage where the cost of using observers or electronic monitoring is the same (i.e. 10 year NPV = $0)

Break even point	Scenario A (relative to Base Case)	Scenario B (relative to Base Case)
Initial analysis (input costs set to 100%)	**9.6%**	**12.5%**
Sensitivity analysis 1 (input costs set to 75%)	**7.1%**	**8.3%**
Sensitivity analysis 2 (input costs set to 90%)	**8.6%**	**10.7%**
Sensitivity analysis 3 (input costs set to 110%)	**10.6%**	**14.6%**

However, where more than 10% of fishing activity is being monitored, electronic monitoring has the potential to deliver substantial cost savings over the “base case” where observers are used to monitor all activity. The use of electronic monitoring is a cost effective option at monitoring levels greater than 9.6% for TEP interactions, and greater than 12.5% when catch composition is being assessed (Figure 11). As the monitoring coverage assessed in the CBA increased, so did the potential cost savings provided by electronic monitoring.

For example, if observers were tasked to monitor and report on 100% of fishing activity for TEP interactions in the fishery, the additional cost of this over an electronic monitoring system would be approximately $12,850,565 in NPV terms over a 10 year period. This equates to an average of $107,088 per boat, per year; a cost that could affect the economic viability of a fishing operation.

The additional cost of reviewing electronic monitoring footage for catch composition mean the benefits of electronic monitoring over observers at high levels of coverage are not so distinct. These additional video review costs mean that if 100% catch composition data were being collected, electronic monitoring would have a $10,844,063 benefit over observers over the 10 year period (Figure 11). It is however unlikely that there would be a requirement to review 100% of electronic monitoring footage for catch composition. The current observer target (monitoring coverage) for areas of the fishery outside of closures for dolphins and sea lions is 10%. If electronic monitoring were implemented to provide catch composition data in the fishery for a coverage level of 10%, our CBA suggests that the fishery would be $247,715 worse off over a 10 year period (an average of $2,064 per boat, per year).

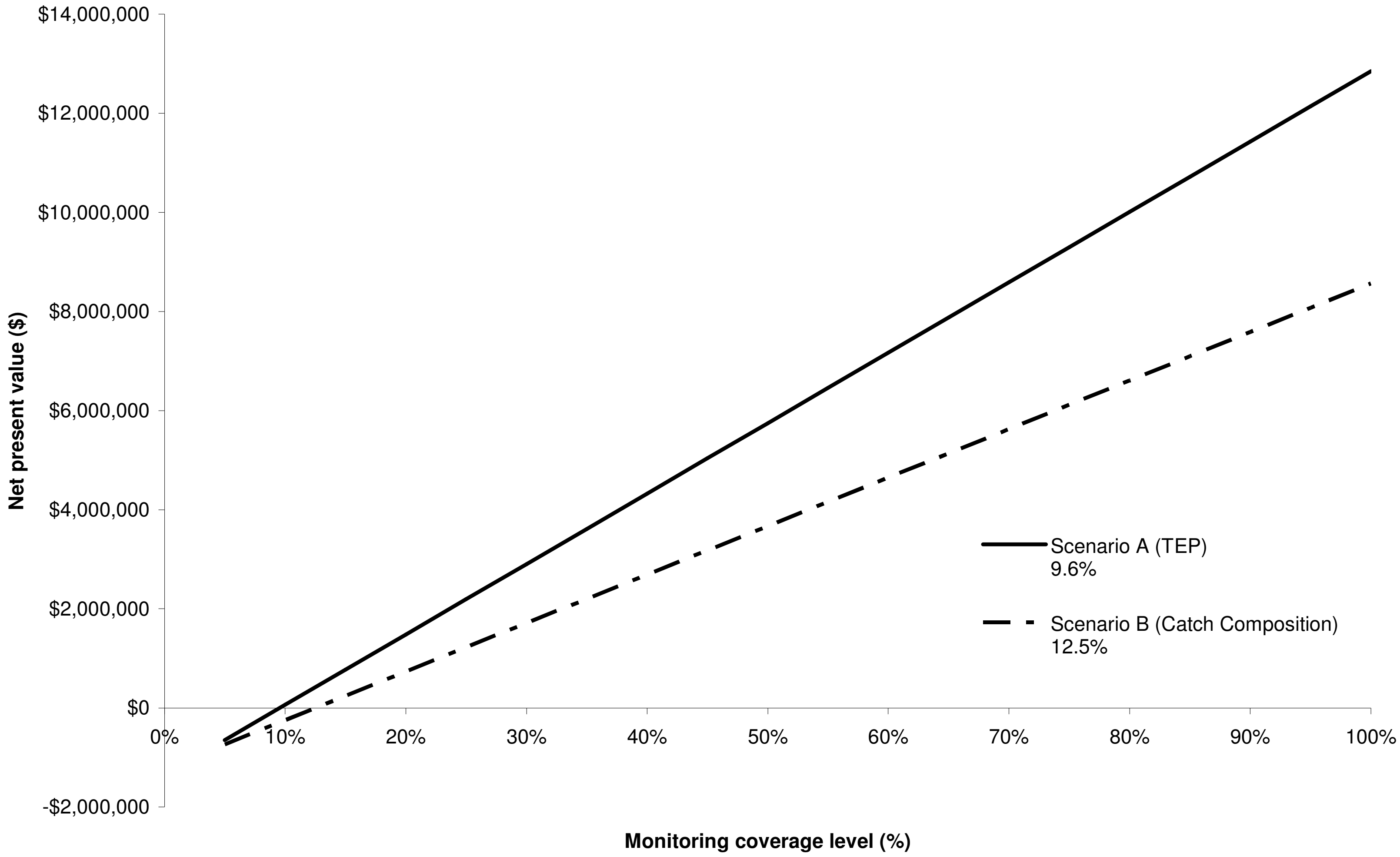

Figure 11: Net present value (10 year period, 5% discount rate) of implementing electronic monitoring when compared to providing monitoring coverage using observers. Scenario A assumes data collected focuses entirely on TEP interactions, while Scenario B assumes data is being collected on the entire catch (including TEP interactions). Percentages shown in the figure legend are the "break even point" where the costs of providing monitoring using observers or electronic monitoring are equal

Sensitivity analysis

The sensitivity analysis conducted showed that the cost savings of implementing an electronic monitoring program are sensitive to input costs. Reducing the input costs (capital, maintenance, program management and analysis costs) to 75% of those used in this CBA makes electronic monitoring a costs effective proposition well below the 10% monitoring level. Reducing input costs to 75% mean that the use of electronic monitoring for monitoring TEP interactions is viable at 7.1% monitoring coverage, and for catch composition at 8.3% monitoring coverage (Figure 12, Table 8).

Reducing input costs to 90% of those used in our original CBA also made it viable to use electronic monitoring in place of observers when 10% monitoring coverage is required. Although this was a more borderline proposition when using electronic monitoring to return catch composition data (10.7%; Figure 13, Table 8), the benefit of being able to readily scale data coverage up in response to management issues when using electronic monitoring would likely make the move worthwhile.

Finally, our sensitivity analysis showed that, should the costs of using electronic monitoring increase, much higher levels of monitoring coverage are required before electronic monitoring becomes financially beneficial (Figure 14).

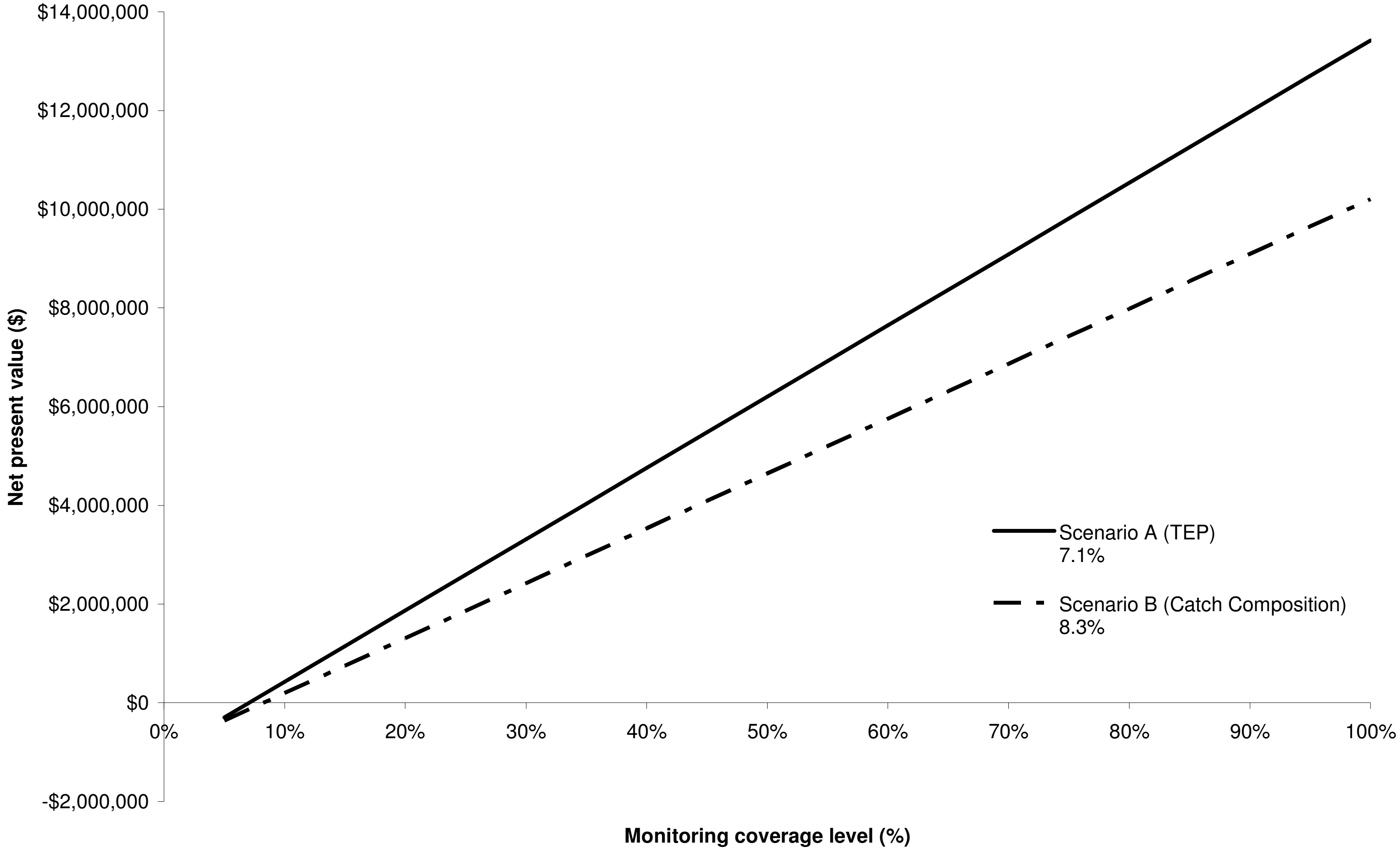

Figure 12: Sensitivity analysis (75% of input costs) of net present value (10 year period, 5% discount rate) of implementing electronic monitoring when compared to providing monitoring coverage using observers. Scenario A assumes data collected focuses entirely on TEP interactions, while Scenario B assumes data is being collected on the entire catch (including TEP interactions). Percentages shown in the figure legend are the "break even point" where the costs of providing monitoring using observers or electronic monitoring are equal

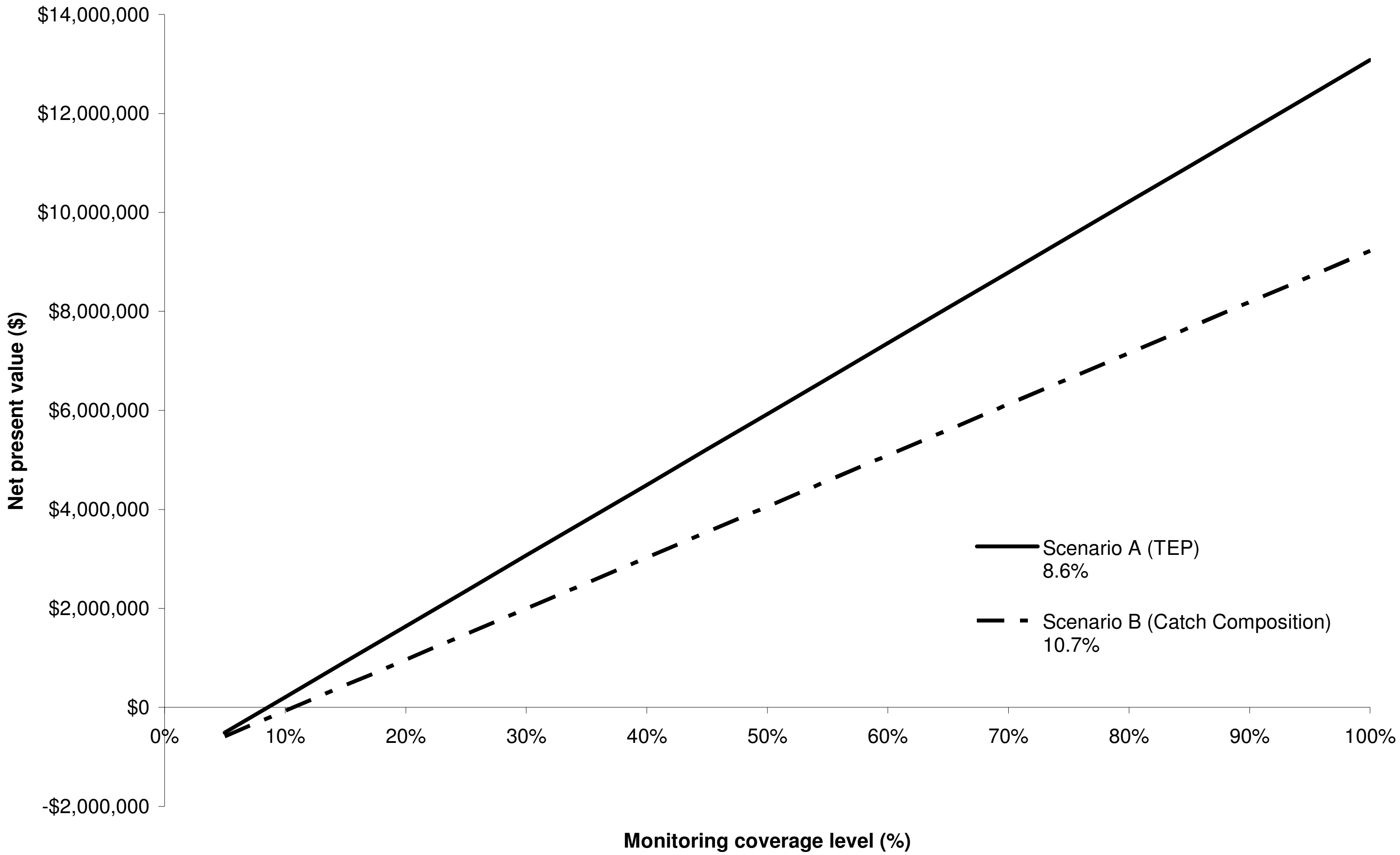

Figure 13: Sensitivity analysis (90% of input costs) of net present value (10 year period, 5% discount rate) of implementing electronic monitoring when compared to providing monitoring coverage using observers. Scenario A assumes data collected focuses entirely on TEP interactions, while Scenario B assumes data is being collected on the entire catch (including TEP interactions). Percentages shown in the figure legend are the "break even point" where the costs of providing monitoring using observers or electronic monitoring are equal

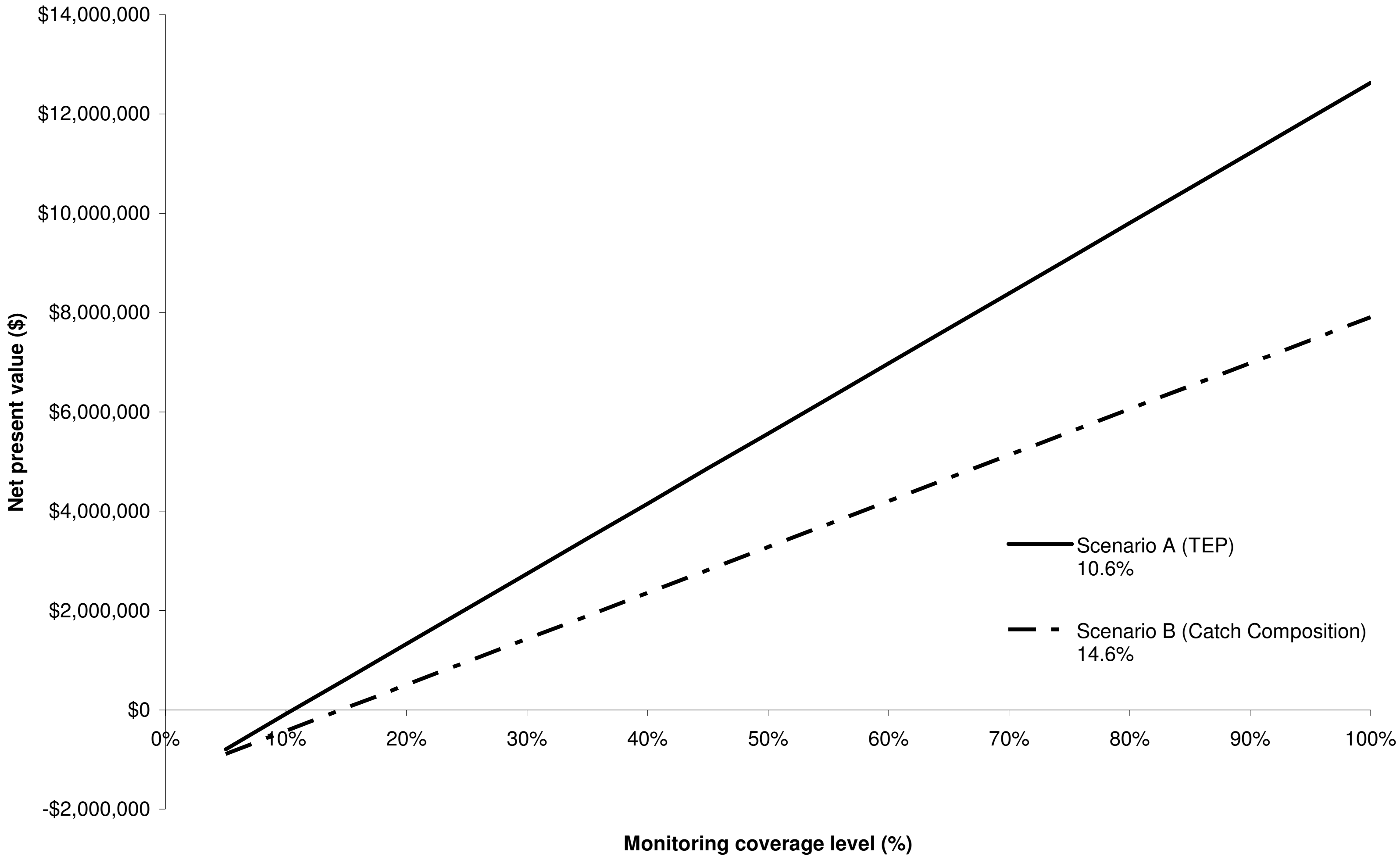

Figure 14: Sensitivity analysis (110% of input costs) of net present value (10 year period, 5% discount rate) of implementing electronic monitoring when compared to providing monitoring coverage using observers. Scenario A assumes data collected focuses entirely on TEP interactions, while Scenario B assumes data is being collected on the entire catch (including TEP interactions). Percentages shown in the figure legend are the "break even point" where the costs of providing monitoring using observers or electronic monitoring are equal

3.4 COST BENEFIT - CONCLUSION

The investment required to establish and run an electronic monitoring program can be considerable. This means the technology is likely to be more cost effective for fisheries and fishing operators where higher monitoring requirements can help realise cost savings, or in cases where other factors such as available space or health and safety make onboard observing unviable.

Our cost benefit analysis suggests that electronic monitoring is likely to be a more cost effective option for providing monitoring coverage at levels above 9.6% for TEP interactions, and above 12.5% for catch composition. Monitoring at these coverage levels would include a 3% at-sea observer component. The existing levels of monitoring coverage in the shark gillnet fishery are 10% for catch composition (in areas outside of ASL and dolphin management zones), and 100% for TEP interactions within those zones[2]. AFMA funded 12 electronic monitoring systems to assist industry comply with the change to a requirement for 100% monitoring coverage in some zones in 2011. Our cost benefit analysis suggests the potential savings of using electronic monitoring for each boat fishing in those areas is in the vicinity of $100,000 per year (based on 100% monitoring coverage).

While our analysis suggests that the use of electronic monitoring may not represent a cost saving when there is a 10% data coverage requirement for catch composition, our sensitivity analysis show that slightly reduced input costs would overcome this. If the input costs included in our CBA were reduced by 10%, the use of electronic monitoring became more cost effective than at-sea observers where 10% monitoring is required. Given the unquantified benefits not picked up in our CBA, it is likely that electronic monitoring would be an attractive alternative in this situation.

Unquantified benefits not included in our model were difficult to ascribe a cost. There is potential for increased cost associated with electronic monitoring system failure and repairs in remote localities; but also considerable cost savings associated with improved data quality from fisher's logbooks. As the electronic monitoring system on a boat records all fishing activity (a percentage is later analysed) fishers can never be certain which of their fishing shots will be analysed. This uncertainty under a random audit scheme means that fishers are much more likely to report catches and threatened species interactions accurately in their logbooks. While it is not an offence to interact with a protected species under the EPBC Act while fishing in accordance with accredited management arrangements if a logbook is correctly filled out, non-reporting of such interactions carries significant sanctions. If fishers can not know which of their logbook records may be reviewed against video footage being recorded, they are likely to provide accurate records to avoid such sanctions. The increased data quality obtained from logbook records (which cover 100% of fishing activity) is a significant benefit of electronic monitoring that is not costed in our CBA.

Our analysis leaves little doubt that the electronic monitoring systems currently deployed in the shark gillnet fishery are providing substantial economic benefits to concession holders operating in areas that require a high level of monitoring in the fishery. Our analysis also shows that, if input costs are carefully controlled and

[2] A third scenario, "Scenario C", that more closely reflects this mix of monitoring coverage under the current management regime is presented in Appendix 5 of this report.

minimised, electronic monitoring is likely to be a cost effective alternative to providing catch composition data at a 10% level of coverage.

4 BENEFITS AND ADOPTION

In response to increasing concerns over the sustainability of ASL populations and the increase in reported dolphin interactions in the shark gillnet fishery, AFMA augmented the level of onboard observer coverage for gillnetting in some areas of South Australia from approximately 7% in 2010 (at-sea observers only), to 100% (combination of at-sea observer and electronic monitoring) in 2011. This decision has also significantly increased the cost of fishing in those zones and presents a strong need for an efficient and cost effective monitoring alternative. Based on the calculations outlined in this report, electronic monitoring has the ability to deliver significant cost savings given the current management scenario in the shark gillnet fishery. While the capital and management costs of an electronic monitoring program are not insignificant, the cost of placing an at-sea observer on every boat, for every fishing day in some parts of the fishery quickly make electronic monitoring an economically attractive technology.

In addition to direct cost savings, electronic monitoring has the potential to provide additional benefits, such as:

- improved spatial and temporal monitoring
- lower OH&S risks by reducing the need for observers to go to sea
- an increased capacity to audit the accuracy of fisher logbook records on protected species interactions and levels of at-sea discards, increasing confidence in self-reported data (e.g. logbook records).

A number of additional benefits associated with improved monitoring have been also identified by Gislason (2007):

- increased compliance with management arrangements, fewer discards and less ‘high grading’
- better science and stock assessments, which will improve fisheries management
- increased confidence and trust amongst user groups, environmental non-government organisations and the public
- potential market access and product certification.

These benefits may result in a positive response from industry members and stakeholder groups in a clearly defined and structured program. In addition, as scrutiny of fishing practices and environmental impacts increased, electronic monitoring has the added advantage of enabling the fishing industry to demonstrate its compliance with management and mitigation strategies and to demonstrate its sustainability.

5 FURTHER DEVELOPMENT

To implement electronic monitoring in the shark gillnet fishery a number of program requirements need to be met. Many of these requirements are well advanced in the fishery, but the list is shown here to give an indication of the infrastructure, services and governance structures that need to be put in place to obtain high quality data. As outlined by McElderry (2008), these requirements include:

- Infrastructure: this comprises equipment supply, field service provision and data processing.
    - Equipment supply includes repairs, replacement parts and spare equipment to ensure continuous operation of electronic monitoring, as well as research and development to fix problems and expand electronic monitoring capabilities.
    - Field service provision involves the availability of technicians in charge of installing and servicing the equipment, assisting fishers with the use of electronic monitoring equipment, custody requirements for handling data, and communication link between fishers and other elements of the program.
    - Data processing involves properly trained personnel to use the software tools to interpret sensor data and footage analyses, and for data handling that involves summarizing, analysing and compiling fishing data.
- Service delivery: this specifies how the program service will be delivered, who will provide personnel training and data management. It also includes data systems, the matching of electronic monitoring data with logbooks, and the development of analysis systems and protocols.
- Governance: this involves both fishery and monitoring compliance issues, which will need to include measures to prevent equipment tampering. In addition, other governance issues critical to a strong AFMA program as per Gislason (2007) are:
    - a legislative basis to implement e-monitoring requirements
    - specification of privacy issues and data ownership and the parties that can have access to these data
    - cost recovery arrangements
    - an implementation schedule that specifies whether the program will be implemented in stages or over the entire the fleet at once. The schedule should also consider an implementation process within AFMA.

AFMA is well advanced in their implementation of many of these components. The work has been assisted and guided substantially by the conduct of this research trial, and other research trials in the ETBF and NPF fisheries. Additional work conducted by AFMA is unlikely to focus on trialling the electronic monitoring equipment. Instead, future development will focus on constructing a program of electronic monitoring management that allows the systems and AFMA to collect the highest quality data in the most cost effective manner possible.

6 PLANNED OUTCOMES

This project sought to test the effectiveness of electronic monitoring as a tool for collecting data in the South Australian gillnet fishery. Management changes in the fishery have increased the required data coverage, increasing the cost of fishing for industry. One solution to increasing data collection costs is to explore the collection of data using electronic means. However, reducing the financial burden of monitoring by implementing an electronic system that cannot collect high quality data would impact on the management of the fishery. This study sought to test whether electronic monitoring could provide data consistent with that collected by at-sea observers.

The data collected in this study demonstrates that electronic monitoring systems are an effective method of collecting information on interactions between gillnets and large marine mammals. While interaction rates were very low, the data on large mammal interactions recorded by at-sea observers and electronic monitoring systems were consistent. This test of electronic data collection has contributed substantially to the level of confidence that can be attributed to the use of electronic monitoring systems to detect threatened species interactions, particularly for large marine mammals.

Data collected by at-sea observers frequently includes catch composition. We assessed whether electronic monitoring systems could collect catch composition with a similar level of accuracy to at-sea observers. Overall, catch composition recorded by at-sea observers and electronic monitoring systems were similar (using multivariate analysis techniques). However, piece counts were much more variable between the two collection methods (using univariate statistical analysis): the data we derived from our electronic monitoring system was different to the data returned by an observer.

On the surface, this appears a less than ideal outcome for our study. However, closer investigation of the reasons for the data variability has contributed substantially to the outcomes of our project. There are two main reasons the data would be different between our two methods; issues introduced by the technology and issues associated with methodology and training. The key question then is ‘can electronic monitoring technology record accurate data?’

By stepping through the methods used by our at-sea observers, the methods communicated to electronic monitoring footage analysts, and the processes used to install camera systems, it is clear that many of the differences we saw related to the methods used, rather than a failure of the technology to accurately record data. This understanding is a substantial contribution to our planned outcomes. Our work has made it clear that the key to obtaining quality data from an electronic monitoring system is to carefully design the systems and the methods used for installation and analysis, as well as the data collection objectives.

This report and extensive international research on electronic monitoring systems have shown that the technology is very capable. Our results clearly show that the future of a strong implementation of electronic monitoring systems relies on process, method, and training.

7 CONCLUSIONS

This study showed that electronic monitoring systems have the potential to provide consistent and high quality data on marine mammal by-catch mortality in the shark gillnet fishery. Likewise, electronic monitoring technology’s ability to monitor catch composition was encouraging despite the data handling issues and the various levels of methodological inconsistencies found between at-sea observers and electronic monitoring system.

The study also demonstrated that monitoring objectives must be well established in order to determine suitable camera configurations. Difficulties will be encountered when trying to achieve a number of monitoring objectives concurrently. Many of these difficulties can be readily overcome by good planning and governance, but without these processes being clearly established and well managed, data quality will suffer.

The configuration used in this study was primarily targeted at monitoring protected species interactions. Changes to camera configuration will need to be made if the monitoring of catch composition becomes a primary objective. Likewise, as fishing methods change on a boat, so must camera configuration. Camera systems, in short, are not a silver bullet that can cover all eventualities. Given extensive trials, research, and implementation across the globe, there is no doubt that cameras can provide cost effective monitoring, high quality primary data, and improve the quality of self-reported data. However, this report demonstrates that a key feature of success (assuming the measure of success is high quality, cost effective data) is a strong management program in the background.

An additional contribution to successful electronic monitoring is industry acceptance and cooperation. Support from industry would allow more standardized catch-handling operations to be developed. This could significantly improve the ability of electronic monitoring systems to accurately record interactions and catch composition.

The key advantages of using electronic monitoring technology versus observers identified in the study are:

- provision of a reviewable record of fishing events
- data reported can be reviewed and is verifiable, unlike observer data, and provides the option of auditing fisher's records from logbook data
- lower cost compared to at-sea observers when monitoring requirements begin to exceed 10% of fishing activity
- ability to monitor small vessels where space is limited for at-sea observers, or on vessels where at-sea observers are not currently deployed for other reasons
- capable of providing in-season data on interactions with ASL and dolphins
- potentially capable for recording catch composition in a suitable camera configuration.

Disadvantages identified are:

- species identification is subject to camera configuration and crew cooperation
- equipment is not tamper proof because of the exposed cameras, sensors and wires, so programs must have measures to discourage tampering
- field of view from cameras is not sufficient to monitor protected species that are in the vicinity of the vessel but are not brought on board

- identification challenges for species that are morphologically similar, and rare species
- inability to collect biological data
- the capital cost of equipment can makes electronic monitoring less economically efficient than observers at data coverage levels less than approximately 7-10%.

Overall, the use of electronic monitoring technology provides clear advantages and benefits in a well established monitoring program. The technology has the capacity to monitor 100% of a fishery for interactions with ASLs and other marine mammals cost effectively, and has the ability to provide catch composition data in the shark gillnet fishery. However, a suitable framework with clear monitoring objectives, program specifications and an operations plan that include personnel training must be in place to ensure the data collected using electronic monitoring systems is of the highest quality possible.

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APPENDIX 1: INTELLECTUAL PROPERTY

Subject to the provisions of the Project Agreement entered into between the Australian Fisheries Management Authority (AFMA) and the Fisheries Research and Development Corporation (FRDC), ownership of this report vests with the FRDC.

APPENDIX 2: STAFF

There were a number of staffing changes within AFMA since the project commenced. The following reflects the staff involved at the end of the project.

Name	**Role**
Josh Davis	Principal Investigator
Robert Stanley	Technical officer
Marcus Finn	Manager, Electronic Monitoring
Malcolm Southwell	Senior Manager, Service One
Narelle Williams	Protected species data analyst
Craig Geier	Protected species data analyst
Gary Adams	Onboard observer and electronic monitoring data analyst (catch composition and protected species interactions)
Laurence Martin	Onboard observer and electronic monitoring data analyst (protected species identification)
Michael Gerner	Onboard observer (catch composition data collection)

APPENDIX 3: CATCH COMPOSITION RAW DATA COUNTS

Table 9: Piece count per species recorded by at-sea observer (O), electronic monitoring systems (E) and industry (L) for the 14 shots analysed for catch composition

	Shot 1			Shot 2			Shot 3			Shot 4			Shot 5			Shot 6			Shot 7		
Species	O	E	L	O	E	L	O	E	L	O	E	L	O	E	L	O	E	L	O	E	L
Angel shark	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Australian salmon	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Blue morwong	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	4	0
Boar fish	3	5	2	2	2	0	0	1	0	1	1	1	0	0	0	0	2	0	0	3	0
Broadnose shark	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	1	0	1	1
Bronze whaler shark	3	1	3	19	4	18	2	0	2	1	1	2	5	0	4	1	0	1	9	0	9
Crustacean	0	0	0	0	0	0	4	1	0	1	1	0	0	0	0	0	0	0	0	0	0
Elephant fish	0	0	0	0	0	0	0	0	0	2	2	0	8	5	5	6	2	0	334	215	41
Flathead	0	0	0	0	0	0	4	0	0	0	0	0	1	1	0	2	0	0	7	0	0
Groper	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0
Gummy shark	3	4	2	79	95	79	64	37	53	111	105	111	135	161	152	270	300	272	336	344	348
Gurnard	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	7	0	9	0	0
Hammerhead shark	0	0	0	2	2	0	0	0	0	1	1	1	3	2	1	0	0	0	0	0	0
John dory	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Nannygai	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Port jackson shark	7	4	0	4	4	0	4	3	0	5	9	0	5	9	0	4	8	0	7	2	0
Ray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saw shark	0	0	16	19	19	4	15	7	17	43	31	21	46	40	23	71	60	6	25	16	14
School shark	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	2	3	2	6	1	3
Shark unidentified	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0
Snapper	3	3	2	0	0	0	3	0	0	0	3	3	7	7	5	27	30	22	18	12	18
Spurdog	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	41	50	0	9	33	0
Swallowtail	7	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0
Thresher shark	3	3	3	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
Trevally	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Whiskery shark	0	0	0	0	2	0	0	1	0	0	6	0	0	0	0	0	0	0	0	0	0
TOTAL	**30**	**27**	**29**	**125**	**133**	**101**	**100**	**50**	**72**	**168**	**170**	**141**	**214**	**228**	**190**	**437**	**473**	**304**	**761**	**631**	**434**

	Shot 8			Shot 9			Shot 10			Shot 11			Shot 12			Shot 13			Shot 14		
Species	O	E	L	O	E	L	O	E	L	O	E	L	O	E	L	O	E	L	O	E	L
Angel shark	1	0	0	8	3	0	0	0	0	2	1	0	6	2	0	1	0	0	3	1	0
Australian salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue morwong	0	0	0	0	2	0	0	0	0	0	1	0	0	2	0	0	2	0	0	0	0
Boar fish	1	0	0	1	1	1	0	0	0	11	2	1	0	0	0	0	0	0	0	0	0
Broadnose shark	0	4	0	0	2	2	0	3	0	0	3	5	0	0	1	0	0	0	0	0	8
Bronze whaler shark	4	3	4	0	0	1	3	0	3	1	3	2	3	2	3	2	0	2	0	3	1
Crustacean	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Elephant fish	58	33	5	15	10	7	15	14	11	91	66	45	3	1	0	3	2	2	0	0	0
Flathead	4	1	0	1	0	0	0	0	0	3	0	0	7	0	0	1	1	0	2	0	0
Groper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gummy shark	198	200	191	65	74	65	123	129	119	146	159	139	74	81	72	25	29	25	255	265	253
Gurnard	9	2	0	18	4	0	1	1	0	24	3	0	30	12	0	3	0	0	0	0	0
Hammerhead shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
John dory	0	0	0	0	0	0	0	0	1	0	0	5	0	1	5	0	0	0	0	0	0
Nannygai	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Port jackson shark	6	16	0	6	22	0	4	5	0	7	22	0	1	32	0	4	8	0	5	9	0
Ray	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0
Saw shark	30	29	22	31	30	18	21	19	18	28	23	26	22	18	0	19	15	50	52	41	21
School shark	1	6	2	1	0	1	4	0	1	3	2	0	0	1	1	0	2	0	0	7	0
Shark unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Snapper	18	18	0	16	15	0	4	4	0	57	62	70	21	24	0	1	1	0	25	26	0
Spurdog	4	5	0	1	0	0	4	2	0	33	50	0	8	2	0	0	0	0	0	3	0
Swallowtail	0	5	0	0	3	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0
Thresher shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trevally	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Whiskery shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTAL	**334**	**323**	**224**	**165**	**167**	**95**	**179**	**179**	**154**	**407**	**415**	**293**	**176**	**178**	**82**	**60**	**64**	**80**	**342**	**357**	**283**

APPENDIX 4: COST OF ELECTRONIC MONITORING AT 100% AND 10% COVERAGE.

Table 10: Cost of electronic monitoring (EM) at 10%, 50% and 100% coverage levels in the South Australian Gillnet Fishery (based on a fleet of 12 active boats). The "NPV category column reflects how the costs were used to calculate Net Present Value for the cost benefit analysis (Section 3 and tables below). The "EM Saving" column in the NPV tables is the difference between the cost of providing monitoring using observers, and the "Analysis and program management" costs for EM.

Item	NPV category	Cost item	Year 1 (set-up cost)			Ongoing annual cost		
			10%	50%	100%	10%	50%	100%
1	Capital	EM systems (12)	$142,104	$142,104	$142,104	$0	$0	$0
2		Uninteruptable power supply units (12)	$27,972	$27,972	$27,972	$0	$0	$0
3		Hard drives (60)	$4,020	$4,020	$4,020	$335	$335	$335
4		EM and UPS installation	$42,000	$42,000	$42,000	$0	$0	$0
5		Certification of installed EM system	$12,024	$12,024	$12,024	$0	$0	$0
6	Maintenance	EM system software licensing and data transmission (12)	$12,720	$12,720	$12,720	$12,720	$12,720	$12,720
7		Servicing and maintenance	$14,210	$14,210	$14,210	$14,210	$14,210	$14,210
8	Analysis and program management	Hard drive postage	$1,498	$1,498	$1,498	$1,498	$1,498	$1,498
10		Program management	$84,590	$84,590	$84,590	$84,590	$84,590	$84,590
14		EM data analysis and data entry: Total catch composition including protected species	$58,408	$292,038	$584,075	$58,408	$292,038	$584,075
		EM data analysis and data entry: Protected species only	$10,124	$50,620	$101,240	$10,124	$50,620	$101,240
15		Independent audit of analysed footage: Total catch composition including protected species (5%)	$2,920	$14,602	$29,204	$2,920	$14,602	$29,204
		Independent audit of analysed footage: Protected species only (5%)	$506	$2,531	$5,062	$506	$2,531	$5,062
16	Observers	Observer cost of providing entire coverage	$173,553	$867,767	$1,735,534	$173,553	$867,767	$1,735,534

Table 11: Net present values for 5% monitoring coverage of TEPs (Scenario A), based on a ten year planning horizon, an annual real discount rate of 5%, and an active fleet of 12 boats

Year	Capital Cost	Maintenance Cost	Electronic monitoring saving	Raw Values	Present Value (5% discount rate)
0	$228,120	$27,265	-$1,437	-$256,822	-$256,822
1		$27,265	-$1,437	-$28,702	-$27,336
2		$27,265	-$1,437	-$28,702	-$26,034
3		$27,265	-$1,437	-$28,702	-$24,794
4		$27,265	-$1,437	-$28,702	-$23,613
5		$27,265	-$1,437	-$28,702	-$22,489
6	$228,120	$27,265	-$1,437	-$256,822	-$191,645
7		$27,265	-$1,437	-$28,702	-$20,398
8		$27,265	-$1,437	-$28,702	-$19,427
9		$27,265	-$1,437	-$28,702	-$18,502
10		$27,265	-$1,437	-$28,702	-$17,621
			Total	**-$771,966**	**-$648,681**

Table 12: Net present values for 5% monitoring coverage of catch composition (Scenario B), based on a ten year planning horizon, an annual real discount rate of 5%, and an active fleet of 12 boats

Year	Capital Cost	Maintenance Cost	Electronic monitoring saving	Raw Values	Present Value (5% discount rate)
0	$228,120	$27,265	-$11,577	-$266,962	-$266,962
1		$27,265	-$11,577	-$38,842	-$36,992
2		$27,265	-$11,577	-$38,842	-$35,231
3		$27,265	-$11,577	-$38,842	-$33,553
4		$27,265	-$11,577	-$38,842	-$31,955
5		$27,265	-$11,577	-$38,842	-$30,434
6	$228,120	$27,265	-$11,577	-$266,962	-$199,211
7		$27,265	-$11,577	-$38,842	-$27,604
8		$27,265	-$11,577	-$38,842	-$26,290
9		$27,265	-$11,577	-$38,842	-$25,038
10		$27,265	-$11,577	-$38,842	-$23,846
			Total	**-$883,501**	**-$737,115**

Table 13: Net present values for 10% monitoring coverage of TEPs (Scenario A), based on a ten year planning horizon, an annual real discount rate of 5%, and an active fleet of 12 boats

Year	Capital Cost	Maintenance Cost	Electronic monitoring saving	Raw Values	Present Value (5% discount rate)
0	$228,120	$27,265	$80,024	-$175,361	-$175,361
1		$27,265	$80,024	$52,759	$50,247
2		$27,265	$80,024	$52,759	$47,854
3		$27,265	$80,024	$52,759	$45,575
4		$27,265	$80,024	$52,759	$43,405
5		$27,265	$80,024	$52,759	$41,338
6	$228,120	$27,265	$80,024	-$175,361	-$130,857
7		$27,265	$80,024	$52,759	$37,495
8		$27,265	$80,024	$52,759	$35,710
9		$27,265	$80,024	$52,759	$34,009
10		$27,265	$80,024	$52,759	$32,390
			Total	**$124,112**	**$61,806**

Table 14: Net present values for 10% monitoring coverage of catch composition (Scenario B), based on a ten year planning horizon, an annual real discount rate of 5%, and an active fleet of 12 boats

Year	Capital Cost	Maintenance Cost	Electronic monitoring saving	Raw Values	Present Value (5% discount rate)
0	$228,120	$27,265	$44,536	-$210,849	-$210,849
1		$27,265	$44,536	$17,271	$16,448
2		$27,265	$44,536	$17,271	$15,665
3		$27,265	$44,536	$17,271	$14,919
4		$27,265	$44,536	$17,271	$14,209
5		$27,265	$44,536	$17,271	$13,532
6	$228,120	$27,265	$44,536	-$210,849	-$157,339
7		$27,265	$44,536	$17,271	$12,274
8		$27,265	$44,536	$17,271	$11,690
9		$27,265	$44,536	$17,271	$11,133
10		$27,265	$44,536	$17,271	$10,603
			Total	**-$266,260**	**-$247,715**

Table 15: Net present values for 50% monitoring coverage of TEPs (Scenario A), based on a ten year planning horizon, an annual real discount rate of 5%, and an active fleet of 12 boats

Year	Capital Cost	Maintenance Cost	Electronic monitoring saving	Raw Values	Present Value (5% discount rate)
0	$228,120	$27,265	$731,717	$476,332	$476,332
1		$27,265	$731,717	$704,452	$670,907
2		$27,265	$731,717	$704,452	$638,959
3		$27,265	$731,717	$704,452	$608,532
4		$27,265	$731,717	$704,452	$579,555
5		$27,265	$731,717	$704,452	$551,957
6	$228,120	$27,265	$731,717	$476,332	$355,446
7		$27,265	$731,717	$704,452	$500,641
8		$27,265	$731,717	$704,452	$476,801
9		$27,265	$731,717	$704,452	$454,096
10		$27,265	$731,717	$704,452	$432,473
			Total	**$7,292,735**	**$5,745,699**

Table 16: Net present values for 50% monitoring coverage of catch composition (Scenario B), based on a ten year planning horizon, an annual real discount rate of 5%, and an active fleet of 12 boats

Year	Capital Cost	Maintenance Cost	Electronic monitoring saving	Raw Values	Present Value (5% discount rate)
0	$228,120	$27,265	$493,438	$238,053	$238,053
1		$27,265	$493,438	$466,173	$443,974
2		$27,265	$493,438	$466,173	$422,832
3		$27,265	$493,438	$466,173	$402,698
4		$27,265	$493,438	$466,173	$383,522
5		$27,265	$493,438	$466,173	$365,259
6	$228,120	$27,265	$493,438	$238,053	$177,639
7		$27,265	$493,438	$466,173	$331,300
8		$27,265	$493,438	$466,173	$315,524
9		$27,265	$493,438	$466,173	$300,499

10		$27,265	$493,438	$466,173	$286,190
			Total	**$4,671,661**	**$3,667,489**

Table 17: Net present values for 100% monitoring coverage of TEPs (Scenario A), based on a ten year planning horizon, an annual real discount rate of 5%, and an active fleet of 12 boats

Year	Capital Cost	Maintenance Cost	Electronic monitoring saving	Raw Values	Present Value (5% discount rate)
0	$228,120	$27,265	$1,546,333	$1,290,948	$1,290,948
1		$27,265	$1,546,333	$1,519,068	$1,446,732
2		$27,265	$1,546,333	$1,519,068	$1,377,840
3		$27,265	$1,546,333	$1,519,068	$1,312,228
4		$27,265	$1,546,333	$1,519,068	$1,249,741
5		$27,265	$1,546,333	$1,519,068	$1,190,230
6	$228,120	$27,265	$1,546,333	$1,290,948	$963,326
7		$27,265	$1,546,333	$1,519,068	$1,079,574
8		$27,265	$1,546,333	$1,519,068	$1,028,165
9		$27,265	$1,546,333	$1,519,068	$979,205
10		$27,265	$1,546,333	$1,519,068	$932,576
			Total	**$16,253,512**	**$12,850,565**

Table 18: present values for 100% monitoring coverage of catch composition (Scenario B), based on a ten year planning horizon, an annual real discount rate of 5%, and an active fleet of 12 boats

Year	Capital Cost	Maintenance Cost	Electronic monitoring saving	Raw Values	Present Value (5% discount rate)
0	$228,120	$27,265	$1,054,565	$799,180	$799,180
1		$27,265	$1,054,565	$1,027,300	$978,381
2		$27,265	$1,054,565	$1,027,300	$931,792
3		$27,265	$1,054,565	$1,027,300	$887,421
4		$27,265	$1,054,565	$1,027,300	$845,162
5		$27,265	$1,054,565	$1,027,300	$804,917
6	$228,120	$27,265	$1,054,565	$799,180	$596,361
7		$27,265	$1,054,565	$1,027,300	$730,083
8		$27,265	$1,054,565	$1,027,300	$695,317
9		$27,265	$1,054,565	$1,027,300	$662,207
10		$27,265	$1,054,565	$1,027,300	$630,673
			Total	**$10,844,063**	**$8,561,494**

APPENDIX 5: ESTIMATED NET PRESENT VALUE OF CURRENT MONITORING STRATEGY IN KEY PARTS OF THE SHARK GILLNET FISHERY

Introduction

The cost benefit analysis described in this report uses two illustrative scenarios:

- Scenario A: providing all but 3% of monitoring coverage using electronic monitoring (with a focus on analysing video footage for threatened species interactions); and
- Scenario B: providing all but 3% of monitoring coverage using electronic monitoring (with a focus on analysing video footage for catch composition (including threatened species interactions)).

These scenarios illustrate the two extremes of video analysis cost. The cost of analysing electronic monitoring video footage for catch composition is more time consuming and costly than reviewing video for TEP interactions. Including a scenario where video is analysed for catch composition right through to high levels of coverage (up to 100%) serves to illustrate how high video analysis costs can quickly reduce the cost effectiveness of electronic monitoring.

However, it is unlikely that there will be a need to analyse 100% of electronic monitoring video footage for catch composition. One of the key benefits of electronic monitoring is the increased accuracy of logbook reporting of catch, discards and TEP interactions. The substantial cost of analysing large amounts of electronic monitoring footage for catch composition is likely to quickly outweigh any benefits. A random audit of logbooks using a smaller percentage of the total recorded video can be completed at a much lower cost, and should increase confidence in the accuracy of logbook data. Such audits will also allow a statistical analysis of the variability inherent in logbook data, leading to a higher level of confidence that can be attributed to such data during fisheries stock assessments.

Current levels of monitoring coverage for gillnet boats in the shark gillnet fishery are:

- 100% monitoring for TEP interactions in the Australian Sea Lion Management Zone and Dolphin Observation Zones in South Australia[3]; and
- 10% monitoring for catch composition across the remainder of the fishery

E-monitoring in the SHARK GILLNET is currently focussed on the detection of TEP interactions in the Australian Sea Lion Management Zone and Dolphin Observation Zones. Should electronic monitoring be implemented more generally across the fishery, a likely scenario for the resulting monitoring coverage may be:

- 3% provided by at-sea observers and port sampling so physical samples could be taken;
- 7% provided by a random electronic monitoring video footage audit; analysed for catch composition; and

[3] Up-to-date information on management zones and monitoring requirements in the fishery can be obtained from the AFMA website (www.afma.gov.au)

- 90% provided by electronic monitoring video footage; analysed for TEP interactions (i.e. all remaining footage).

While there are variations to this level of monitoring coverage, the scenario above (Scenario C) would provide physical samples required for ISMP and stock assessments, catch composition data (and audited logbooks), and complete coverage of TEP interactions (particularly of currently high profile species such as ASLs and dolphins).

Net present value calculations and results

When the net present value is recalculated for Scenario C, electronic monitoring becomes cost effective at lower levels of monitoring cover (Figure 15). If all video footage above the 3% baseline provided by at-sea observers is analysed for catch composition, the point at which electronic monitoring becomes a cost effective alternative is at 12.5% monitoring coverage. Scenario C, which analyses catch composition for coverage up to 10%, and the TEP interactions after that, is a cost effective alternative once coverage reaches 11.5%.

Once monitoring coverage of 10% is reached and all additional analysis is to focus on TEP interactions, the cost additional monitoring coverage mirrors the cost of providing TEP interaction coverage in Scenario A (Figure 15). The difference in the NPV between Scenario A and Scenario C at 100% coverage is minimal; a total of $309,520 over the 10 year timeframe of the NPV calculation (Table 19), or a 2.4% decline in NPV over Scenario A.

Table 19: Net present value (10 year horizon, 5% annual discount rate) of scenarios in this report. Includes Scenario C, which covers analysis of catch composition up to 10%, and TEP interaction analysis from 10%-100%.

NPV	Scenario A (relative to Base Case)	Scenario B (relative to Base Case)	Scenario C (relative to Base Case)
5% monitoring coverage	-$648,681	-$737,115	-$737,115
10% monitoring coverage	$61,806	-$247,715	-$247,715
20% monitoring coverage	$1,482,779	$731,086	$462,772
50% monitoring coverage	$5,745,699	$3,667,489	$5,436,178
100% monitoring coverage	$12,850,565	$10,844,063	$12,541,045

Conclusion

The scenarios of electronic monitoring implementation used in this report were chosen to illustrate the effect of analysis costs increasing as data requirements increase. While the scenario portrayed in this appendix is more likely give current management and monitoring requirements in the fishery, the results of a net present value calculation show that its economic benefits fall between the two scenarios shown in the body of the report.

This suggests that the economic benefits of future mixes of monitoring coverage will likely fall between the scenarios shown in this report. Monitoring coverage that focuses more heavily on data requiring reduced analysis time (e.g. seabird densities during net shooting) will tend to align more closely to Scenario A. Monitoring coverage seeking detailed information that can only be provided using time consuming video review methods are likely to align more closely to Scenario B. The scenario dealt with in this appendix reinforces a key point of our study; when high levels of monitoring coverage are required in a fishery, the use of an electronic monitoring system to provide is a cost effective alternative.

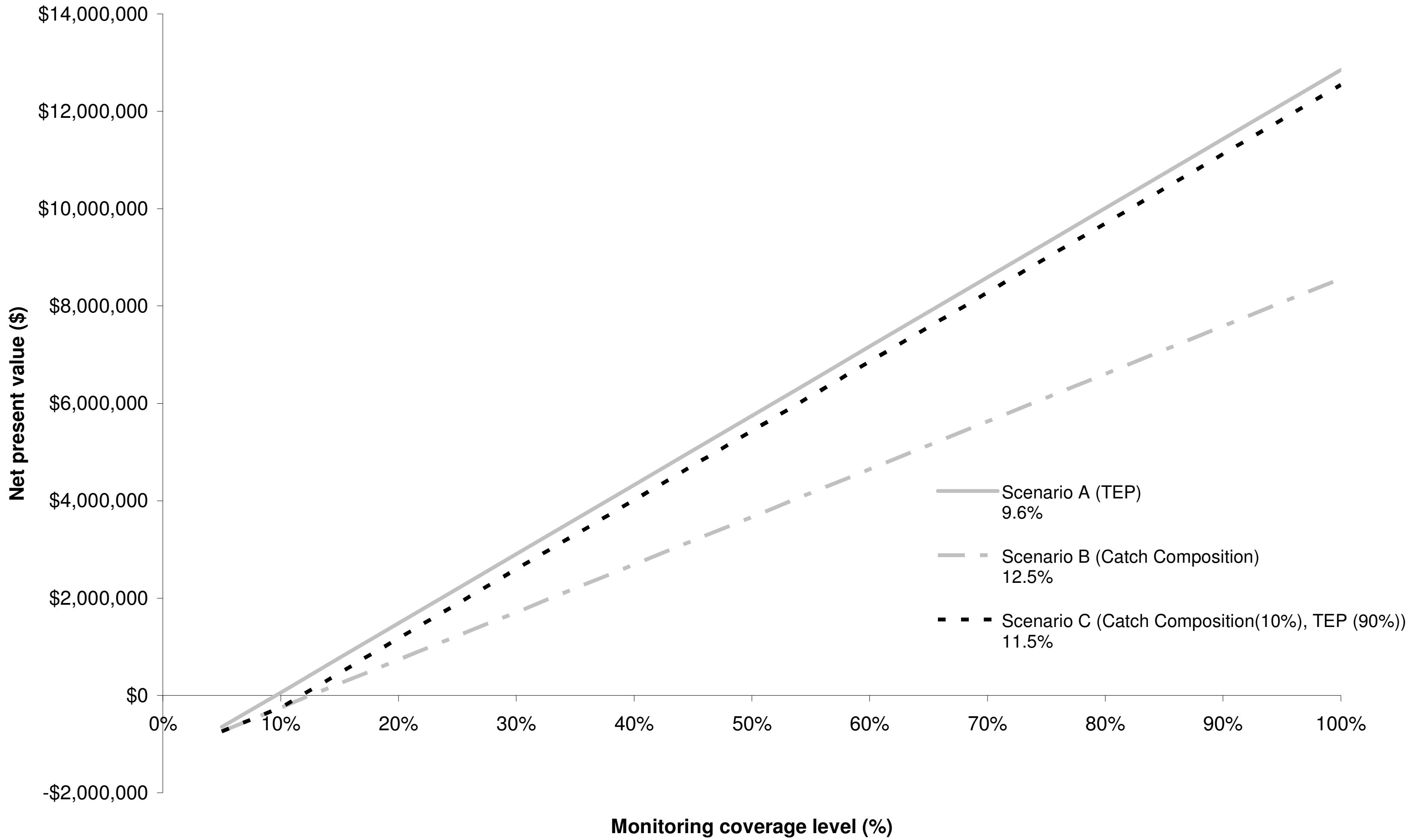

Figure 15: Net present value (10 year period, 5% discount rate) of implementing electronic monitoring when compared to providing monitoring coverage using observers. Scenario A (analysis for TEP interactions); Scenario B (analysis on entire catch (including TEP interactions)); Scenario C (analysis on catch composition to 10%, and TEP interactions for 90%). Percentages shown in the figure legend are the "break even point" where the costs of providing monitoring using observers or electronic monitoring are equal

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